UNIVERSITY OF EDUCATION, WINNEBA

GUIDING PRE-SERVICE TEACHERS TO IDENTIFY AND NAME ALIPHATIC ORGANIC COMPOUNDS USING MOLECULAR MODEL KITS:

A CASE STUDY

SAMUEL NOAH AMEKO

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(8130130001)

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

OCTOBER, 2015

DECLARATION

STUDENT'S DECLARATION

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

SIGNATURE……………………………….DATE…………………………………

SUPERVISORS' DECLARATION

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

NAME OF SUPERVISOR: PROF. K.D. TAALE

SIGNATURE………………………………….DATE……………………………….

NAME OF SUPERVISOR: DR. VICTUS SAMLAFO

SIGNATURE…………………………………..DATE…………………………………

DEDICATION

This work is dedicated to my children: Perfect Ameko, Bless Ameko, Wise Ameko and Lesley Ameko.

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ABBREVIATIONS

FDC : Foundation Course

IUPAC : International Union of Pure and Applied Chemistry

AOCCT : Aliphatic Organic Chemistry Concept Test

RPKT : Relevant Previous Knowledge Test

CoEs : Colleges of Education

3D : Three Dimensional

2D : Two Dimensional

ABSTRACT

This study was conducted in the context of the organic chemistry aspect of the Integrated Science course for the pre-service teachers in St. Teresa's Colleges of Education, Hohoe in the Volta Region of Ghana. The study examined new ways of guiding students to conceptualise organic chemistry that was developed to promote in-depth understanding of aliphatic organic compounds to students. Applying a case study and action research paradigm, pre-test and post-test questions were employed in the collection, analysis, and interpretation of data. The research population included fifty (50) first year students of the St. Teresa's College of Education, Hohoe in the Volta Region. The study was conducted using hands-on exploration of the molecular models to guide students to identify organic compound functional groups, name them and draw or write their structures / formulae. Descriptive statistics and t-Test were used to analyse data collected. Findings indicated that the integration of model-based learning enhanced students' understanding of aliphatic organic compounds; their functional groups, naming and drawing/writing of formulae. Findings also indicated that teachers' demonstrations of the use of the molecular models kits to build various organic molecules did enhance students' 'knowledge'- a low order thinking skill; however, in order to enhance higher levels of thinking, students should be able to explore the use of the molecular models on their own. Applying constructivist and interpretative analysis of the data, three themes were emerged, corresponding to cognitive, affective, and social aspects of learning while exploring model-based learning.

CHAPTER ONE

INTRODUCTION

Overview

This chapter is organised under the following headings: Background to the study, statement of the problem, purpose of the study, objectives of the study, significance of the study, research questions, hypothesis, delimitations of the study, limitations of the study, and organisation of the study.

Background to the Study

Organic chemistry is a branch of chemistry studied by almost all students in Ghanaian schools. It is studied by students at the JHS level to the tertiary level of education in Ghana. At the higher levels of education such as master's level, some students study organic chemistry as an area of specialisation. It is an area in chemistry where many students, as well as some teachers find it very difficult to understand.

Organic chemistry is a branch of chemistry that deals with carbon and its related compounds (Schmid, 1996). It can be defined as the chemistry of carbon compounds. Organic compounds have one thing in common: they all contain the element carbon. An understanding of organic chemistry is essential to the understanding of the chemistry of life. Organic chemistry is used in chemical industry to prepare many important compounds that are available only in nature. Organic chemistry, like any branch of study, has its own terms and definitions (Schmid, 1996). A good understanding of chemistry requires the ability to navigate properly between four levels of understanding: macroscopic, microscopic, symbolic and process levels (Barak & Dori, 2005; Dori & Hameiri, 2003). According to Chandrasegaran, Treagust and Mocerino, (2008), students' ability to use macroscopic, microscopic and symbolic representations are essential to understanding chemistry concepts and phenomena. Students who study chemistry are required to think at the molecular level and explain changes at the macroscopic level in terms of interactions between individual atoms and molecules (Dori, Barak, & Adir, 2003).

Studies have shown that many students find it difficult to properly connect the different levels of understanding (Chandrasegaran *et al*, 2008; Dori & Barak, 2001; Gabel, 1998). Apparently, students don't have sufficient understanding of the macroscopic and microscopic representations of molecules, as well as the meaning of the symbols and formulae in chemical equations (Kaberman & Dori, 2008). These difficulties coupled with difficulties in understanding the spatial orientation of atoms in structures of molecules, obstruct students' ability to solve problems in chemistry (Dori *et al*, 2003; Gabel 1998).

Science educators suggest several solutions to overcome these difficulties such as: integrating three-dimensional (3D) visualisation tools, presenting the dynamic and interactive lesson in chemistry, and promoting the transitions across different chemical representations (Wu & Shah, 2004). Advanced technologies can provide tools that enable students to rotate objects, manipulate representations of spatial structures, and construct molecular models (Barak, 2007; Barak & Dori, 2005; His, Linn, & Bell, (1997). Research on technology-enhanced instruction identified the need for providing learners with knowledge representation tools (Barak, Harward, Kocur, & Lerman, 2007; Jackson, Krajcik, & Soloway, 2000) and inquiry experience (Barak & Dori, 2011; Linn, 2003).

Studies have shown that integrating visual representations such as computerised molecular models, simulations and animations in instructional contexts may afford students with opportunities to promote their understanding of unobservable phenomena in science (Barak, Ashkar & Dori, 2011; Gilbert, 2005; Zhang, Liu, & Krajcik, 2006), and provide learners with the opportunities to make abstract concepts visible (Jackson *et al*., 2000; Yarden & Yarden, 2010). Visual aids may help students relate the macroscopic, microscopic and symbolic representation levels of chemical entities to each other (Gilbert, 2005).Visual aids can enhance students' conceptual understanding and spatial ability (Barak & Dori, 2011; Williamson & Abraham, 1995), it can also facilitate the processing of complex data, make the scientific process more dynamic, and provide ways for studying interesting and complex phenomena (Barak & Dori, 2005). In addition, teachers use textbooks and two-dimensional (2D) pictures to illustrate organic molecules. Some studies claimed that the use of still pictures enable the construction of mental model of new concepts and phenomena (Mayer, 2002). Others claimed that still pictures are not sufficient and the use of animated pictures is essential for promoting conceptual understanding (Barak *et al*., 2011).

Based on the model-based teaching and learning theory of Gobert and Buckley (2000), molecular models would be used to explain the concept of aliphatic organic compounds to the students.

Statement of the Problem

The inability of students of Colleges of Education in Ghana to understand the concept of organic chemistry has become a matter of concern to many chemistry teachers, examiners, policy makers as well as students themselves. Organic chemistry, for that matter, aliphatic organic compounds is one of the courses students at the Colleges of Education take in the second semester of the first year of their three years' Diploma in Basic Education progamme. Over the years, the Chief Examiner's reports from the University of Cape Coast (UCC), up to date indicates that students perform poorly in this area of the integrated science course coded (FDC 124) organised by the University of Cape Coast (UCC) at the end of the second semester. Students in the colleges of education could not identify, name and draw the structures of the first-ten members of the homologous series of alkane let alone other aliphatic organic compounds. According to Bodner (1991) lack of sufficient background in organic chemistry (from senior high school) affects students' participation and performance in organic chemistry.

This observation came to light when the researcher, a science tutor in the St. Teresa's College of Education, Hohoe in the Volta Region was teaching this course, (FDC 124). This situation does not pertain to the colleges of education students only but cuts across all educational levels throughout the country, even in the universities. Organic chemistry for that matter, aliphatic organic compounds is very important aspect of chemistry as we use them in our daily activities. Therefore, the study of organic chemistry will enable students to pursue higher education in this field and to be well-equipped to become chemists, chemical engineers, analytical chemists, biochemists, etc. to take up managerial positions in the oil and gas sector in the country in the near future.

Purpose of the Study

Basically, the purpose of the study was to guide students in the colleges of education to identify, name and draw the structures of aliphatic organic compounds using molecular model kits. To enhanced students' knowledge and understanding of identifying, naming and drawing of structures of aliphatic organic compounds using their functional groups.

Objectives of the Study

The objectives of the study are to guide students to:

1. Identify organic compounds' functional groups.
2. Draw the structures of some aliphatic organic compounds and name them.
3. Use molecular model kits to construct some aliphatic organic compounds.

Research Questions

The following research questions guided the study:

1. To what extent will the identification of the functional groups help students to draw the structures and name aliphatic organic compounds?
2. To what extent will the understanding of nomenclature help students to draw and name aliphatic organic compounds correctly?
3. What is the effect of using molecular model kits to teach identification, drawing and naming of aliphatic organic compounds?

Significance of the Study

The outcome of the research would provide policy makers with credible information on the benefits of using models in the teaching and learning of chemistry and the need to integrate it in the teaching and learning chemistry.

It would encourage other colleague chemistry teachers to integrate models in the teaching and learning chemistry to enhance students' understanding of the concepts of aliphatic organic compounds.

The research would also help students to change their perception that organic chemistry is an abstract subject and difficult, this would change their attitude towards the learning of chemistry.

Delimitations of the Study

The study would have been extended to the other areas of organic chemistry, such as amines, amides, phenols, ketones, aldehydes, etc., but due to the limited time available, the study was limited to only some aliphatic organic compounds like: hydrocarbons, alcohols, carboxylic acids, and esters.

Limitations of the Study

Insufficiency of the molecular model kits in the College imposed limitations on the randomisation and the size of the population. These have threatened the validity of the research outcomes. Some of the students were absent from lessons during the intervention stage and this equally affected their understanding of the concepts taught.

Another limitation of the study was the failure of the respondents to answer all questions.

Organisation of the Study

The study is organised into five (5) chapters. Chapter one is the introduction and captures the following: background to the study, statement of the problem, purpose of the study, hypothesis, significance of the study, delimitations of the study and the limitations of the study. Chapter two looks at the review of related literature under the following: Theoretical frame work; Implication for teaching and learning, Empirical frame work (conceptual understanding); Students' conceptions; The teaching and learning of chemistry; Difficulty areas in chemistry. (curriculum content, overload of students' working memory space, language and communication, concept formation and motivation); Reducing obstacles to learning. (working memory space overload, paying attention to incoming information and recalling previous knowledge easily); Factors that affects students' performance in organic chemistry;

The role of the science teacher in a constructivist classroom; The use of molecular models kits in teaching and learning organic chemistry; The study on functional groups. (alkenes, alkynes, alkanols, carboxylic acids and esters); Ways of understanding functional groups; Common functional groups in organic compounds; The IUPAC systematic approach to nomenclature (alkanes, alkyl halkides, some important behaviour trends and terminologies, alkenes, alkynes, alkanols, carboxylic acids and alkyl alkanoates); Summary of the chapter.

Chapter three is the methodology under the sub-headings: the research design, study area, target population, sample and sampling techniques, research instruments, validity of the instruments, reliability of the instruments, pilot testing the instruments, pre-intervention activities, intervention design, post-intervention activities, data collection procedure, and methods of data analysis. Chapter four focuses on results and discussions and chapter five is dedicated to the conclusions, summary and recommendations.

CHAPTER TWO

LITERATURE REVIEW

Overview

This chapter reviews literature related to the study: Literature was reviewed under the following headings:

Theoretical frame work (constructivism,)

Implication for teaching and learning

Empirical frame work (conceptual understanding),

Students' conceptions

The art of teaching and learning chemistry

Difficulty areas in chemistry. (curriculum content, overload of students ' working memory space, language and communication, concept formation and motivation).

Reducing obstacles to learning. (working memory space overload, paying attention to incoming information and recalling previous knowledge easily).

The role of the science teacher in a constructivist classroom

Factors that Affect Student's Performance in Organic Chemistry

The use of molecular models in teaching and learning organic chemistry,

The study on functional groups. (Alkenes, alkynes, alkanols, carboxylic acids and esters).

Ways of understanding functional groups

Common functional groups in organic compounds

The IUPAC systematic approach to nomenclature (alkanes, alkyl halides, some important behaviour trends and terminologies, alkenes, alkynes, alkanols, carboxylic acids and alkyl alkanoates).

Summary of the chapter.

Theoretical Framework

The theoretical framework underpinning this study is hinged on Lev Vygotsky's social constructivism theory, Jean Piaget's cognitive development theory and Robert Gagne's instructional learning theory.

According to Vygotsky (1978), social learning precedes development. To Vygotsky (1978), every function in the child's cultural development appears twice: first on the social level, (inter-psychological) and later, on the individual level; (intra-psychological). According to Vygotsky (1978), children are capable of performing at higher intellectual levels when asked to work in collaborative situations than when asked to work individually. Vygotsky (1978) stated that less skillful individuals are better able to develop a more complex level of understanding and skills through collaboration, under the direction of an expert or a more capable peer than they could independently; this is what is termed 'scaffolding'.

Social interaction extends a child's zone of proximal development (ZPD), which is the difference between a child's understanding and potential to understand more difficult concepts (Vygotsky, 1978). According to Vygotsky (1978), learning occurs in this zone. Thus with Vygotsky (1978), children are capable of constructing their own knowledge through collaboration, direction or help of an expert or a more capable peer. In other words, children are socially engaged in constructing their own knowledge. This is what has been termed "social constructivism". Social constructivism not only acknowledges the uniqueness and complexity of the learner but also actually encourages, utilises and rewards it as an integral part of the learning process (Wertsch, 1997). Vygotsky's views concerning the zone of proximal development (ZPD) provide a strong support for the inclusion of cooperative learning strategies in classroom instruction. Research studies have clearly shown that the effectiveness of the cooperative learning method over other competitive or individual learning methods helps the learner, in the development of higher order thinking skills as well as the achievement of greater learning outcomes (Johnson & Johnson, 1985). Kagan (1989) has pointed out that every cooperative learning strategy, when used appropriately, enables learners to move beyond the text memorization of basic facts and learning lower level skills.

According to Piaget (1983), cognitive development of a child towards formal thought could be facilitated through three cognitive processes: accommodation, assimilation and equilibration. To Piaget (1983), accommodation is a process by which children reprogram or modify their existing schemata or mental representation of the external world to fit their new experiences for learning to occur. Hence, as exercise existing mental structures in particular environmental situations, accommodation, assimilation and disequilibrium results and the children construct new mental structures to resolve the disequilibrium (Piaget, 1970). The state of disequilibrium and contradiction arising between the existing schemata and the more sophisticated mode of thought adopted by the new experience, therefore, has to be resolved through equilibrium process.

According to Piaget (1983), when children assimilate, they perceive new objects and events according to their existing schema (mental models or cognitive structures). The mental modes of children formed by their prior knowledge and experience therefore, control how they incorporate new experiences and new information into their minds.

This may occur when the new experiences of the children are aligned with their existing schemata (mental models or internal representations of the world) or as a result of their failure to change a faulty understanding (Piaget, 1970). Sometimes when children's experiences contradict their existing knowledge, internal representations, or schemata, they may change their perceptions of the experiences to fit their internal representations.

Equilibration maintains the balance between, always taking in new knowledge and always assimilating knowledge with previously gained knowledge. Knowledge is therefore, not a mirror of the world but is created or "constructed" from the individual's constant revision and reorganization of cognitive structures in conjunction with experiences (Piaget, 1983). Thus in the view of Piaget, learners are actively involved in constructing of their own knowledge. It is therefore argued that knowledge is constructed through action and that children must continually reconstruct their own understanding of phenomena through active reflection on objects and events till they eventually achieve an adult's perspective. Piaget (1983) hence concluded that the process of intellectual and cognitive development is similar to a biological act, which is adaptation to environmental demands.

Gagne's theory of learning focuses on what is described as intentional or purposeful learning; which he said is the type of learning that occurs in schools or specific training programs. Gagne (1985) stated that events in the environment influence learning process. Gagne's theory of learning is aimed at identifying the general types of human capabilities that are learned. According to Gagne (1985) the capabilities are the behavioural changes (learning outcomes) in learners that a learning theory must explain. According to Gagne (1985) once the learning outcomes are identified, an analysis of the conditions that governs learning and remembering can occur. For example, a learner who is participating in a situation where the right conditions for learning are evoked, the learner will experience the five categories of learning outcomes. Gagne (1985) postulates five categories of learning and the nine events of instructions. (p. 14). These are:

1. Intellectual Skills ("knowing how" or having procedural knowledge.)

2. Verbal Information (being able to state ideas, "knowing that" or having declarative knowledge)

3. Cognitive Strategies (having certain techniques of thinking, ways of analysing problems)

4. Motor Skills (executing movement in a number of organised motor acts such as playing sports or driving a car.)

5. Attitudes (mental states that influence the choice of personal actions.)

Gagne (1985) relates the five learning outcomes to the nine events of instructions and provides a systematic statement of the theory to describe how the instructional events are designed for each of the learning outcomes. According to Gagne (1985) the five categories of learning outcomes are designed based on characteristics of the content that a learner must learn.

Gagne (1985) believes that cognitive strategies were learning strategies the learners adopted and applied in the process of learning, and that they are not subject specific. Gagne's conditions of learning theory draws upon general concepts from various learning theories in order to define what learning is. The theory looks at the observable changes in human behaviour that confirm that learning has occurred. The theory provides an answer to the question, “what is learning”? (p. 16).

According to Gagne (1985) in order to answer this question, a description of the condition under which learning takes place must be provided by referring to situations in ordinary life and in school where learning occurs and by referring to experimental studies in learning. Gagne (1985) postulated that proof of learning shows by a difference in a learner’s performance before and after participating in a learning process. Gagne (1985) claimed that the presence of the performance alone does not make it possible to conclude that learning has occurred; but instead, it is necessary to show that there has been a change in performance. The theory also talked about something calls Association Learning. According to Gagne (1985) there are three basic prototypes of learning that demonstrated the characteristics of Association Learning and these are: Classical Conditioning, Operant Conditioning and Verbal Conditioning.

The theory talks about conditions of learning and outlined two different types of conditions that exit in learning: namely Internal Conditions and External Conditions. According to Gagne (1985), the capabilities that already exist in a learner before any new learning begins, make up the internal conditions of learning and the external conditions include different stimulus that exist outside the learner such as the classroom environment, the teacher and the learning situations. The nine events of instructions are the environmental events that help learning to occur and are designed to achieve each of the five different learning outcomes (Gagne, 1985). The nine events of instruction are:

Gaining Attention, Informing learners of the objective, Stimulating recall of prior learning, Presenting the stimulus, Providing learning guidance, Eliciting performance, Providing feedback, Assessing feedback, and Enhancing retention and transfer.

These five conditions of learning, the association learning and the nine events of instruction, describe the frame work for Gagne's conditions of learning theory.

Implication for Teaching and Learning

From Gagne's theory of learning, it can be pointed out that for effective teaching and learning to take place, the internal and the external conditions for both the learner and the teacher should be addressed. Adequate information must be provided to the learner by the teacher on his/her studies.

Conceptual Understanding

Conceptual understanding is the ability to deduce, perceive, and comprehend a concept. Byrnes (1996) defines conceptual understanding as having knowledge of principles and what it means. Conceptual understanding is considered to be one of the highest levels of thinking skills in the cognitive psychology (Novak, 1988; Piaget, 1970). Providing a proper learning environment and experiential basis for students to develop conceptual understanding is one of the most important goals of effective instructions (Smith, diSessa, & Roschelle, 1993). Conceptual understanding is a critical outcome of educational process and knowledge construction (Byrnes, 1996; She, 2004). This does not suggest that teachers need to teach concepts and students need to memorize definitions. On the contrary, in order to promote conceptual understanding, students should learn in context and experience the concept or phenomenon learned (Bruner, 1990). Various methods to promote students' conceptual understanding in science education were investigated in recent research conducted by (Bruner, 1990; She, 2004). Incorporating active learning methods, such as drawing and analyzing diagrams, writing summaries, and solving problems, were found to promote students' conceptual understanding (Wandersee, Mintzes & Novak, 1994). Indeed, active learning is consistent with the constructivists' theory that maintains that knowledge cannot simply be transmitted from teachers to learners; rather learners must be engaged in constructing their own knowledge (Bruner, 1990; von Glasersfeld, 1995). Active learning environments encourage students to be engaged in solving problems, sharing ideas, giving feedback, and teaching each other (Johnson & Johnson, 1987). From this perspective, educational studies have suggested that integrating active learning strategies, as part of the formal learning sessions, can advance students' learning, and their conceptual understanding (Duit & Treagust, 2003).

Students' Conceptions

The study of students' conceptual problems in science and what to do with them has become a central focus of research in science education in recent years: (Mintzes, Wandersee & Novak, 2005a, b; Wandersee, 1994), provided a solid rationale and a strong theoretical and empirical frame work for teachers and instructional planners. The consistent and widespread conclusions of this research tradition have become acceptable "common-places" among science educators.

Among the most of these conclusions are the following:

(a). Learners subscribe to a host of alternative scientific concepts which contrast with views offered by scientists, teachers and textbooks.

(b). These alternative ideas are found in males and females, individuals of all ages and educational levels, abilities, social classes and cultures and often serve a useful function in everyday life of people.

(c).Alternative ideas are often “tenacious and resistance to extinction” (Ausubel, Novak & Hanesia1978) even when confronted with excellent teachers and instructional materials. (p. 420).

(d). Alternative scientific views have many sources, including direct observation, per culture, everyday language, the mass media, and formal classroom instruction.

(e). Overcoming these conceptual difficulties requires conscious effort by learners to construct meaning and to monitor and regulate progress.

(f). Deep or radical change in the way learners understand scientific phenomena is not easily or quickly achieved, and may require a significant shift in the way we view learning and what teachers do in their classrooms.

Teaching

According to Smith (2007), teaching is a process of carrying out activities that provide students with experiences that can include learning. One may say that teaching takes place when the teacher organizes a series of activities, experiences with the intention of which is to make students learn new knowledge, and acquire skills and competence in a particular subject. Teaching is not merely lesson delivering or merely dispensing of subject matter (Melby 1963). He said what is needed to make the art complete is to is the involvement of students in the teaching process. Moore, (1998) also defines teaching as the action of someone who is trying to assist others to reach their fullest potential in all aspects of development.

According to Farrant (1980), teaching is a process that facilitates learning through knowledge and skills acquired by a learner from an experienced person. Teaching is getting at the heart and mind of the learner so that the learner begins to value learning and to believe that learning is possible in his/her own case. Not all teaching results in learning. For example, a teacher might anticipate that certain activities will make students to learn the use of the venier calipers for taking measurements, but cannot guarantee that learning actually occurs if, despite the instructional experiences the learners are unable to perform related tasks effectively (Lowman 1995). How well learning takes place depends on the quality of teaching and the quality of a teacher's interaction with the learners (Stiggins 1999). Teaching and learning are inter-related activities that bind the teacher and the learners together. Teaching activities are carried out with the intention to facilitate learning. The teacher carries out a variety of activities such as explaining concepts, asking questions, moderating discussions, going through assignments, performing experiments, or giving tests. These activities of the teacher connote teaching because they are aimed at facilitating intellectual understanding of a subject. The students however take part in activities like group discussion, watching the teacher solving problems; performing experiments etc. these learners' activities result in gaining knowledge or ability, constitute learning. For effective teaching the teacher has to adopt some strategies; these strategies are called teaching styles or teaching techniques. Teaching styles or teaching techniques are strategies a teacher employs in impacting knowledge to his/ her learners (Grasha, 1995). Teaching style is the manner in which a teacher effectively and efficiently interacts with learners within the classroom environment to bring about quality learning of a subject matter among learners. Three of such styles are identified: discipline- centred, teacher- centred, and student-centred (Woods, 1995).

Discipline Centred Style

This type of teaching technique focuses more on the subject matter more than on what the teacher does. The aim is to teach content as prescribed in the syllabus or textbook regardless of whether it meets the needs of the learners or not (Woods, 1995).

Teacher Centred Style

In teacher centred technique, the teacher is the focus, acting as the authoritative expert, the main source of knowledge, and the focal point of all activity (Grasha, 1995). In such teaching environment, the learners are passive learners and they merely regurgitate content. Teaching is merely to transmit information and to help learners to master facts for examination purpose, through lectures, explanations and illustrations, it allows for minimal teacher-student interaction. Its strength, however, lies in the efficiency that is achieved in communicating much information quickly to learners.

Student-Centred Style

This type of teaching technique allows for a dynamic classroom environment and it most effective for teaching (McCombs and Whistler, 1997). The focus is on the students, their cognitive abilities and interests. The teacher's concern is how to make the students take an active role in their learning by making them to conduct their own investigations, develop their ideas, and share ideas with others through discussions or collaborative work. The instructional goals place more emphasis on cognitive understanding and skills development, than merely passing examinations. Classroom activities, instructional content, and teaching methods are selected to facilitate active learning, encourage independent thoughts and critical thinking, stimulate interest and promote positive attitude towards learning. Whichever style or technique a teacher adopts in teaching will depend on how he or she perceives his or her in the learning process. If perceived as an instructor, the teacher will select the teaching approaches that give an authoritative role, whereas as a facilitator he or she will prefer approaches that introduce more flexibility and more student engagement as co-creator in the learning process (McCombs and Whistler, 1997). All teaching techniques can stimulate learning if used appropriately, although the student-centred style leads to better retention, better problem solving, better application of knowledge, and better motivation for learning (Mckeachie, 1994).

The art of Teaching and Learning Chemistry

According to Osborene and Collins (2000), learning cycle in children consists of exploration; which is manipulation of materials, investigation; that is testing of hypothesis, and reflection; that is more on the activity. Young (1990) also states that in order to teach chemistry well, you need to use a well-organized classroom with the right type of equipment and apparatus and also the teacher needs to prepare carefully. Young (1990) continued that teachers often think that they cannot teach science without experiments and complicated apparatus. It is certainly true that some apparatus are necessary but most of the things needed can be collected or made with the help of the students. Gallagher (1992) observed that the use of a single method in teaching affects learners' participation, hence the need to use a variety of methods to allow for individual differences and maximum participation by learners. Nakhleh (1992) suggested that traditionally organic chemistry has been thought as too difficult for students, and that chemistry as a subject is very difficult for students to conceptualize since most of the topics are taught in abstract.

Akpan (1992) also stated that the reasons for this unfortunate behaviour of teachers are lack of: skills on the part of teachers to improvise, limited amount of materials, laboratories, and science equipment due to large class size, etc. Ebenezer and Zoller (1993) observed that the kind of science teaching which students experience was the most important factor in forming their attitudes towards science.

Difficulty Areas in Chemistry.

A look at the enormous range of papers, which have addressed various facets of the learning difficulties can be categorised into various areas. In the analysis presented here, the work has been grouped into five main areas of concern, recognising that there are overlaps and potential omissions. Each is discussed briefly.

(a) Curriculum Content

The advent of revised school syllabi in the 1960s and 1970s in many countries saw a move towards the presentation of school chemistry in a logical order. Similarly, early chapters in almost all textbooks for first level higher education courses start with topics like atomic theory, line spectra, Schrödinger equations, orbital, hybridisation, bonding, chemical formulae, chemical equations, balancing chemical equations, organic chemistry, and stoichiometry. This is the 'grammar and syntax' (Jenkins, 1992) of chemistry but is daunting for the student. Johnstone (2000) has made arguments against this 'logical' presentation cogently: The logical order may well not be psychologically accessible to the learner.

Much school chemistry, taught before 1960, laid great emphasis on descriptive chemistry, memorization being an important skill to achieve examination success. The sub-microscopic interpretation and symbolic representation were left until later. Today, the descriptive is taught alongside both the 'micro' and 'representational'. Johnstone (1982) has argued that the learner cannot cope with all three levels being taught at once. Gabel (1999) supports this argument. Indeed, today, there is a danger that chemistry depends too much on the representational, with inadequate emphasis on the descriptive.

Chemical knowledge is learned at three levels: “sub-microscopic,” “macroscopic” and “symbolic”, and the link between these levels should be explicitly taught (Johnstone, 1991; Gabel, 1992; Harrison & Treagust, 2000; Ebenezer, 2001; Ravialo, 2001; Treagust, Chittleborough, & Mamiala, 2003). The interactions and distinctions between these levels are important characteristics of chemistry learning and necessary for comprehending chemical concepts. Therefore, if students possess difficulties at one of the levels, it may affect the other. Thus, determining and overcoming these difficulties should be our primary goal. Johnstone (1984, 1991) indicated that, the nature of chemistry concepts and the way the concepts are represented (macroscopic, microscopic, or representational) make chemistry difficult to learn. The methods by which students learn are potentially in conflict with the nature of science, which, in turn, influences the methods by which teachers have traditionally taught the subject (Johnstone, 1980).

In order to determine whether student's understanding of organic chemistry would increase if the particulate nature of matter (sub-microscopic level) was emphasized, Gabel (1992) introduced extra instruction to the experimental group that required students to link the particulate nature of matter to other levels (macroscopic and symbolic levels), Gabel (1992) found that, the experimental group performed higher in all levels than the control. It seems that this kind of additional instruction is effective in helping students make connections between the three levels on which chemistry can be taught and understood. Sawrey (1990) found that, in an introductory chemistry course, significantly more students were able to solve the problems that used symbols and numbers than they could solve those depicting particles. Bunce, Gabel and Samuel (1991) interviewed students who had solved problems out loud. This study indicated that students rarely thought about the phenomenon itself but they searched in their minds until they came upon something that fitted the conditions of the problem.

Osborne and Cosgrove (1983) showed how students (at several school age levels) understood little about the particulate nature of matter or about chemical phenomena in their everyday lives. Surprisingly, some of the incorrect explanations that students gave to common phenomena are concepts that they developed after formal school instruction. Bodner (1991) used the same questions developed by Osborne and Cosgrove (1983) to determine how prevalent these ideas were among the graduate students. Bodner (1991)'s findings indicated that non-scientific explanations persist for some students even after students had graduated with a major in chemistry, and concluded that students have difficulty in applying their knowledge and they do not extend their knowledge into the real world.

Wheeler and Kess (1978) suggested that the chemistry curriculum should not be defined by the logic of the subject but by the needs of the learner. According to Johnstone (2000) in his complementary paper emphasizes that the order and method of presentation must reflect the psychology of the learner. These two fundamental principles would offer a constructive basis for dialogue in re-structuring the way Chemistry is offered in school and higher institutions: in simple terms, define the material to be taught by the needs of the learner, and define the order of presentation by the psychology of learning. Such a statement is relatively easy to make but it may well prove to be very difficult to implement. Most curricula are defined by the needs of the next stage and are not defined by the needs of those (often the majority) who will not study chemistry at the next stage (Za'rour, 1975). Similarly, chemistry is a logical subject and its inherent logic is a tempting structure on which to build a syllabus. However, the logic is that of the expert and not the learner.

(b) Overload of Students' Working Memory Space

The working memory space is of limited capacity (Baddeley, 1999). This limited shared space is a link between what has to be held in conscious memory, and the processing activities required to handle it, transform it, manipulate it, and get it ready for storage in long-term memory.

When students are faced with learning situations where there is too much to handle in the limited working space, they have difficulty in selecting the important information from the less important information. The latter has been described as "noise". The students have difficulty in separating the signal from the noise (Johnstone & Letton, 1991).

Faced with new and often conceptually complex proplem, the chemistry student needs to develop skills to organize the ideas so that the working space is not overloaded. Without the organizing structures available to the experienced teacher, the student frequently has to resort to rote learning, which does not guarantee understanding. To solve this type of problem, Johnstone (1991) has argued that teachers have to look more closely at what is known about human learning and also look at the nature of the discipline of chemistry and its intellectual structure in an effort to harmonize them.

The ability to develop strategies to cope with information overload depends heavily on the conceptual framework already established in the long-term memory (Baddeley, 1999). Working space cannot be expanded but it can be used more efficiently. However, this depends upon some recognisable conceptual framework that enables students to draw on old, or systematise new, material. Miller (1956) suggested the idea of "chunking" (the ability to use some strategy to bring together several items into one meaningful unit, thus reducing working space demands).

Difficulties in conceptual understanding have been related to working memory space and the idea of chunking (Johnstone & Kellett, 1980; Johnstone, 1980). Salvaratnam (1993) discussed the use of summary frameworks while Johnstone outlines ways by which extraneous excess information ("noise") can be reduced (Johnstone, 1980; Johnstone & Wham, 1982).

(c) Language and Communication

Language has been shown to be another contributory factor to information overload Johnstone, (1984). Language problems include unfamiliar or misleading vocabulary, familiar vocabulary which changes its meaning as it moves into chemistry, use of high - sounding language, and the use of double or triple negatives (Cassels & Johnstone, 1985). An interesting example of the effect of language on working memory space overload is the study carried out to measure working memory space, using the second language of the pupils. The study found that, where the learner was operating with a second language, the usable working memory space dropped by about one unit. It was suggested that this unit was being "used" to handle the language transfer (Johnstone & Selepeng, 2001).

Gabel (1999) noted that, the difficulties students have with chemistry may not necessarily be related to the subject matter itself but to the way of discussing it. Gardner (1972) conducted a study on the vocabulary skills of students in secondary schools and drew up word lists to show which non-technical words were inaccessible to learners at various stages. Gardner (1972) also examined the words and phrases which connect parts of a sentence and which give logical coherence to it (development of logical arguments are impossible without these logical connectives). According to Gardner (1972), many words used frequently by chemistry teachers were just not accessible to their learners.

Similar investigations conducted and extended to higher education by Cassels and Johnstone (1980) have shown that the non-technical words associated with science (chemistry) were the causes of misunderstanding for pupils and students. Words, which were understandable in normal English usage, changed their meaning (sometimes quite subtly) when transferred into, or out of, a science (chemistry) situation. For example, the word "volatile" was assumed by students to mean "unstable", "explosive" or "flammable". Its scientific meaning of "easily vaporised" was unknown. The reason for the confusion was that "volatile", applied to a situation, does imply instability or excitability and this meaning was naturally carried over into the science context with consequent confusion.

White (1977) argued that learning involves the interaction of the information that the learner receives through the sensory system and the information that already existed in long-term memory. This enables the learner to recognise and organise the incoming information and make sense of it. Unfamiliar or confusing words and constructions come into conflict with the organisational process. White (1977) emphasised that the cognitive processes may be considered to involve the interaction of the components of the working memory and long-term memory. Language influences the thinking processes necessary to tackle any task. This is supported by the observations made by Cassels and Johnstone (1984), who noted that memory span is not determined by the number of words but by the grammatical structures (e.g., embedded clauses) that may themselves load the memory. Cassels and Johnstone (1984) stressed that the important factor in the sentence is its meaning, while negative sentences require more of working memory capacity than positive identical sentences. The problem of language, including the use of representational symbolisms, needs careful thought. Language helps or hinders interactions with long-term memory but it can also be a source of significance information overload. Perhaps this suggests that there should be more opportunity for the learner to verbalise and discuss ideas as they are being presented (Cassels & Johnstone, 1984).

(d) Concept Formation

Chemistry learning requires much intellectual thought and discernment because the content is full of many abstract concepts. Concepts such as dissolution, particulate nature of matter, and chemical bonding are fundamental to learning chemistry (Abraham,Grzybowski, Renner, & Marek, 1992; Nakhleh, 1992).

Until these fundamentals are understood, topics including reaction rate, acids and bases, electrochemistry, chemical equilibrium, organic chemistry and solution chemistry become arduous. Therefore, inquiring into students' conceptions of the fundamental concepts in chemistry has been a research focus of several researchers in many countries for the past two decades (Stavy, 1988; Peterson & Treagust, 1989; Ebenezer & Gaskell, 1995; Quiles-Pardo & Solaz-Portoles, 1995; Ayas & Demirbaş, 1997; Ayas & Coştu, 2002; Çalik, Ayas, & Ebenezer, 2005). Real understanding requires not only the grasp of key concepts but also the establishment of meaningful links to bring the concepts into a coherent whole. A study by Ausubel (1968) laid the basis for understanding how meaningful learning can occur in terms of the importance of being able to link new knowledge onto the network of concepts, which already exist in the learner's mind. Concepts develop as new ideas are linked together and the learner does not always correctly make such links. This may well lead to misconceptions. Conceptions or pieces of intellectual thought either reinforce each other or act as barrier for further learning. To overcome obstacles in learning, researchers have focused on identifying and assessing students' "misconceptions" (Helm, 1980), "alternative frameworks" (Driver, 1981), "children's science" (Gilbert, Osborne & Fensham., 1982), or "preconceptions" (Novak, 1977). These labels are attached when students' conceptions are different from the scientific ideas and explanations (Nakhleh, 1992; Taber, 2000; Nicoll, 2001; Ayas, Köse and Taş, 2002). There have been a lot of studies on misconceptions in chemistry and there are several reviews on this area (Anderson, 1990; Stavy, 1991; 1995; Nakhleh, 1992; Gabel & Bunce, 1994; Wandersee, Mintzes, & Novak, 1994). In addition, various studies indicate that students' difficulties in learning science (chemistry) concepts may be due to the teachers' lack of knowledge regarding students ' prior understanding of concepts (Driver & Easley, 1978; McDermott, 1984). Bodner (1986) made a helpful point when he noted that, 'We can teach, and teach well, without having the students learn".

Alternative conceptions may not be students' fault. Chemical knowledge structures, for example, in "combustion," "physical and chemical change," and "dissolving and solutions" by their very nature lead to alternative conceptions argued Griffiths (1994). Students' conceptions are constrained both by the perceiver (learner) and the perceived (chemical phenomena) Ebenezer (1991). Thus, learning involves knowledge that needs to be restructured, adapted, and even discarded (Duschl & Osborne, 2002).

Other studies have focused on students' conceptions and their inter-connections. Fensham and George (1973) investigated problems arising from the learning of organic chemistry while Kellett and Johnstone (1974) indicated that students had little conceptual understanding of functional groups and their role. This caused difficulties with, for example, esterification, carboxylic acid and hydrocarbons. Kempa and Nicholls (1990b) found that problem-solving ability, above the algorithm level, depends on the strength of concept interlinking in a student's mind. Kempa and

Nicholls (1990b) also found that a student's ability was dependent on context, such that individual student can do well in some areas and badly in others.

Bodner (1991) listed several factors that may lead to misconceptions in the minds of learners. Bodner (1991) noted the problems of rote learning where students possess knowledge without understanding. When the teacher first introduces an idea, the learner may already possess previous experience (derived from the world around, including the media), which leads to misconception. In addition, there is also the problem where the scientific language remains constant while the meanings of the terms change until they become misleading. Many research tools appear in the literature to identify students' misconceptions. Examples include the diagnostic tests developed by Treagust (1988), Krishnan and Howe (1994). While the literature is replete with papers, which provide evidence of misconceptions, fewer papers suggest potential remedies. It is worth recognising that misconceptions will occur, a learner does not come to chemistry class with empty minds. The process of learning chemistry will involve the modification or alteration of previously held ideas and this is a natural process. It is individual in nature and there is no way by which the teacher has the time or capacity to approach each learner on an individual basis (Krishnan & Howe, 1994).

However, in practice, if concepts are developed with care, building on the language and thought already present, while allowing concepts to be approached from several directions, the learner will be able to develop ideas more meaningfully. In addition, learners need the opportunity to "play with ideas', to share ideas, to verbalize concepts so that, in a natural, step-wise fashion, concepts steadily move forward on a secure base. This will allow inadequate conceptions to be modified in an acceptable way. Nonetheless, misconceptions will always occur, even among those highly experienced in chemistry (Treagust, 1988).

The whole area of misconceptions (including alternative frameworks and the ideas in constructivism) probably needs some re-thinking. It appears to be a natural part of the developmental process and it appears to be individually idiosyncratic. However, strategies can be adopted to take advantage of this natural process in the development of more secure understanding of concepts. A useful future line of research might be to explore the effects of strategies, which teachers might use to take advantage of this natural process in order to give the learners an enriched understanding of important concepts. Group work, dialogue and the exchange of ideas may all be very important in allowing misconceptions to be corrected effectively (Krishnan & Howe, 1994).

(e) Motivation

There is no doubt that motivation to learn is an important factor controlling the success of learning. However, the difficulty of a topic, as perceived by students, will be a major factor in their ability and willingness to learn it (Johnstone & Kellett, 1980). Students' motivation to learn is important but does not necessarily determine whether it employs a deep or a surface approach: Aspects of students' motivation to learn can be classified as either intrinsic (e.g. wanting to know for its own sake) or extrinsic (e.g. wanting to learn what is on an exam syllabus) (Entwistle, Thompson &Wilson, 1974). There is also a third class, called 'a motivational' learning, which covers the situation where students do things (like attending lectures) without any conscious belief that this will help them learn something (Vallerand & Bissonnette, 1992). Resnick (1987) found that students will engage more easily with problems that are embedded in challenging real-world contexts that have apparent relevance to their lives. If the problems are interesting, meaningful, challenging, and engaging they tend to be intrinsically motivating for students. However, Song and Black (1991) indicated that students may need help in recognizing that school-based scientific knowledge is useful in real-world contexts.

White (1997) argued that the issue of long-term and short-term goals is relevant to the learning of science. The student who goes to lectures with a short-term goal of passing examinations often has a specific approach to learning. Scientific laws and potentially meaningful facts are learned as propositions unrelated to experience. Too often examinations reward the recall of such facts. On the contrary, the students who have a stronger sense of achievement, or who want to learn about science (chemistry), may attend the lectures with a long-term goal of a deeper understanding and appreciation of science (chemistry). Learners may approach it using advanced learning strategies of reflection and inter-linking of knowledge. With the pace of normal lectures, there is unfortunately little opportunity for this to occur during the lectures. Ames and Ames (1984) pointed out that students' motivations for learning from lectures have important consequences for what they are attending to, how they are processing information, and how they are reacting to the lectures.

Kempa and Diaz (1990a) proposed the existence of four motivational traits that are attributable to students' needs. Kempa and Ayob (1995) introduced the notion of motivational pattern and implied that learners differ with respect to their preference for and responsiveness to different instructional features. Kempa and Ayob (1995) were able to identify empirically the four major motivational patterns in students' sample. The students were divided into four types (groups): the achievers, the curious, the conscientious, and the sociable. Hofstein and Kempa (1985) followed this line of research and found that students of different motivational patterns have their preferred modes of learning as well. Kempa and Diaz (1990a) found that a high proportion of the total student population could be clearly assigned to one of the four motivational patterns. Kempa and Diaz (1990a) went on to suggest that students with the conscientious or achievers type of motivational pattern would exhibit a strong preference for formal modes of teaching. Numerous other studies have sought to probe motivational features of learning (such as Ward & Bodner, 1993; Nakhleh & Mitchell, 1993). Together, they give an insight into the vital importance of considering motivational features in a learning situation.

Reducing Obstacles to Learning

It is, of course, the aim of chemistry teachers at all levels to make the subject accessible in such a way that maximum meaningful learning can take place. Salvaratnam (1993) has listed a number of important aspects to aid such learning. These are consistent with two broad principles:

(1) The need to avoid working memory space overload;

(2) The importance of taking into account concepts already held.

These two fundamental ideas are explored now in some detail:

(a) Working Memory Space Overload

There are some problems associated with limitations in working memory space. The importance of these limitations cannot be underestimated. The working memory space not only has to hold incoming information, it also has to draw information from long-term memory and process information to make sense of it. The potential for overload is, therefore, considerable.

One of the greatest difficulties in avoiding working space overload lies in the fact that the learner does not yet have the experience (such as the development of "schema, tricks, techniques and previous knowledge" which may be called "strategies") to be able to reduce the working space overload (Johnstone & El-Banna, 1986). Unfortunately, the acquisition of such strategies e.g. chunking (Miller, 1956), is a highly personal process. Therefore, it is not easy to teach the learner how to chunk although it is possible to present information in such a way that the learner can more easily develop personal chunking skills. According to White (1988) we chunk the world; that is we combine our sensations into a small number of patterns. Therefore, chunking is a function of knowledge. The size and number of chunks perceived in a situation is one of the big differences between the knowledgeable person (e.g. expert, teacher, adult) and the novice (e.g. beginner, student, and child). The knowledgeable person can collect the phenomena or events into a smaller number of meaningful units. The teacher already has such strategies but no students can necessarily apply these. It is important, therefore, to minimize working space demands and to provide several routes to meaningful learning, allowing the learner to seek to develop their own strategies, which might enable them to reduce the overload.

Items are handled in the working memory as 'chunks' of information. These can vary from single characters to abstract concepts and complex images (Johnstone & Kellett, 1980). It is possible to compensate for the limited capacity of working memory by restructuring the information. For example, a telephone number (009722799753) is difficult to remember as twelve (12) digits, but if the same number is broken up into three smaller groups (00972-279-9753- representing area, district and number), it is much easier to remember. The effect is to reduce the storage required from twelve (12) chunks to three.

Therefore, chunking is a process of organizing information, which allows a number of items to be viewed as a single unit, with probably a name or label. It is an important factor in both communication and learning (White, 1988). Ability to chunk information is a learning strategy, and the act of chunking will show how well the topic is known. The more you know about the topic the easier it is for you to chunk within it. The number of chunks a person can hold may be a fixed characteristic for an individual but will vary from person to person. Johnstone (1980) pointed out that "The teacher's working memory is already organised, but this is not the case for the learner. Each learner has to analyze the information coming in and organize it for himself, or be helped to organize it, if the learning is to become part of him. If a learner tries to take on the teacher's information and structure, the learner has to resort to rote memorization which certainly does not guarantee understanding". In trying to solve a problem, the student may find the working memory under stress. Solving problems is full of "noisy" things; "noisy" in the sense that they distract attention from the "signal" or "message" that is to be conveyed. The "noise" can occupy a substantial part of working memory leaving little space for the "signal" and even less space for thinking. Information crowds in, from lecture notes, textbooks, workshops, tutorials, peer discussions, things to recall, and then to interpret. To overcome these limitations, expansion of the size of each chunk of information is necessary. For example, experienced instructors (unlike novices) can condense a complicated stoichiometry problem to one chunk by recognising a key relationship.

Similarly chemists do not see a carbon atom, two oxygen atoms, two hydrogen atoms, a double bond, and three single bonds (nine pieces of information). Instead, they see it as a carboxylic acid (one piece). Pattern formation is one way of chunking, which is, integrating a larger number of information bits into a smaller number. Kellett (1978) proposed a relationship between information content, conceptual understanding, and difficulty and stated that where the learners had a lack of conceptual understanding then these learners may perform reasonably in low information load situations, but their performance would decrease in high information load situations, causing complaints of difficulty.

Learners with high conceptual understanding could use this to chunk information, and thus reduce the information load to one, which their working spaces could handle. High conceptual understanding would also allow the learners to separate relevant information from irrelevant ones and focus on the relevant only, which would also reduce the information load burden. According to Kellett (1978), as the information load increases, for a student with low conceptual understanding, so the perceived difficulty barrier increases. The reverse is the case for a student of high conceptual understanding.

A new learner is naturally at the lower end where concept understanding axis. If the teacher presents his new learner with material at the high end of the information load, then the perceived difficulty barrier will prevent the learner from "seeing" what is going on. If this continues, then the student's complaint of "I don't understand" may easily become "I will never understand". Such an attitude towards a topic may prove difficult or impossible to alter later (Kellett, 1978). If the teacher adopts a lower information load, increasing it only as the learner's concept understanding develops, then the difficulty would remain (essentially) constant.

(b) Paying Attention to Incoming Information

Learners not only have to focus on a specific task within a 'noisy' environment (irrelevant material), but also, within the task, that needs specific information that is relevant (meaningful) for learners. Teachers can only really find out whether learners are registering the information (Ausubel, 1968). Learners need to know when, where and what to pay attention to: Fox (1993) claimed that attention is affected by the complexity of the task and the motivation of the individual. The focus of the learners' attention determines what information is processed. Learners can attend to only a very limited number of demands that compete for their attention. Johnstone and Percival (1976) found that attention breaks do appear to exist and occur generally throughout lectures. The observer can detect such breaks relatively easily and the attention breaks appear as genuine loss of learning in subsequent diagnostic tests. A learners' ability to select the important information is a key strategy for effective learning. Selective or discriminatory attention has been shown to underlie learners' rates of learning.

Preparing the mind of the learner is one way of helping students focus their attention on the new information by linking it to the previous knowledge (the knowledge they already know and understand). This is discussed in more detail in Sirhan, Gray, Johnstone and Reid (1999) where the use of pre-lectures is shown to be effective as a way to prepare the minds of learners, with special emphasis on learners' background knowledge and experience. Students who know more about a topic find it easier to identify and focus on important information. For this reason, carefully choosing the delivered material may greatly facilitate learning. This has been explored in detail in Sirhan (2000) and is outlined in Sirhan and Reid (2001; 2002).

(c) Recalling Previous Knowledge Easily

To make the material easier for recall, learners actively need to construct, organise, and structure internal connections that hold the information together. The systematic organisation of knowledge, which may be considered to be the ordering of the component knowledge items in a logical, coherent, concise, and principle-based manner, is of fundamental importance for the effective learning, recall, manipulation, and use of knowledge. Salvaratnam (1993) found that effectiveness of knowledge organisation is increased if the: (i) Knowledge stored in memory is principle/concept based, coherent, systematic and concise, and (ii) Organisation is around the minimum amount of essential knowledge (number of principles and concepts). This latter point is one that has been confirmed in very recent work (Otis, 2001). It was found that the concept maps generated by medical students at various stages in their learning shows that many students move from a simple, but inadequate, concept maps at early stages of learning through increasingly complex maps until they move back to much simpler but more adequate maps when concepts have been grasped much more fully. It is, therefore, important that unnecessary principles, concepts, definitions, and terms be excluded as concepts are built up in the minds of learners.

Salvaratnam (1993) also listed five aspects, which would aid the learning, understanding, recalling, and application of knowledge. The following constitute these five aspects; (p. 825).

(1) Use the underlying principles and concepts as the sole basis for knowledge organisation;
(2) Exclude unnecessary laws, concepts, definitions, and terms;
(3) Use systematic and meaningful terms and definitions;
(4) Link the component items of knowledge sharply and coherently; and
(5) Store knowledge concisely.

These ways could help to reduce memory overload, aid learning and understanding, and avoid mistakes. As a result of this complexity and knowledge construction, students often are tempted to engage in rote learning rather than meaningful learning. The teachers' task is to try to find ways to increase meaningful learning, possibly by actively involving students in the process of knowledge construction (Novak &

Gowin, 1984). The study suggests that it is useful to empower students to become responsible for their own learning.

Learners need to decide on the level of complexity at which they will process new information. For example, a student can take notes and either writes them as key words or makes connections between this information and the previous knowledge (Su, 1991). The more elaborative, or complex, the learner's processing of the information, the more the learner tries to make meaningful the new information, the more likely the student is to remember it. This could be done by giving different examples on the same problem and making interconnections between it and the learners' knowledge to facilitate memorization.

Factors that Affect Student's Performance in Organic Chemistry

According to Keeves and Morgenstern (1992), attitude of the learner affects performance. This was also supported by Anderson (2006) and Freedman (1997) who explained that attitude and achievement are related and that a positive attitude towards science lesson results in a good achievement. Most students of Colleges of Education developed some negative attitude towards science from their basic levels to the secondary school level. This negative attitude manifested in the form of lack of interest, satisfaction and motivation (Gardner & Gauld, 1990).

The pedagogical content knowledge of a teacher is also crucial in teaching and learning of concepts in chemistry. Pedagogical content knowledge has been viewed as a set of special attributes that helped in transfer of knowledge to others (Geddis, 1993). It deals with the most useful forms of representation of ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations which are the ways of presenting and formulating a subject/topic that makes it comprehensible to others (Shulman, 1987).

Again, Shulman (1987) stated that pedagogical content knowledge includes those special attributes a teacher possesses that helps him/her guide a student to understand content in a manner that is personally meaningful. Shulman explained further that pedagogical content knowledge includes "an understanding of how some particular topics, problems, or issues are organised, presented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (pg. 8). Shulman (1987) also suggested that pedagogical content knowledge is the best knowledge base of teaching: The key to distinguishing the knowledge base of teaching lies at the intersection of content and pedagogy, in the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background that students have. This is supported by Ausubel (1968) that the important single factor influencing meaningful learning is indeed, what the learner already knows, and as such should be ascertained to teach him/her accordingly.

Other factors that affect students' performance in organic chemistry lesson are: past experiences of the learners and availability of materials (Murphy, 1990), presentation of concepts and topics in an abstract manner (Ornstein, 2006) and teachers' emotional disposition (Tatar, 2005).

Also truancy, lack of motivation, time available for teaching and learning, learning strategies students employ and self-efficacy are also identify as factors affecting students' performance (Bandura, 1997; Nisbet & Shucksmith, 1986). Finally, selfregulations and school climate are also among other factors that affect student performance in organic lesson / exams (Shunk, 2005).

The Role of the Science Teacher in a Constructivist Classroom

Crawford and Cobb (1999), state that the teacher must form effective groups, assign appropriate tasks, be keenly observant during group activities, diagnose problems quickly and supply information or direction necessary to keep all groups moving forward. The group discussion must be centered on critical thinking issues in science so that students do not give straight forward answers to the questions the teacher pose but rather discuss the question exhaustively with their peers in order to arrive at the right answer. In dealing with students' input in the discussion, the teacher must give counter examples to wrong answers from the students so that the students reorganize their input well.

A classroom environment that elicits thinking must be the one in which students feel safe enough to share their formative thoughts (McKeown & Beck, 1999). Therefore the input from the students must be dealt with in such a way that they feel safe to contribute more effectively in the classroom.

Even though teaching science in a constructive way may disrupt the routine of the "normal" classroom instruction, it makes the science classroom to be a community of inquiry; a problem solving environment in which learners developed a thinking attitude towards scientific issues (Schifter, 1996).

The use of the Molecular Models in Teaching and Learning Organic Chemistry

Models are tentative mental pictures of a concept that help scientists to understand and explain abstract concepts. Models serve as useful guide to man's thinking in his search for nature's secrets (Toon & Ellis, 1973). Models can be held in the hand and rotated to view all parts of the molecule (Kotz & Treichel, 2003). According to Gagné, Briggs and Wager (1992) teaching in a technology rich classroom, leads to events of instructions and these events lead to the achievement of the objectives and goals of the lesson and the course.

A model in this sense is an object that is used to stand for a part of the world (Giere, 2004). Being objects, there are a variety of models. By virtue of the fact that these models stand for a part of the world, at least some of the claims that are true about the model can be leveraged into facts about the part of the world that they depict.

The molecular model kits contain balls of various colors and sticks with which these balls can be connected together to form molecules of compounds. One of the principal uses of these physical models is to teach the students how to draw and interpret structural formulas. Once a student has mastered these skills, it is generally possible for the student to move back and forth between a structural formula and a corresponding physical model (Giere, 1999). The structural formula in its use as a model can then, roughly, be thought of as two-dimensional version of its corresponding physical model (Gobert, & Buckley, 2000). As a result, in many of the uses of structural formulas in the explanations of organic chemistry, a ball-and-stick could be substituted for the atoms and bonds.

Many chemical phenomena can be explained (and sometimes predicted) on the basis of manipulation of these physical models and/or their corresponding structural formulas (Giere, 2004). Of course, not all the features of the model are significant, and there are substantial, and evolving, theoretical commitments that underwrite these sorts of inferences. Much of the usefulness of these models in the explanation of the organic chemistry are derived from the fact that the features of the models that are relevant to explanation transcend the features used to convey the descriptive content of the model (Giere, 1999).

There are several kinds of molecular models, one of which is called the ball-and-stick model spheres usually in different colours made up of plastic, that represent the atoms and the sticks represent the bonds holding them together. These models make it easy to see how atoms are attached to one another. According to Kozma and Croninger (1992), models help to address the cognitive, motivational and social needs of low performance students. Another means by which molecules can be represented is the use of space filling models. These models are more realistic because they are a better representation of relative sizes of atoms and molecules (Kotz & Treichel, 2003).

According to Coll, France, and Taylor (2005), models provide useful representations of objects or actual situations that can bring out the concepts that are to be learned. Models are used as visual objects to convey the meaning of a concept or system. Models are useful for visual learners. Molecular models are set designed for teaching and for laboratory research. It's Ball-and-Stick structure model, which can be used to build most of organic molecules and most of crystal structure models and as usual inorganic molecules (Gobert & Buckley 2000). The balls have 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. Single bonds are represented by (fairly) rigid grey sticks. Double and triple bonds use two longer flexible bonds which restrict rotation and support conventional cis/trans stereochemistry (Gobert & Buckley, 2000).

Table 1 shows the various atoms, their number of hole(s) and their colour codes.

Table 1

Atoms and Their Colour Codes

Atom	Holes	Colour
Hydrogen (H)	1	White
Carbon (C)	4	Black
Oxygen (O)	2	Red
Nitrogen (N)	3	Blue
Chlorine (Cl)	1	Green
Bromine (Br)	1	Orange

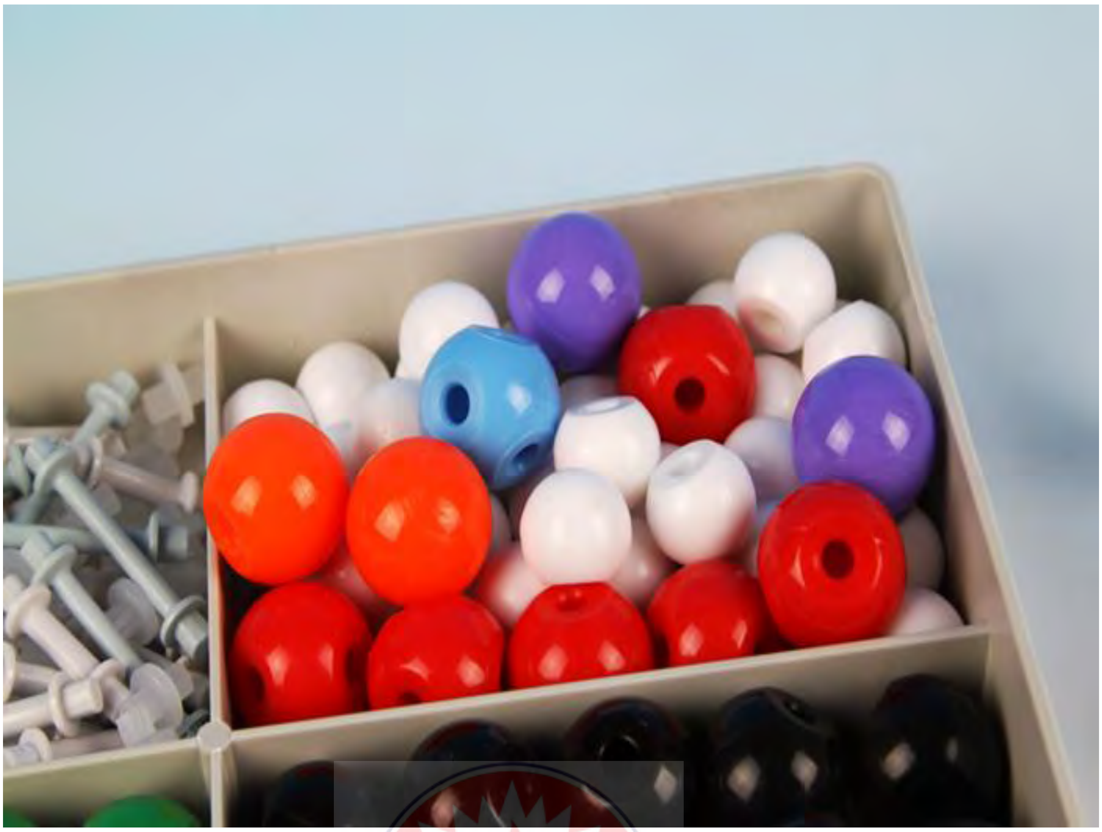


Fig. 1: The Molecular Model Kits

The concept of the chemical bond as a direct link between atoms can be modelled by linking balls (atoms) with sticks/rods (bonds) (Gobert & Buckley 2000).

Study on Functional Groups. (Alkanes, Alkenes, Alkynes, Alkanols, Carboxylic Acids and Esters).

In organic chemistry, functional groups are specific groups of atoms or bonds within molecules that are responsible for the characteristic chemical reactions of those molecules. The same functional group will undergo similar chemical reaction(s) regardless of the size of the molecule however; its relative reactivity can be modified by other nearby functional groups (Jerry, 1985).

A functional group is an atom, or group of atoms, or bond between carbon atoms, which gives an organic molecule its characteristic reactions (Abbey, Ameyibor, Alhassan, Essiah, Fometu & Wiredu, 2001).

Functional groups are structural units that determine the chemical reactivity of a molecule under a given set of conditions. The overall chemical and physical properties of any organic molecule depend on both the nature of the carbon chain and the functional group. Organic compounds are classified into several major categories based on the functional groups they contain (Abbey et al., 2001).

A functional group is a group of bonded atoms which give an organic compound its characteristic chemical properties (Ameyibor & Wiredu, 2001). According to Brown, LeMay and Bursten (1997), the reactivity of organic compounds can be attributed to particular atoms or group of atoms within the molecules. The site of reactivity in an organic molecule is called a functional group; because it controls how the molecule behaves or functions. Furthermore, these functional groups each undergo characteristic reactions. Each distinct kind of functional group undergoes the same kinds of reactions in every molecule regardless of the size and complexity of the molecule. Thus, the chemistry of an organic molecule is largely determined by the functional group it contains (Brown, LeyMay, & Bursten, 1997).

According to Caret, Denniston, and Topping (1997), a functional group is an atom or group of atoms arranged in a particular way that is primarily responsible for the chemical and physical properties of the molecule in which it is found. All compounds that have a particular functional group are members of the same family (Caret, Denniston & Topping, 1997). The functional group is critical to the study of organic and biological chemistry. The chemistry of an organic compound is usually controlled by the functional group found in the molecule. Understanding the chemistry of the functional groups allows one to understand organic molecules, as well as the large biological molecules that allow life to exist (Caret, Denniston & Topping, 1997).

According to Abbey et al., (2001), the concept of functional groups is central in organic chemistry, both as a means to classify structures and for predicting properties. A functional group is a molecular module, and the reactivity of that functional group is assumed, within limits, to be the same in a variety of molecules. Functional groups can have decisive influence on the chemical and physical properties of organic compounds. Molecules are classified on the basis of their functional groups. Most functional groups feature heteroatoms (atoms other than C and H). Organic compounds are classified according to functional groups: alkanes, alkenes, alkynes, alcohols, carboxylic acids, esters, etc.

There are more organic compounds known than all the other (inorganic) compounds discovered. Fortunately, organic chemicals consist of a relatively few similar parts, combined in different ways, that allow us to predict how a compound never seen before may react, by comparing how other molecules containing the same types of parts are known to react (Jerry, 1985).

These parts of organic molecules are called functional groups. The identification of functional groups and the ability to predict reactivity based on functional group properties is one of the cornerstones of organic chemistry (Jerry, 1985). Caret, Denniston and Topping, (1997), pointed out that functional groups are specific atoms, ions, or groups of atoms having consistent properties. A functional group makes up part of a larger molecule.

For example, -OH, the hydroxyl group that characterizes alcohols, is an oxygen with a hydrogen attached. It could be found on any number of different molecules.

Just as elements have distinctive properties, functional groups have characteristic chemistries. An -OH group on one molecule will tend to react similarly, although perhaps not identically, to an -OH on another molecule.

According to Jerry (1985), reactions in organic compounds usually take place at the functional group site, so learning about the reactivity of functional groups prepares an individual to understand many other things about organic chemistry.

Functional Group for Alkenes

Alkenes are unsaturated hydrocarbons with a general formula C_nH_{2n}. The functional group for alkenes is carbon - carbon double bond (C=C). So in every alkenes, the structure or the bond (C=C) is found in it. It is this structure which gives the characteristic properties to all members of the alkene homologous series.

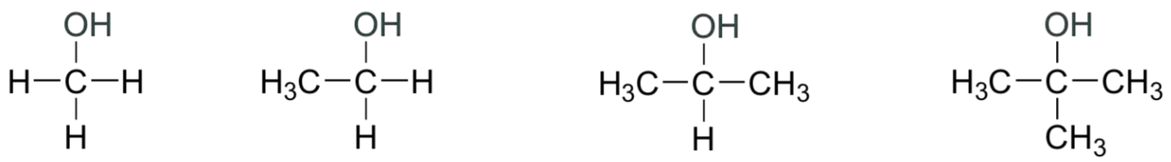
Functional Group for Alkynes

Alkynes are also unsaturated hydrocarbons with a general formula, C_nH_{2n-2}. The functional group for the alkyne is carbon - carbon triple bond (C≡C). This structure or type of bond (C≡C) is found in all alkynes. It is this structure or bond (C≡C) that gives a characteristic property to the members of the alkyne.

Functional Group for Alkanols

According to Ameyibor and Wiredu (2001), an alkanol is a compound containing one or more hydroxyl group (-OH) attached to an alkyl group or the side-chain or a substituent group in a benzene ring. The saturated form of alkanol has the general formula, $C_nH_{2n+1}OH$ or R-OH. It is this functional group (-OH) hydroxyl group which gives this class of molecules their characteristic properties and names (Ameyibor & Wiredu, 2001).

The simplest possible example of an alcohol functional group is seen in methanol. In the alcohol functional group, a carbon is single-bonded to an -OH group (this -OH group, by itself, is referred to as a hydroxyl group). If the central carbon in an alcohol is bonded to only one other carbon, we call the group a primary alcohol. In secondary alcohols and tertiary alcohols, the central carbon is bonded to two and three carbons, respectively. The figure shows the structural formulae for primary, secondary and tertiary alcohols respectively.



methanol   a primary alcohol   a secondary alcohol   a tertiary alcohol

Fig. 2: Structural formulae for some alkanols

Functional Group for Carboxylic Acids

Carboxylic acids or alkanoic acids are organic compounds with a general formula, $C_nH_{2n+1}COOH$ or R-COOH. The functional group for alkanoic acids is (COOH) carboxyl group. It is this functional group (COOH) of this class of organic molecule that gives them characteristic properties (Ameyibor & Wiredu, 2001).

Functional Group for Esters

Esters are organic molecules with a general formula $RCOOR^1$, where R and R^1 are alkyl groups from carboxylic acid and alkanol. The functional group for ester is (-

COO). This is the part of the molecule responsible for its chemical and physical properties (Brown, LeMay, & Bursten, 1997).

Ways of Understanding Functional Groups

One of the easiest ways to learn and understand functional groups is by making flash cards. Get a pack of index cards and write the name of the functional groups on one side, and draw its chemical representation on the other side.

A list of the most important ones is provided to be studied by the students. These include: Alkene, Alkyne, Alkyl halide (or Haloalkane), Alcohol, Carboxylic Acid, Ester, After all these are learned, add a couple more cards and learn those. Then add a few more and learn those. Every functional group below is eventually discussed at one point or another in the textbooks. Don't just look at the cards. Say and write the names and draw the structures. To understand it better, try going through the cards and looking at the names and then drawing their structures on a sheet of paper. Then try and go through, look at the structures and name them. Writing is a good technique to help one understand, because it is more active than simply reading. Again, using the French analogy, it's like trying to ignore learning the vocabulary and then picking up a novel in French and expecting to be able to read it.

In organic chemistry functional groups are sub-molecular structural motifs, characterized by specific elemental composition and connectivity that confer reactivity upon the molecule that contains them.

Combining the names of functional groups with the names of the parent alkanes generates a powerful systematic nomenclature for naming organic compounds. The non-hydrogen atoms of functional groups are always associated with each by covalent bonds, as well as with the rest of the molecule. The first carbon after the carbon that attaches to the functional group is called the alpha carbon.

Common Functional Groups in Organic Compounds

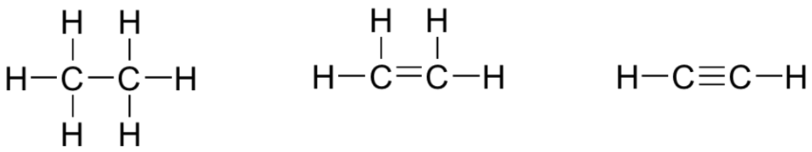
Functional groups are structural units within organic compounds that are defined by specific bonding arrangements between specific atoms. In the study of organic chemistry, it becomes extremely important to be able to quickly recognize the most common functional groups, because they are the key structural elements that define how organic molecules react. For now, the only worry is about drawing and recognizing each functional group, as depicted by Lewis and line structures. Much of the rest of the study of organic chemistry talk about how different functional groups tend to behave in organic reactions.

Some examples of very common functional groups have already been discussed. Ethene, for example, contains a carbon-carbon double bond. This double bond is referred to, in the functional group terminology, as an alkene (Toon & Ellis 1973). Table 2 shows some organic compounds' functional groups.

Table 2: Some Organic Compounds' Functional Group List

Functional Group	Compound	Suffix	Example	IUPAC Name
C-C	alkane	-ane	CH_3CH_3	ethane
C=C	alkene	-ene	$H_2C{=}CH_2$	ethene
C≡C	alkyne	-yne	HC≡CH	ethyne
-OH	alcohol	-ol	CH_3OH	methanol
COOH	carboxylic acid	-oic acid	CH_3COOH	ethanoic acid
COO	ester	-oate	CH_3COOCH_3	methyl ethanoate

The figure shows the structural formulae for alkane, alkene and alkyne.



ethane (an alkane) | ethene (an alkene) | ethyne (an alkyne)

Fig. 3: **Structural formulae for ethane, ethene and ethyne**.

The carbon-carbon triple bond in ethyne is the simplest example of an alkyne functional group (Toon & Ellis, 1973).

All the bonds in alkane are carbon-hydrogen and carbon-carbon single bonds, so in a sense one can think of ethane as lacking a functional group entirely. However, there is no general name for this 'default' carbon bonding pattern: molecules or parts of molecules containing only carbon-hydrogen and carbon-carbon single bonds are referred to as alkanes.

The IUPAC Nomenclature

In order to name organic compounds there is the need to first understand a few basic names. These names are listed within the discussion of naming alkanes. In general, the base part of the name reflects the number of carbons assigned to be the parent chain. The suffix of the name reflects the type(s) of functional group(s) present on (or within) the parent chain. Other groups which are attached to the parent chain are called substituents (Woodcock, 2014).

A rational nomenclature system should do at least two things. First, it should indicate how the carbon atoms of a given compound are bonded together in a chain. Secondly, it should identify and locate any functional groups present in the compound. Since hydrogen is such a common atom in organic compounds, its amount and locations can be assumed from the tetravalency of carbon, and need not be specified in most cases. The IUPAC nomenclature system is a set of logical rules devised and used by organic chemists to circumvent problems caused by arbitrary nomenclature. Knowing these rules and given a structural formula, one could write a unique name for every distinct compound. Likewise, given an IUPAC name, one could write a structural formula. In general, an IUPAC name has three essential features:

1. A root or base indicating a major chain or ring of carbon atoms found in the molecular structure.

2. A suffix or other element(s) designating functional groups that may be present in the compound.

3. Names of substituent groups, other than hydrogen, that complete the molecular structure. (Woodcock, 2014).

Alkanes

Hydrocarbons having no double or triple bond functional groups are classified as alkanes or cycloalkanes, depending on whether the carbon atoms of the molecule are arranged only in chains or in rings. Although these hydrocarbons have no functional groups, they constitute the framework on which functional groups are located in other classes of compounds, and provide an ideal starting point for studying and naming organic compounds. The alkanes are members of a larger class of compounds referred to as aliphatic hydrocarbons. Simply put, aliphatic compounds are compounds that do not incorporate any aromatic rings in their molecular structure and also are not alicyclic (Woodcock, 2014).

The following table lists the IUPAC names assigned to simple continuous-chain alkanes from C-1 to C-10. A common "ane" suffix identifies these compounds as alkanes. Longer chain alkanes are well known, and their names may be found in many reference and text books. The names methane through decane should be well understood, since they constitute the root of many IUPAC names. Fortunately, common numerical prefixes are used in naming chains of five or more carbon atoms.

Table 3

Lists of Some Alkanes

Name	Molecular Formular	Condensed Formular
Methane	CH_4	CH_4
Ethane	C_2H_6	CH_3CH_3
Propane	C_3H_8	$CH_3CH_2CH_3$
Butane	C_4H_{10}	$CH_3CH_2CH_2CH_3$
Pentane	C_5H_{12}	$CH_3(CH_2)_3CH_3$
Hexane	C_6H_{14}	$CH_3(CH_2)_4CH_3$
Heptane	C_7H_{16}	$CH_3(CH_2)_5CH_3$
Octane	C_8H_{18}	$CH_3(CH_2)_6CH_3$
Nonane	C_9H_{20}	$CH_3(CH_2)_7CH_3$
Decane	$C_{10}H_{22}$	$CH_3(CH_2)_8CH_3$

Examples of some common alkyl groups are given in Table 4.

Table 4

Some Alkyl Groups

Name	Group
Methyl	CH_3
Ethyl	CH_3CH_2 or (C_2H_5)
Propyl	$CH_3CH_2CH_2$ or (C_3H_7)
Butyl	$CH_3CH_2CH_2CH_2$ or (C_4H_9)

Note that the "ane" suffix is replaced by "yl" in naming alkyl groups. The names of the substituents formed by the removal of one hydrogen atom from the end of the chain are obtained by changing the suffix -ane to -yl. Here is a simple list of rules to follow. Some examples are given in the table above. Identify the longest carbon chain. This chain is called the parent chain. Identify all the substituents (groups appending from the parent chain).

Number the carbons of the parent chain from the end that gives the substituents the lowest numbers. When comparing a series of numbers, the series that is the "lowest" is the one which contains the lowest number, at the occasion of the first difference. If two or more side chains are in equivalent positions, assign the lowest number to the one which come first in the name (Goodwin, 2003).

If the same substituent occurs more than once, the location of each point on which the substituent occurs is given. In addition, the number of times the substituent group occurs is indicated by prefixes (di, tri, tetra, etc.) depending on the number of same groups.

If there are two or more different substituents they are listed in alphabetical order using the base name (Brown, LeyMay, & Bursten, 1997).

If chains of equal length are competing for selection as the parent chain, then the choice goes in series to select the chain which has the greatest number of side chains. In summary, the name of the compound is written out with the substituents in alphabetical order followed by the base name (derived from the number of carbons in the parent chain). Commas are used between numbers and dashes are used between letters and numbers. There are no spaces in the name.

Alkyl Halides

Halogens are treated as a substituent on an alkane chain. If the carbon of an alkane is bonded to a halogen, the group is now referred to as a haloalkane; (fluoroalkane, chloroalkane, etc.). Chloroform (tetrachloromethane), $CHCl_3$, is an example of a simple haloalkane. A halo- substituent is considered of equal rank with an alkyl substituent in the numbering of the parent chain. The halogens are represented as follows in table 5.

Table 5

Halo-Substituents and Their Names

Substituent	Name
F	fluoro-
Cl	chloro-
Br	bromo-
I	iodo-

Some Important Behaviour Trends and Terminologies:

(i). The formulas and structures of these alkanes increase uniformly by a CH_2 group.

(ii**).** A uniform variation of this kind in a series of compounds is called homologous series.

(iii**).** These formulae all fit the C_nH_{2n+2} rule. This is also the highest possible H/C ratio for a stable hydrocarbon.

(iv). Since the hydrogen/ carbon (H/C) ratio in these compounds is at a maximum, it is called saturated (with hydrogen).

The IUPAC system requires the names for simple unbranched chains, as noted above, and the names for simple alkyl groups that may be attached to the chains (Gabel, 1998).

Alkenes and Alkynes - Unsaturated Hydrocarbons

According to Schmid (1996), double bonds in hydrocarbons are indicated by replacing the suffix **-ane** with **-ene**. If there is more than one double bond, the suffix is expanded to include a prefix that indicates the number of double bonds present (-diene, -triene, etc.). Triple bonds are named in a similar way using the suffix **-**yne. The position of the multiple bond(s) within the parent chain is (are) indicated by placing the number(s) of the first carbon of the multiple bond(s) directly in front of the base name.

Here is an important list of rules to follow:

The parent chain is numbered so that the multiple bonds have the lowest numbers (double and triple bonds have priority over alkyl and halo substituents) (Goodwin, 2003).

For a branched unsaturated hydrocarbon, the parent chain is the longest carbon chain that contains the maximum number of double and triple bonds. If there are two or more chains competing for selection as the parent chain (chain with the most multiple bonds), the choice goes to (1) the chain with the greatest number of carbon atoms, (2) the number of carbon atoms being equal, and the chain containing the maximum number of double bonds (Benfey, 1996).

If there is a choice in numbering not previously covered, the parent chain is numbered to give the substituents the lowest number at the first point of difference.

Alcohols (Alkanols)

Alcohols are named by replacing the suffix -ane with -anol. If there is more than one hydroxyl group (-OH), the suffix is expanded to include a prefix that indicates the number of hydroxyl groups present (-diol, -triol, etc.). The position of the hydroxyl group(s) on the parent chain is (are) indicated by placing the number(s) corresponding to the location(s) on the parent chain directly in front of the base name (same as alkenes).

The hydroxyl group takes precedence over alkyl groups and halogen substituents, as well as double bonds, in the numbering of the parent chain.

When both double bonds and hydroxyl groups are present, the -en suffix follows the parent chain directly and the -ol suffix follows the -en suffix (notice that the "e" is left off, -en instead of -ene). The location of the double bond(s) is (are) indicated before the parent name as before, and the location of the hydroxyl group(s) is (are) indicated between the -en and -ol suffixes. Again, the hydroxyl gets priority in the numbering of the parent chain.

If there is a choice in numbering not previously covered, the parent chain is numbered to give the substituents the lowest number at the first point of difference.

Carboxylic Acids (Alkanoic Acids)

Carboxylic acids are named by counting the number of carbons in the longest continuous chain including the carboxyl carbon and by replacing the suffix -ane of the corresponding alkane with **-**anoic acid. If there are two -COOH groups, the suffix is expanded to include a prefix that indicates the number of -COOH groups present (**-**anedioic acid - there should not be more than two (2) of these groups on the parent chain as they must occur at the ends). It is not necessary to indicate the position of the -COOH group because this group is always at the end of the parent chain and its carbon is automatically assigned C-1.

Here is an important list of rules to follow:

The carboxyl group takes precedence over alkyl groups and halogen substituents, as well as double bonds, in the numbering of the parent chain.

If the carboxyl group is attached to a ring the parent ring is named and the suffix -carboxylic acid is added.

When both double bonds and carboxyl groups are present, the (-en) suffix follows the parent chain directly and the (-oic acid) suffix follows the (-en) suffix (notice that the e is left off, (-en) instead of (-ene). The location of the double bond(s) is (are) indicated before the parent name as before, and the (-oic acid) suffix follows the (-en) suffix directly. Remember it is not necessary to specify the location of the carboxyl group because it is automatically the firs carbon. Again, the carboxyl gets priority in the numbering of the parent chain.

If there is a choice in numbering not previously covered, the parent chain is numbered to give the substituents the lowest number at the first point of difference.

Alkyl alkanoates (Esters)

Systematic names of esters are based on the name of the corresponding carboxylic acid.

The alkyl group is named like a substituent using the "-yl" ending. This is followed by a space. The acyl portion of the name (what is left) is named by replacing the "**-**ic acid**"** suffix of the corresponding carboxylic acid with "**-**ate**"**.

The names of organic compounds are either systematic, following logically from a set of rules, or nonsystematic, following various traditions. Systematic nomenclature is stipulated by specifications from IUPAC. Systematic nomenclature starts with the name for a parent structure within the molecule of interest (Goodwin, 2003). This parent name is then modified by prefixes, suffixes, and numbers to unambiguously convey the structure. Given that millions of organic compounds are known, rigorous use of systematic names can be cumbersome. Thus, IUPAC recommendations are more closely followed for simple compounds, but not complex molecules. To use the systematic naming, one must know the structures and names of the parent structures (Clayden, Greeves, & Warren, 2012).

In the systematic names of organic compounds, numbers are used to indicate the positions of functional groups in the basic hydrocarbon framework. The number of known organic compounds is quite large.

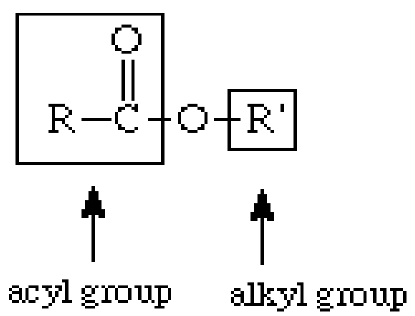


Fig. 4: General Structural Formular for Ester.

Summary of the Literature Review

This research is based on the constructivists' theory of learning. Thus the role of the researcher is to facilitate and guide the learners in the learning process of identification of functional groups, naming and drawing the structures of aliphatic organic compounds in the colleges of education to construct their own knowledge by the use of molecular model kits. Researchers have identified different types of models and their uses in the teaching and learning of chemistry. Typical examples include representational models of which molecular model kits belongs. Others are: phenomenological, analogical, electron density model and other advanced ones which involve computer generated models. The use of models in teaching about identification of functional groups, structure drawing and naming organic compounds especially aliphatic organic compounds had proven to be very successful by researchers (Tasker & Dalton, 2006; Bader, 1991). Also researchers viewed the usefulness of models and as a tool which promotes first-hand information and make what is learnt more permanent in the learner. Notwithstanding, some drawbacks in the use of models (Dori, Barak, & Adir, 2003; Coll & Treagust, 2003), the pedagogical content knowledge of the teacher makes models an outstanding resources in learning about the identification of functional groups, names and the structures of aliphatic organic compounds. In naming aliphatic organic compounds in general, the IUPAC system is used. Alkanes form the basis of naming organic compounds for that matter it must be taught well before proceeding to the other classes or groups. In writing and drawing the molecular, structural and condensed formulae, care must be exercised to account for all the constituent atoms and the way each atom is bonded in the molecule. In conclusion, the literature has reviewed on a lot of models used in the teaching and learning science of which the 3D molecular model kit is one. Most of these models are made of plastics and come in various colours, shapes, and structures to enable building of different organic molecules (Giere, 2004).

CHAPTER THREE

METHODOLOGY

Overview

This chapter provides description of the methodology employed in the study. It includes the research design, study area, target population, sample and sampling techniques, research instruments, validity, reliability, pilot testing the instruments, pre-intervention activities, intervention design, post-intervention activities, data collection procedure, and methods of data analysis.

Research Design

According to Gay and Airasian (2000), a research design is used as the overall plan for obtaining answers to the research questions being investigated. Amedahe (2002) asserts that research design is a plan or blue-print that specifies how data relating to a given problem should be collected and analysed. Seidu (2007) also discloses that, research design describes the procedures and methods used to gather data. Seidu (2007) further explained that for every research study, the choice of design must be appropriate to the subject under investigation. According to Seidu (2007) there are various designs which are used in research, all with specific advantages and disadvantages. Which one the researcher uses, depends on the aim of the study and the nature of the phenomenon. Some examples of research designs are case study, action research, survey and quasi-experimental; but for this study, a case study design was employed. The various research designs are discussed below.

Case Study

A case study is an in-depth study of a particular research problem rather than a sweeping statistical survey (Yin, 2003). It is often used to narrow down a very broad field of research into one or a few easily researchable area. The case study research design is also useful for testing whether a specific theory and model actually applies to phenomena in the real world. It is a useful design when not much is known about a phenomenon.

This involves collecting data, generally from only one or a small number of cases. It usually provides rich detail about those cases of a predominantly qualitative nature. The case study approach is appropriate for individual researchers as it gives the opportunity for one aspect of a problem to be studied to some required depth within a limited time scale (Seidu, 2007). A case study generally aims to provide insight to a particular situation and often stresses the experiences and the interpretations of those involved. It may generate new understanding, explanations or hypothesis. This method gives researchers opportunity to identify particular cases with the smallest details by focusing on examining specific subjects or situation (Wellington, 2000) and explain the cause-effect relationship among variables (Cohen, Manion, & Morrison, 2008; Çepni, 2010). Cepni (2010) further explained that the greatest strength of this study is that it allows the researcher to concentrate on a specific instance or situation and to identify, the various interactive processes at work. These processes may remain hidden in a large scale survey but may be crucial to the success or failure of the study. However it does not usually claims representativeness and should be care not to over-generalise.

Survey

According to Creswell (2008) surveys are good for asking people about their perceptions, opinions and ideas, though they are less reliable for finding out how people actually behave. (Çepni, 2010) also explains that where an empirical study involves collecting information from a large number of cases, perhaps using questionnaire, it is usually describe as survey. Survey also makes use of already available data collected for another purpose. A survey may be cross-sectional (data collected at one time) or longitudinal (data collected over a period of time).According to the Cepni (2010), issues on generalisation are usually important in presenting survey results so it is vital to report how samples were chosen, what response rates were achieved and comment on the validity and reliability of any instruments used. The author further disclosed that survey design methods enable a researcher to collect data from a large sample within a short period of time and that because the survey method studies are carried out in order to determine current situations and they prepare the required background for the case studies.

Quasi-experimental

Quasi-experimental research design involves selecting groups, upon which a variable is tested, without any random pre-selection processes (Shuttleworth, 2008). Quasi-experimental research designs include, but are not limited to: the one-group posttest only design; the one-group pretest posttest design; the removed-treatment design; the case-control design; the non-equivalent control groups design; the interrupted time-series design and the regression discontinuity design (Shadish, Cook & Campbell, 2002).According to Shadish, Cook and Campbell (2002), quasi-experiments are exceptionally useful in instances, such as, evaluating the impact of public policy changes, educational interventions or large scale health interventions, where it is not feasible or desirable to conduct an experiment or randomised control trial.

Action Research

According to Seidu (2007), an action research is a problem solving research devoted to the solution of an immediate problem in a given situation. According to him, an action research fosters on informed decision-making and systematic problem solving among practitioners. Action research seeks to develop teaching and learning strategies with a particular emphasis on application of profile dimensions that could improve students' academic performance in biology.

The linking terms "action" and "research" highlight the essential features of this method: trying out ideas in practice as a means of increasing knowledge about or improving curriculum, teaching and learning process. Action research involves systematic observations and data collection which can be used by practitioner-researcher in reflection, decision making and development of more effective classroom strategies (Parson & Brown, 2002). Mills (2000) also believes that the purpose for choosing action research is to effect positive educational change.

According to Labaree (2011), the essentials of action research design follow a characteristics cycle where initially an exploratory stance is adopted. This helps the researcher to learn and understand the problem under consideration so that some form of intervention strategy could be developed. The intervention is carried out during which pertinent observations are made in various forms to collate and examine data to improve the intervention strategy. The approach enables researchers and their participants to learn from each other through a cycle of planning, action, observation and reflection (Steepless, 2014).According to Steepless (2014), the cyclical nature fosters deeper understanding of a given situation starting with conceptualising and moving through several interventions and evaluation. The cyclical nature of the action research model was described by Steepless (2014). Action Research design follow a characteristic cycle whereby initially an exploratory stance is adopted, where an understanding of a problem is developed and plans are made for some form of interventionary strategy. Then the intervention is carried out (the *action* in Action Research) during which time, pertinent observations are made in various forms. The new interventional strategies are carried out, and the cyclic process repeats, continuing until a sufficient understanding of (or implement able solution for) the problem is achieved. The protocol is interactive or cyclical in nature and is intended to foster deeper understanding of a given situation, starting with conceptualising and particularising the problem and moving through several interventions and evaluations (Yin, 2003).

They include reflecting on one's practice and identifying a problem or concern, planning a strategy or intervention that may solve the problem, acting or carrying out the plan, and finally, observing the result or collecting the data. This cycle is continually repeated seeking improvement until the problem is solved.

Ferrance (2000) proposed that action research refers to a disciplined inquiry done by a teacher with the intention that the research will inform and change his/ her practices in future. To him it is an interactive process rather than a one-off exercise of transmitting information by the teacher and that it is mostly chosen when circumstances require flexibility, the involvement of the participants in the research, or change must take place quickly or holistically.

The Study Area

The study was conducted at the St. Teresa's College of Education, Hohoe in the Hohoe Municipality of the Volta Region. The college is a female Catholic institution with a boarding facility. The area is a vast growing commercial and residential settlement. Trading and farming are the most pre-dominant economic activities of the area.

Population.

The term population refers to a group of people inhabiting a specific geographical location. In research, the term is used in a more general sense to include all members or elements, such as human beings, cases, objects, trees, events, etc. of a well-defined group (Seidu, 2007). Seidu (2007) further explained that population in research refers to the aggregate or totality of objects or individuals regarding which inferences are to be made in a sampling study. A population, according to Punch (2006) is the target group of people about whom a researcher wants to develop knowledge.

A population is a group of individuals or objects who have the same characteristics (Creswell, 2008). According to Creswell (2008), a population defines the limits within which research findings are applicable and that a population could be large or small and a researcher needs to decide what group to use for the study. Population as used in this study refers to students with common identified characteristics that the researcher has decided to use for the study.

In any research design the concept of population and sample are very important.

The target population was two hundred and fifty (250) students, all females. With regards to the objectives and the aims of this study using the molecular model kits to enhance pre-service teacher's understanding on naming, drawing and identifying the functional groups of some aliphatic organic compounds, it became prudent to select a college where molecular model kits were available.

Sample and Sampling Techniques.

A sample is a smaller group which is drawn from a larger population and studied (Robson, 2002; Punch, 2006).

According to Creswell (2008), a sample is a true representative of the population from which it was selected or a subgroup of the target population that the researcher plans to study for generalising about the target population. A sample is a small group of individual or elements drawn through a definite procedure from a specified population. The individuals or elements making up the sample are those that are actually studied. The small portion of a population which is used for the study is the sample. It is the selected subject of the whole which is being used to represent the population (Seidu, 2007).

Kumekpor (2002) explains sampling as, the use of definite procedure in the selection of a part for the express purpose of obtaining from its description or estimates certain properties and characteristics of the whole. Sampling, according to Amoani (2005), is the procedure whereby elements or people are chosen from a population to represent the characteristics of that population. Sampling is thus the process of selecting a representative unit from a population. There are two types of sampling strategies that are used in educational research which are probability sampling and non-probability sampling (Cohen, Manion & Morrison, 2008). According to Cohen, Manion and Morrison (2008), probability sampling is useful if the Researcher wishes to make generalisations, because it seeks representativeness of the wide population. The authors also disclosed that it involves random selection of the sample where by every member or unit of the population has an equal, calculable and non-zero probability of being selected for the sample. There are several types of probability sampling techniques. Four of such techniques are: simple random sampling, stratified random sampling, cluster random sampling and systematic random sampling. They further explained that non-probability sampling is a deliberately selected sample to represent the wider population; it seeks only to present a particular group, a particular named section of a wider population, such as a class of students, a group of students who are taking a particular examination, and a group of teachers. There are several types of non-probability sampling techniques: convenience sampling, quota sampling, snowball sampling, volunteer sampling and purposive sampling (Cohen, Manion & Morrison, 2008).

Sample Size

Out of the entire target population of two hundred and fifty (250), fifty (50) students were selected for the study. The selection of the respondents was done using systematic random sampling technique. The sample size of fifty (50) for the study was obtained by finding 20% of the population of two hundred and fifty (250) students. The sample interval of five (5) was calculated by dividing the population of two hundred and fifty (250) by the sample size of fifty (50). In other to get the first start, lottery approach was used. This was done by writing 'yes' or 'no' on five sheets of papers of which there was only one 'yes'. Students with index numbers STCE/001/2016 to STCE/005/2016 were asked to select from the folded papers. This was done to ensure that the random start's index number should be less or equal to the sample interval which is five (5). A student with index number STCE/003/2016 selected the paper with inscription 'yes'. This meant that the student with index number STCE/003/2016 was chosen as first start and every fifth person was selected for the study until the sample size of fifty (50) was exhausted. This method of sampling was used because a systematic sample is spread more evenly over the universe, so it is likely to produce a sample that is more representative and more efficient. It is operationally convenient.

Research Instruments

Research instruments are tools used to gather data. Zohrabi (2013) points out that there are various procedures of data collection. According to him some of them are questionnaire, interview, classroom observation and test. These instruments are discussed below.

Questionnaire

According to Jack and Norman (2003), a questionnaire is a written document usually in survey research that has a set of questions given to respondents or used by an interviewer to ask questions and record answers. According to the authors, a questionnaire could be answered by the person from who information is sought or through an interpreter. The answers provided by the respondents constitute the data for the research. They also pointed out that questionnaire items may be designed as structured or unstructured. Structured questionnaire items are those in which some control or guidance is given for the answer. This is also described as closed-ended form because the questions are basically short, requiring the respondent to provide "yes" / "no" responses. The respondent's choices are limited to the set of opinions. However, the unstructured questionnaire which is also termed as open-ended or unrestricted calls for a free response in the respondent's own words. The respondent frames and supplies the answers to the questions raised in the questionnaire. It gives the respondent an opportunity to express his / her opinion. The advantage of questionnaire is that it can be mailed or given to a large number of people at the time

Interview

Thomas (2003) describes interview as an effective means of eliciting responses from participants in a study. To him it provides elaborate responses and forum for sincere participation in a study. Merriam (2001) also discloses that interview is the best technique to use when conducting intensive case studies of a few selected individuals. He further explained that this is in the form of oral questionnaire and that instead of writing the responses, the interviewee gives the needed information orally and face-to-face. With a skillful interviewer according to Merriam (2001), interview is often superior to other data gathering devices. Interview is usually adopted as a way of overcoming some of the weaknesses of questionnaires. Annum (2015) points out that interview maybe structured or unstructured. According to him, structured interviews follow specific questions to be asked and the order of the questions are pre-determined and set by the researcher. The unstructured interview is formal and highly individualised, Interviewers develop questions as they go along and probe respondents' answer with follow-up inquires. Annum (2015) further explained that interview has the advantage of the respondents seeking for clarifications which cannot be done in a questionnaire. Again where the respondent misinterprets the question the researcher follow up with an explanation or an alternate question.

Observation

According to Annum (2015), observation is one of the important methods for obtaining comprehensive data in qualitative research especially when a composite of both oral and visual data become vital to the research. He further explained that it involves watching people, events, situations, or phenomena and obtaining first-hand information relating to particular aspects of such people, events situation or phenomena. It deals with perceiving data through the senses: sight, hearing, taste, touch and smell. Sidhu (2007) also explains that observation seeks to ascertain what people think and do by watching them in action as they express themselves in various situations and activities. Ary and Razavied (2002) point out that observation is employed when children are to be studied while busy in different activities such as games, dramatics or social services. To them, observation is indispensable for studies on infants who can neither understand our queries nor express themselves clearly.

Test

According to Kagan (1989), test is a research instrument that is used to gather information about the participants in a study. According to Airasian (1991), a test is a formal, systematic, usually paper-and-pencil procedure for gathering information about pupil's behaviour.

In this study tests were the main instruments used for data collection because test could serve as a reliable instrument that can help obtain credible information about students' performance.

Description of the Research Instrument

The Test

Pre-test and immediate post-test were used to collect data from the students. Each test consisted of 10-items based on the integrated science, (FDC 124) course outline for the first year diploma in basic education (DBE) programme for the colleges of education. Each test consisted of three (3) parts, namely: identification of functional groups, naming of compounds and writing/drawing of structural formulae.

The pre-test called relevant previous knowledge test (RPKT) was used to assess students' prior knowledge and difficulties on the concept of aliphatic organic compounds before the implementation of the intervention. The post-test called aliphatic organic compounds concept test (AOCCT) was administered a month later to assess the impact of the use of the molecular model kits in teaching and learning the concept of aliphatic organic compounds.

Each test was made up of two (2) parts; the first part asked for preliminary information about the student's index number and the date on which the test is written; and the second part consisted of ten (10) test items on functional groups, naming and drawing/writing of structures. Five (5) marks were given to each correct answer, with the total score of fifty (50) marks.

Validity of the Instrument

Joppe (2000) explains validity as whether a research truly measures what it is intended to measure or how true the research results are. In other words, does the research instrument allow you to hit "the bull's eye" of your research objectives?

For the purpose of content validity and reduction of errors, the two (2) tests were presented to two (2) senior chemistry lecturers in the Science Department, UEW and one experienced chemistry tutor from the chosen college for their comments on the appropriateness of the items based on the Colleges of Education organic chemistry course outline. Their comments were used to reconstruct the test items before they were administered.

Reliability of the Instruments

The reliability of the main instrument was determined using Pearson's test-retest correlation coefficient. The magnitude of the Pearson's correlation coefficient depends on the number of test items used. The fundamental principle influencing this value states that the more test items there are in a scale designed to measure a particular concept, the more reliable the measurement will be (Ary, Jacobs & Razzavieh. 2002). It is in the light of this that, as many as possible test items were drawn from the topic of interest so as to maximize the value of the Pearson reliability coefficient. To determine the coefficient of reliability of the instruments the tests items were pilot tested on thirty (30) level 100 students of St. Francis College of Education, Hohoe. The results of the pilot test were used to calculate the reliability coefficient. The Pearson's reliability coefficient was calculated using SPSS version 16.0 and it was found to be 0.646 Appendix L. According to Borg, Gall and Gall (1993); if the measurement results are to be used for making a decision about a group or for research purposes, or if an erroneous initial decision can be easily corrected, then the scores with modest reliability coefficients in the range 0.50 to 0.70 may be acceptable. The coefficient of reliability value of 0.646 gave an indication that the instruments were considerably reliable.

Data Collection Procedures.

The data collection which lasted for six (6) weeks was divided into three stages, namely: pre-intervention stage, intervention stage and post-intervention stage.

Pre-Intervention Activities

During pre-intervention stage, the tests were pilot tested on thirty (30) first year students of St. Francis College of Education, Hohoe. The results were used to determine the coefficient of reliability of the instruments.

After that the Relevant Previous Knowledge Test, Pretest (RPKT) was administered by the Researcher to the fifty (50) selected students in the St. Teresa's College of Education, Hohoe which lasted for 60 minutes to determine each student's prior knowledge and performance on aliphatic organic compounds prior to the start of intervention (Appendix A). The test was conducted in line with the laid down regulations of the Institute of Education, University of Cape Coast in use at all the CoE for conducting examinations. All the answered test scripts were marked, recorded and the scores were collated for further analysis.

Intervention Design

After the administration of the pretest, the students were taught the identification of organic compounds' functional groups, naming of aliphatic organic compounds using IUPAC nomenclature, drawing/writing of structural, condensed and molecular formulae using the molecular model kits to enhance their understanding of the concept. Four (4) weeks of instruction was used for this. Each instructional period was two (2) periods of 120-minutes per week (i.e. 240 minutes of contact periods per week).

The steps or stages involved are illustrated in Fig.6

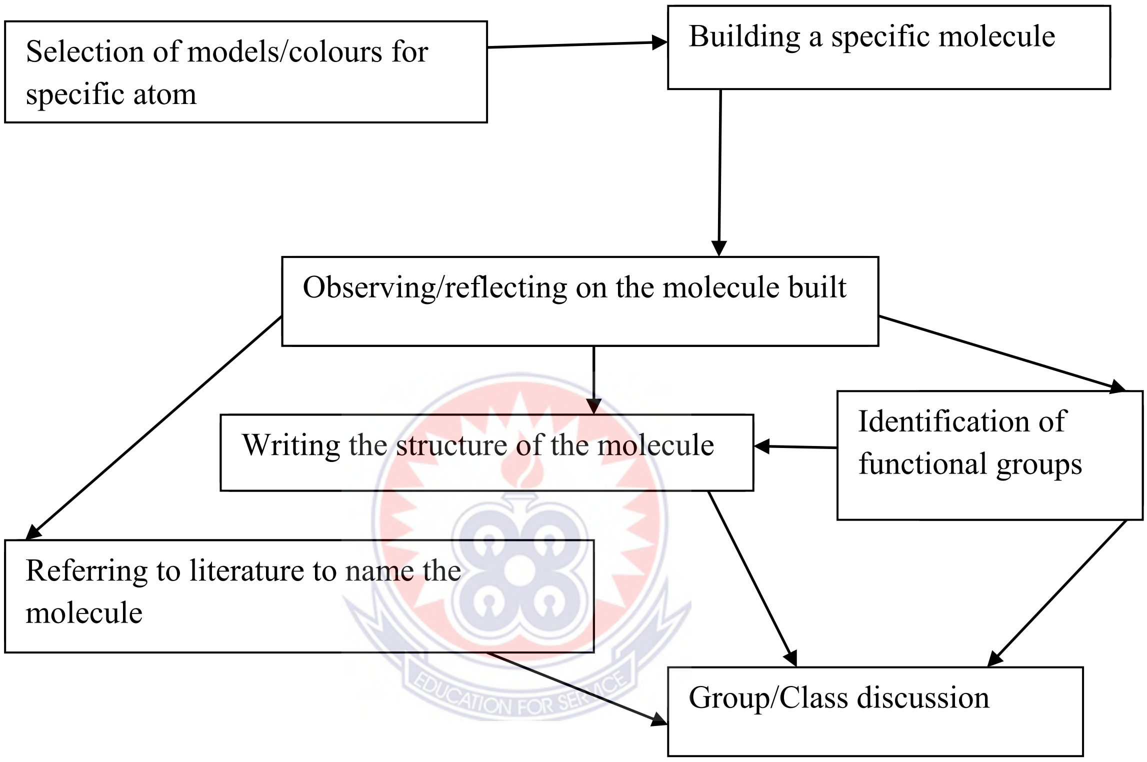


Fig.5: Diagrammatic Representation of Interventional Strategies.

Implementation of Intervention Strategies

Week One

HYDROCARBONS

Students were grouped into ten (10) groups of five (5) and each group was given one molecular model kit to use.

Students were guided to identify the models of the various atoms, their respective colours, the number of hole(s) a particular atom has and the type of stick(s) that should be used to represent a particular bond.

The first lesson was on hydrocarbons. The objectives of the lesson were clearly stated. The students were informed that there are three types of hydrocarbons, namely: Alkanes, Alkenes and the Alkynes. Students were guided on how to identify hydrocarbons. Students were guided that hydrocarbons contain carbon(s) and hydrogens only in their structures. The general formulae for alkanes, alkenes and alkynes were given as: Alkanes; $C_nH_{2n}+_2$, Alkenes; C_nH_{2n} and Alkynes; C_nH_{2n-2}. Students were taught that (n) stands for the number of carbons in the structure or the formular and that when the substitution is made; the number of hydrogen atoms would be found. Students were guided that from alkanes to alkenes, the number of hydrogen atoms is decreased by two (2) and from the alkenes to alkynes too, the number of hydrogen atoms is decreased by two (2) as such there would be a double bond in alkenes to cater for the two (2) hydrogen atoms since two electrons are represented by a single bond also from alkenes to alkynes the number of hydrogen atoms is decreased by two (2), hence there would be a triple bonds in alkynes. Students were guided to build the structures for the following molecules: (C_2H_6, C_2H_4 and C_2H_2) of which they did under the guidance of the researcher. Students were guided that for a given molecule, all the carbon atoms (models) must be in a horizontal line and each carbon atom (model) is separated by stick(s) depending on the molecule be it an alkane, alkene or alkyne. Students were guided on how to identify the functional group of the various molecules. Students were guided that for alkanes the functional group is $C-C$ bond, for alkenes the functional group is $C=C$ bond and for alkynes the functional group is $C\equiv C$ bond. Students were guided on nomenclature of alkanes, alkenes and alkynes. Students were guided to use the table to name the molecules.

No of carbons	Prefix	Alkane	Alkene	Alkyne
1	Meth	Methane		
2	Eth	Ethane	Ethene	Ethyne
3	Prop	Propane	Propene	Propyne
4	But	Butane	Butene	Butyne
5	Pent	Pentane	Pentene	Pentyne
6	Hex	Hexane	Hexane	Hexyne
7	Hept	Heptane	Heptene	Heptyne
8	Oct	Octane	Octene	Octyne
9	Non	Nonane	Nonene	Nonyne
10	Dec	Decane	Decene	Decyne

The researcher explained to students that for alkenes and alkynes if the number of carbon atoms is more than two (2) then the position of the double and triple bonds must be identified as a number in naming the molecule. The tutor guided the students that in naming alkenes and alkynes, there should be a dash (─) between a figure and an alphabet. For example, the molecule ($CH_3CHCHCH_2CH_3$) is called 2 ─ pentene or pent–2– ene.

This means the double bond is between the second and the third carbon atoms as such the least number which is two (2), must be used. The tutor explained to the students that the same procedure is used to name alkynes.

Week Two

ALKANOLS

In guiding students to identify alkanols (alcohols), the tutor explained to students that alkanols have a general formular (C_nH_{2n+1} OH), where (n) is the number of carbon atom(s) in the molecule and (-OH) is their functional group. The tutor explained to students that all alkanols have (OH) in their structure and an alkanol is formed when one hydrogen atom is removed from an alkane and been replaced by (-OH) the hydroxyl group. The tutor guided students to build the following alkanols using the molecular models: (CH_3OH and $CH_3CH_2CHOHCH_3$) of which they did. Students were guided on how to name alkanols by using the prefix of their corresponding alkanes but by removing the last letter (e) and replacing it with (ol), hence the name of the compound (CH_3OH) is methanol which is obtained from methane (CH_4). Students were guided that as the number of carbon atoms increases from three carbons, there is the need to identify the position of the functional group (-OH) in the name, hence the compound ($CH_3CH_2CHOHCH_3$), 2 – butanol or butan–2– ol. This implies that the hydroxyl group (-OH) is on the second carbon atom and not on the third carbon.

Week Three

CARBOXYLIC ACIDS

Carboxylic acids were also taught the same way as hydrocarbons and alkanols. The tutor explained to students that carboxylic acids have their general formular,

C_nH_{2n+1} COOH, where again (n) is the number of carbon atoms and COOH is the functional group known as the carboxyl group for carboxylic acids. The carboxyl group (-COOH), consists of a carbon atom bonded by a double bond to an oxygen atom and by a single bond to a hydroxyl group (-OH). The tutor explained to the students that any organic compound that has (COOH) is carboxylic acid. The students were guided that a carboxylic acid is formed when the last hydrogen atom at the end of an alkane is removed and replaced with COOH. Then students were guided by the researcher to build the following compounds: (CH_3CH_2COOH, $CH_3CH_2CH_2COOH$). The students were taught that in carboxylic acids, the last carbon is having a double bond with one of the oxygen atoms and a single bond with the other oxygen atom and this oxygen atom has a single bond with the hydrogen. The tutor explained to students that the name of carboxylic acids follow the same pattern of alkanes but here, the last letter (e) of the alkane is removed and replaced with (oic) and acid is added to the name, hence the compound CH_3CH_2COOH is named propanoic acid from propane and the molecule $CH_3CH_2CH_2COOH$ is named butanoic acid.

Week Four

ALKYL ALKANOATES (ESTERS)

The researcher explained to students that esters are formed by the reaction between an alkanol and a carboxylic acid. Students were guided that esters have the general formula $RCOOR^1$, where R and R^1 are alkyl groups.

The students were guided that the alkanoate functional group, ─COO─, derived from the carboxylic acid functional group, (–COOH) consists of a carbon atom bonded by a double bond to an oxygen atom and by a single bond to another oxygen atom which in turns has a single bond with an alkyl group. The hydrogen atom has been replaced by an alkyl group from an alkanol. The functional group suffix is (-oate). The students were guided that in naming esters, the acyl group RCOO and the alkyl group R^1 are combined to form one name. The name of the alkyl group R^1 from the alcohol is written first followed by a space and the acyl group RCOO from the carboxylic acid added.

Students were guided to use the molecular models to build the following esters: (CH3CH2COOCH3 and CH3COOCH2CH3).

Students were guided that the systematic names of esters are based on the name of the corresponding carboxylic acid.

The alkyl group is named like a substituent using the "-yl" ending. This is followed by a space. The acyl portion of the name (what is left) is named by replacing the "**-**ic acid**"** suffix of the corresponding carboxylic acid with "**-**ate**"**. Therefore the molecule $CH_3CH_2COOCH_3$, is called methyl propanoate.

Post-intervention Activities

Just after the intervention measures, the post-test called aliphatic organic compounds concept test (AOCCT) of comparable standards as the pre-test, was administered to the fifty (50) selected students under study, after instruction which also lasted for 60 minutes. This was done to compare students' performance of the concept in the pre-test and after the intervention (instructional period), Appendix B. The marking scheme for both pre-test and post-test could be seen in Appendix C.

Method of Data Analysis

According to Osuala (1993), data analysis is the ordering and breaking down of data into constituent parts and performing of statistical calculations with the raw data to provide answers to the questions guiding the research.

The data collected was analysed using quantitative approach. Descriptive statistics was used to analyse the various pre-test and post-test on functional groups, nomenclature and drawing of structures. The overall test score analysis was done using paired t-test with alpha value of (α = 0.05) to determine if there were any significance improvement in the performance of the students after the intervention strategies. Both the pre-test and the post-test were grouped under three (3) headings: (1) identification of functional groups, (2) IUPAC nomenclature (naming of compounds) and (3) writing of structural, condensed and molecular formulae.

The table shows how the tests items were distributed during the pre-intervention and post-intervention stages.

Table 6

Distribution of Items in the Tests.

Demand of question	Range of question	Number of questions
Identification of functional groups	Q1-Q3	3
IUPAC Nomenclature	Q4-Q6	3
Writing of formulae	Q7-Q10	4

The analysis of the pre-test and the post-test were done using Excel. Descriptive statistic was used to compare the means, standard deviations and the variances for each of the three (3) headings (see Appendices D, E and F).

There was an overall analysis of the pre-test and the post-test using pair t-test to test the hypothesis (see Appendix I). As much as possible, the data collected was analyzed with regards to the research questions for the study.

To analyze the extent to which the use of molecular model kits enhanced students' understanding of aliphatic organic compounds, students took two achievement tests on the topic "Aliphatic Organic Compounds". The pre-test was given to students before the intervention while the post-test was given to students just after the treatment.

CHAPTER FOUR

RESULTS AND DISCUSSION

Overview

This chapter discusses the results and findings of the analysis of the data collected. The results and findings were based on the identification of functional groups for both pretest and posttest, IUPAC nomenclature for both pre-test and post-test, the writing/drawing of formulae for both pre-test and post-test and the overall analysis of pretest and posttest based on the research questions. The presentation of results followed the order in which the research questions were posed in chapter one. Therefore the following research questions were addressed:

1. To what extent will the identification of the functional groups help students to draw the structures and name some aliphatic organic compounds?
2. To what extent will the understanding of nomenclature help students to draw and name some aliphatic organic compounds?
3. What is the effect of using molecular model kits to teach identification, drawing and naming of aliphatic organic compounds?

Descriptive and inferential statistics were used in analysing the data using alpha <0.05 level of significance.

Presentation of Results and Discussion

Research Question one: To what extent will the identification of the functional groups help students to draw the structures and name some aliphatic organic compounds? The table 7 shows statistical analysis of pre-test and post-test with regards to functional group.

The mean for the pre-test was nine (9.000) and the mean for the post-test was (13.160) and the mean different was (4.160), it can be seen clearly that the mean score for the post-test was greater than the mean score for the pre-test (M-Posttest > M-Pre-test). Also the standard deviations and the variance for both pre-test and posttest were reported accordingly. SD-Pre-test = 3.071; SD-Post-test = 2.606; variance-Pre-test =9.429 and variance-Post-test = 6.790. The results of the statistics showed that students' understanding on the identification of functional groups have improved since most of the students performed well in the post-test compared to the pre-test. Most students were able to identify the various functional groups in the study. The functional groups for alkanes, alkenes, alkynes, alcohols, carboxylic acids and esters were well understood and answered by students and this could be seen in their performance in table 7 below. The raw score and the detailed analysis for this could be seen in Appendix D and E respectively.

Table 7

Analysis of Pre-test and Post-test with Regards to Functional Group

PRETEST		*POSTTEST*	
Mean	9.000	Mean	13.160
Standard Deviation	3.071	Standard Deviation	2.606
Sample Variance	9.429	Sample Variance	6.790
Range	10	Range	7
Minimum	5	Minimum	8
Maximum	15	Maximum	15

Research Question two. To what extent will the understanding of nomenclature help students to name some aliphatic organic compounds?

The statistical analysis of tests on nomenclature is shown below.

Table 8 shows students' understanding of nomenclature of aliphatic organic compounds. The mean, standard deviation and the variance for both the pre-test and the post-test are reported accordingly. The mean for the pre-test was M = 7.900 and the mean for the post-test was M = 11.980 and the mean difference was (4.080). Again the mean score for the post-test is greater than the mean score for the pre-test for this section. The standard deviations for both pre-test and post-test are SD-Pre-test = 2.121 and the SD- Posttest = 2.227. The sample variances for both pre-test and post-test are: V – Pre-test = 4.500 and the V – Post-test = 4.959.

The comparison of the means, standard deviations and the variances showed that students' understanding of naming of aliphatic organic compounds have improved remarkably after the molecular models was used to guide them. Here, the analysis of the students' scores revealed that a sizeable number of students were able to use the knowledge of nomenclature to name most of the compounds. However some few students were unable to name some of the molecules. This could be attributed to students' low chemistry background from their senior high school. The raw scores and the detailed analysis of this part could be seen in Appendices F and I respectively.

Table 8

Analysis of Pre-test and Post-test with Regards to Nomenclature

PRETEST		*POSTTEST*	
Mean	7.900	Mean	11.980
Standard Deviation	2.121	Standard Deviation	2.227
Sample Variance	4.500	Sample Variance	4.959
Range	7	Range	7
Minimum	5	Minimum	8
Maximum	12	Maximum	15

Research Question Three. What is the effect of using molecular model kits to teach identification of functional groups, writing of formulae and naming some aliphatic organic compounds?

The analysis revealed that students' understanding of the concept have improved as mean score for post-test (M = 12.280) as against the mean score for pre-test (M = 8.160), the mean difference was (4.120).

The mean score for the post-test is greater than the mean score for the pre-test (M-Post-test > M – pre-test). This showed a significant improvement on students' understanding of the concept after the interventional strategy. The standard deviation for post-test (SD – Post-test =2.071) and the standard deviation for pre-test

(SD – Pre-test = 2.333). The sample variance for the post-test and pre-test are (V- Post-test = 4.287 and V –Pre-test = 5.443) respectively. The result from the analysis showed that the used of molecular model kits in teaching and learning some aliphatic organic compounds have improved as most of the students were able to use the model kits to build some aliphatic organic molecules. The analysis also revealed that a large number of student were able to use the knowledge to write or draw the various formulae for the organic molecules. Students were able to identify the various functional groups of the molecules built by sing the molecular model kits and were also able to name the molecules.

Table 9

Analysis of Pre-test and Post-test Based on the Writing of the Structural, Condensed and Molecular Formulae.

PRETEST		*POSTTEST*	
Mean	8.160	Mean	12.280
Standard Deviation	2.333	Standard Deviation	2.071
Sample Variance	5.443	Sample Variance	4.287
Range	10	Range	7
Minimum	4	Minimum	10
Maximum	14	Maximum	17

The Overall Scores Analysis

To determine whether there was a significant difference between the performance of students' pre-test and post-test after the use of the molecular model kits to teach them, a paired t-test was carried out using a confidence level of 0.05.

According to the analysis, the mean score for post-test (37.380) is greater than the mean score for pre-test (24.960); the mean difference was (12.420);

M – Post-test > M – Pre-test. The variances for both post-test and pre-test are (23.465 and 39.590) respectively this could be seen in Table 10.

The overall analysis of results also showed that students' understanding on aliphatic organic compounds in general has been enhanced. This attest to the fact that the intervention strategy adopted, guided the students to understand aliphatic organic compounds.

The calculated t–test and the critical t-test using the alpha value of (α =0.05 and degree of freedom df = 49), are -18.095 and 2.100. The result on the t-test of the statistical difference analysis of pre-test and post-test marks on the study of aliphatic organic compounds indicated that the calculated t-value of -18.095 is greater than the critical t-value of 2.100 at alpha level of 0.05. Since the calculated t-value is greater than the critical t-value, there is a significant difference or improvement on students' performance in post-test over the pre-test. This means that the intervention adopted had yielded a positive result by improving on the students' performance as shown in table 10. The detailed analysis of the overall pre-test and post-test could be seen in appendix J

Table 10

Statistical Difference Analysis of Pre-test and Post-test Marks

	PRETEST	*POSTTEST*
Mean	24.96	37.38
Variance	39.590	23.465
Observations	50	50
Df	49	
t Stat	-18.095	
t Critical two-tail	2.100	

Findings/ Discussion

The data gathered in response to the three research questions formulated for the study are now discussed. The discussion was done based on each of the three research questions.

The analysis of the various pre-test and post-test and the overall analysis provided some information on students' understanding on aliphatic organic compounds.

Research Question one: To what extent will the identification of the functional groups help students to draw the structures and name some aliphatic organic compounds?

Research question one (1) was meant to ascertain how the identification of functional groups could help students to draw the structures and name some aliphatic organic compounds. The analysis of students' scores in Table 7 revealed that, students generally have good knowledge about functional groups as a guide for naming and drawing some aliphatic organic compounds after the intervention. The results of the study indicated that the understanding of functional groups enabled students identified, drew and named some aliphatic organic compounds; this made them to develop interest and improved upon their understanding of the nomenclature of organic compounds. These findings are in consonance with Young (1990), who agreed that the use of appropriate teaching techniques and strategies in a well-organized classroom setting can increase understanding of learners, make them focus and spend more time on learning tasks.

The results revealed that students' understanding on the identification of functional groups and the writing of formulae were enhanced as compared with the IUPAC nomenclature. These could be seen from the mean differences of the various categories in the analysis. Most students were able to identify the various functional groups in the post-test. They were even able to write the names and the structures for the various functional groups in the post-test questions. This showed a remarkable improvement.

Most students also gave correct answers to the questions on structural, condensed structural and molecular formulae. These findings are in line with Kozma and Croninger (1992), who stated that models help to address the cognitive, motivational and social needs of low performance students. This was also shown in the responses of students after the use of the molecular models in their learning. Molecular models can be used with ease without any difficulty.

From the findings, the use of the molecular models for teaching and learning uncovered difficult and abstract ideas to learners and this made the lesson real and meaningful to learners. This assertion was in line with earlier findings of Gagné, Briggs and Wager (1992) which elaborated on the facts that, teaching in a well-equipped science classroom or laboratory, some events of instructions should be followed and these events should lead to the achievement of the objectives and the goals of the lesson and the course.

Generally students' knowledge about the functional groups in teaching and learning processes for naming and drawing of structures of aliphatic organic compounds were positive and these were observed in their various responses to the test given them in Table 7.

Research Question two. To what extent will the understanding of nomenclature help students to name some aliphatic organic compounds?

Although students' responses to the post-test questions on nomenclature were not all that good, there was an improvement over the pre-test.

The analysis revealed that in table 8, some students found it difficult to answer the questions correctly due to the notion that organic chemistry is difficult. This was in line with Nakhleh (1992) who opined that traditionally organic chemistry has been thought as too difficult for students. The study confirmed that chemistry as a subject is very difficult for students to conceptualize since most of the topics are taught in abstract. The results of the study also indicated that lack of teaching / learning materials such as the molecular models makes learning of organic chemistry boring and affects understanding and participation of students. This confirmed a study conducted by Coll, France, and Taylor (2005) which pointed out that models provide useful representations of objects or actual situations that can bring out the concepts that are to be learned. Models are used as visual objects to convey the meaning of a concept or system. Models are useful for visual learners. Hence there should be the use of models in teaching and learning situations so as to benefit every student.

The findings of the study showed that to participate actively in organic chemistry lessons students have to practice enough before coming to class. This seems to be in line with Ausubel, (1968) who stated that enough revision on relevant materials to be studied in a class makes learners participate effectively.

The study proved that weak chemistry background affects students' participation in organic chemistry. This has been suggested also in the findings of Bodner (1991) that lack of sufficient background in organic chemistry (from Senior High School) affects students' participation in organic chemistry lessons.

The study also revealed that interaction with friends and other people on organic chemistry lessons learnt make them understand the concept being taught them. This was in agreement with Vygotsky (1978), who stated that group discussions and interactions assist other peers to learn through explaining of topics to each other, i.e. collaboration learning has been correlated with academic achievement .

The study ascertained the fact that the use of molecular models helped students to acquire in-depth knowledge in organic chemistry. This finding was in accordance with earlier studies conducted by Wu and Shah (2004) who found that higher achievement scores and class participation were linked with certain kinds of technology used at certain level of education.

It was established from the study that students' lackadaisical attitude towards the learning of organic chemistry makes them perform poorly in it. This was also in line with Anderson (2006) and Freedman (1997), who explained that attitude and achievement are related and that a positive attitude towards science lesson results in a high achievement.

The outcome of the study confirmed that excessive co-curricular activities before and after organic chemistry lessons cause students to participate less. This finding also gives credit to Johnstone (1984) who argued that engaging students too much in activities that are irrelevant to a particular topic to be studied affects their performance.

Lack of relevant organic chemistry textbooks and molecular models in schools may cause learners to perform poorly in organic chemistry lessons. This is confirmed by Ornstein (2006) who states that learning in abstract without relevant textbooks and other teaching and learning materials such as molecular models in schools affects students' participation and performance in classroom learning.

Research Question Three. What is the effect of using molecular model kits to teach identification of functional groups, writing of formulae and naming some aliphatic organic compounds?

The results of the data analysis presented in Table 9 revealed that, there was no significant difference between the use of molecular models and the use of textbooks in teaching and learning aliphatic organic chemistry. This means that before the molecular models were used to teach the concept, students had relevant previous knowledge about the topic.

However, the mean test scores and the t-test analysis of their post-test scores in Table 10 indicated that there was a significant difference between the use of molecular models 3D and the use of textbooks 2D. The performance of the students after the intervention indicated that the intervention strategy was very effective hence such classic performance. This performance is supported Barak *et al*., (2011) who argued that the use of teaching aids such as molecular models in teaching and learning increases knowledge and expands the understanding of learners. Models also link learners to their real and true world of information that can make them understand concepts and apply them effectively. It can also increase learners' interest in a particular topic that they dislike (Yarden & Yarden, 2010). This is so because it helps learners to perform better and this motivates them intrinsically. Yarden and Yarden (2010) concluded that the use of molecular models can increase learners understanding of concept and broaden their knowledge base if they are well directed by someone knowledgeable in the use of it.

According to Barak and Dori (2011), effective use of any form of teaching aid in the teaching and learning can result into effective learning. Indeed this was seen in a classic performance by students after the molecular model kit was used to guide students during the intervention stage. The finding supports the views of Barak, Harward, Kocur, and Lerman, 2007; Jackson, Krajcik, and Soloway (2000) who suggested that, the use of models, computers and overhead projectors in teaching can arouse learners' attention and inevitably enable them remember what they have learnt. The use of well-organized molecular models in the teaching of abstract concept in organic chemistry can make learning effective and teaching very easy with marvelous output of work (Gagné, 1985).

The overall analysis also indicated that students' understanding on the concept of aliphatic organic compounds have improved, hence the need to advocate for the use of the molecular model kits in the teaching and learning of organic chemistry in the Ghanaian schools throughout the country.

Discussions of Students' Conceptions.

The conceptions students held on the identification of functional groups, naming of aliphatic organic compounds and writing of the formulae. The conceptions were being represented with regards to the requirements of the questions. In this regard, students gave responses that were closer to the answers in the marking scheme but could not be considered as the correct responses. Some students were unable to give the correct functional group specified in the questions due to partial understanding. Some students also gave wrong functional groups which have no bearing on the compound. This misconception may be due inadequate ideas on functional groups. Some students just repeated information given in the question or no answer was given.

In the writing of IUPAC names the following criteria were used: correct spelling, separating fiqures from fiqures and separating fiqures from words, keeping the alphabetical order of substituents, correct indication of substituents and correct indication of the carbon atom that carries the substituent. Some students were able to give the correct answers whilst a few of them could not follow the rules; this may be due to lack of revision on the part of students.

A sampled answer to question (4i), showing the correct naming of the given compound ($CH_3CH\ (CH_3)\ CH_2CH_3$, 2-methylbutane) is given as follows:

With regards to naming, students gave answers that were closer to the marking scheme but could not be taken as correct responses. Some students were not in the position to give the correct IUPAC names stated in the questions due to partial understanding. Some students also gave wrong IUPAC names which have no relation on the compound. This misconception may be due inadequate ideas on functional groups. Another observation made was that students provided irrelevant or unclear answers. Some students just repeated information given in the question or no answer was given.

With regards to the writing of structures / formulae, the correct procedures were followed. In case of the structural formulae (SF), the number of carbon atoms, the number of hydrogen atoms and the types of bonds between carbon, carbon and the bonds between carbons, hydrogen were taken into consideration.

A sampled answer to question (8.v) showing the correct condensed structural formular for ethyl butanoate, is given as: $CH_3CH_2CH_2COOCH_2CH_3$.

The writing of the structural formular, condensed formular and the molecular formular follow the same pattern as that of functional groups and naming. Here too, students were unable to write the correct structures as a result of partial understanding. Some students also gave wrong structural, condensed and molecular formulae which have no bearing on the compound. This misconception may be due to inadequate ideas on the drawing or writing of the formulae. Another observation made was that students gave irrelevant or unclear answers. Some students just repeated information given in the question or no answer was given.

Responses given by students here were of sound understanding as many students were able to identify the various functional groups in the given compounds. Most students were able to give the names and the structures of the required functional groups.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Overview

The initial stage of this chapter summarizes the study, the implication for science teaching and learning follows. Recommendations to stakeholders of education have been made. The chapter was closed with suggestion for further studies into this same topic.

Summary of Major Findings

The summary of the major findings was done in line with the research questions. The study revealed that:

1. Students' knowledge on identification of functional groups of various classes of aliphatic organic molecules have been improved as a result of the use of the molecular model kits for teaching and learning. However, students need to do a lot more reading on identification of aliphatic organic compounds to enable them increase their understanding.

2. Lack of relevant teaching/learning materials such as molecular model kits was also identified as a major set-back which affected students' participation and performance. Some students were also unable to give the IUPAC names for the various aliphatic organic molecules. This was attributed to their low background knowledge in

chemistry from the senior high school. Some students were also not able to draw or write the structures for the various aliphatic organic molecules. This could also be attributed to the fact that most students lack the fundamental knowledge about aliphatic organic compounds, hence their poor performance.

3. Students had an overall positive perception about the use of the molecular model kits in learning, naming, drawing and identifying organic compounds. Due to the use of the molecular model kits in teaching, students developed interest towards the learning of aliphatic organic compounds. In effect, the students enjoyed the use of the molecular model kits in learning the identification, drawing and naming of organic compounds.

Conclusions.

It was evidently clear from the results and discussions that students' understanding of identification of functional groups, naming of compounds and writing of the structural, condensed and molecular formulae of aliphatic organic compounds were largely influenced by their alternative conceptions. These alternative conceptions or misconceptions range from partial understanding, misunderstanding and no understanding.

This study showed that the use of the model-based learning could serve as a legitimate or even better alternative to the lecture, ("teacher centered") teaching which is frequently used in science courses especially chemistry. Furthermore, this study indicates that the model-based version of a "hands-on" instruction may actually provide more freedom for students to explore and deviate from prescribed procedures. Such approaches are consistent with 21st Century learning environments whereby students construct their understanding of the expository world in learning environments that are active, digital, virtual, and online (Oblinger & Oblinger, 2005). It is apparent clear that technology has reached a threshold where virtual or model-based approaches can meet or exceed the learning outcomes of textbook/ lecture (teacher-centered) approaches.

The results of the study indicated that on the whole the students' understanding or knowledge on aliphatic organic compounds was enhanced when the molecular model kits was used to explain the concept to them.

The overall performances of students were better after the intervention.

Despite the improved understanding from the various pre-test and post-test, the problem still persists among most students.

Implication for Science Teaching/ Learning

Teachers especially those teaching organic chemistry in the St. Teresa's College of Education should make good use of the molecular models in teaching in order to help their students understand the concept of organic chemistry. Teachers should also teach students to work cooperatively with other students to carry out activities and projects in chemistry and consequently develop the values of cooperation, tolerance and diligence.

Colleges of Education students should make conscious effort to study organic chemistry so that they can develop interest in studying the subject to a higher level in preparation for professional and careers in chemistry education and a variety of working environments.

It should be noted that although this study provides some pieces of evidence to support the practicality of using molecular model kits in teaching in the St. Teresa's Colleges of Education, the application of this teaching approach should be cautious until more is known about its effects on students' learning.

Recommendations

Considering the above findings of this study at St. Teresa's College of Education, Hohoe, the following recommendations have been made:

1. The use of the molecular model kits during teaching and learning of organic chemistry should be enhanced by teachers to arouse students' interest during lesson delivery. This would enable them to participate fully during lesson delivery.

2. All science students at St. Teresa's College of Education, Hohoe, should be encouraged to read a lot on aliphatic organic compounds and use the molecular model kits to build aliphatic organic molecules, to enhance their understanding.

3. Science teachers at St. Teresa's College of Education, Hohoe, should teach from the known to the unknown; that is the identification of various classes of aliphatic organic compounds' functional groups should be taught first, follow by nomenclature and writing/drawing of structures, identify students' background in chemistry, creating enough and conducive environments for students' to interact with one another before, during and after organic chemistry lessons.

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APPENDIX A

RELEVANT PREVIOUS KNOWLEDGE TEST (PRE-TEST)

Date……………………………….Student's Number……………………………….

Answer all questions on the question paper.

Time allowed 1hr

Q1. Identify the functional group in the following compounds:

i). $CH_3CH_2CHCHCH_3$…………………………………………………………

ii). CH_3CCH……………………………………………………………………

iii). $CH_3CH_2CH(OH)CH_3$..

iv). $CH_3CH_2COOCH_3$…………………………………………………………….

v). $CH_3CH_2CH_2COOH$……………………………………………………………

Q2. Classify the following compounds as alkane, alkene alkyne, alkanol, carboxylic acid or ester.

i). $CH_3CH_2CH_2OH$…………………………………………………………………

ii). $CH_3CH_2CH_3$……………………………………………………………………….

iii). $CH_3CH_2COOCH_2CH_3$…………………………………………………………….

iv). CH_2CH_2……………………………………………………………………………

v). CH_3COOH…………………………………………………………………………….

Q3. Draw the functional group for the following compounds:

i). Carboxylic acid…………………………………………………………………

ii). Alkyne……………………………………………………………………………

iii). Alkanol………………………………………………………………………

iv). Alkene……………………………………………………………………………

v). Ester………………………………………………………………………………

Q4. Give the IUPAC names to the following compounds:

i). $CH_3CH(CH_3)CH_2CH_3$…………………………………………………………..

ii). CH_3COOH………………………………………………………………………

iii). CH_3CCCH_3……………………………………………………………………..

iv). $CH_3CH(OH)CH_2CH_2CH_3$…………………………………………………

v). $CH_3COOCH_2CH_3$……………………………………………………………….

Q5. Explain the following terms:

i). IUPAC……………………………………………………………………………

ii). Nomenclature……………………………………………………………………

Q6. Name the following substituents:

i). CH_3CH_2…………………………………………………………………………….

ii). Cl…………………………………………………………………………………

iii). CH_3…………………………………………………………………………….

iv). Br…………………………………………………………………………………

v). F……………………………………………………………………………………

Q7. Draw the structural formula for the following compounds:

i). 2-methylpropane……………………………………………………………..

ii). Butan-2-ol…………………………………………………………………

iii). Methyl propanoate…………………………………………………………

iv). 3-methylpent-1-ene…………………………………………………………

v). Ethanoic acid………………………………………………………………

Q8. Write the condensed formula for the following compounds:

i). 2-chlorobut-2-ene…………………………………………………………….

ii). 3-fluorobutanoic acid…………………………………………………………

iii). 2,2-dimethylheptane…………………………………………………………

iv). Propan-2-ol…………………………………………………………………

v). Ethyl butanoate…………………………………………………………

Q9. Write the molecular formula for the following compounds:

i). 2-chlorobutane………………………………………………………………

ii). Propanoic acid……………………………………………………………

iii). 2-butanol……………………………………………………………………

iv). 2-penthyne…………………………………………………………………

v). Hexane……………………………………………………………………………

Q10.How many atom(s) of carbon, oxygen and hydrogen will you use to build the following compounds using the molecular model kits?

i). Ethanol…………………………………………………………………………

ii). But-2-yne……………………………………………………………………..

iii). Methanoic acid………………………………………………………………

iv). Ethyl methanoate……………………………………………………………

v). Pentane…………………………………………………………………………….

APPENDIX B

ALIPHATIC ORGANIC COMPOUNDS CONCEPT TEST (AOCCT)

(POST-TEST)

Date……………………………….Student's Number……………………………….

Answer all questions on the question paper.

Time allowed 1hr

Q1. Identify the functional group in the following compounds:

i). $CH_3CH_2CHCHCH_3$……………………………………………………………..

ii). CH_3CCH……………………………………………………………………….

iii). $CH_3CH_2CH(OH)CH_3$……………………………………………………….

iv). $CH_3CH_2COOCH_3$……………………………………………………………..

v). $CH_3CH_2CH_2COOH$…………………………………………………………….

Q2. Classify the following compounds as alkane, alkene alkyne, alkanol, carboxylic acid or ester.

i). $CH_3CH_2CH_2OH$……………………………………………………………….

ii). $CH_3CH_2CH_3$…………………………………………………………………….

iii). $CH_3CH_2COOCH_2CH_3$……………………………………………………….

iv). CH_2CH_2………………………………………………………………………….

v). CH_3COOH…………………………………………………………………………

Q3.Draw the functional group for the following compounds:

i). Carboxylic acid…………………………………………………………………

ii). Alkyne………………………………………..……………………………………

iii). Alkanol……………………………..……………………………………

iv). Alkene………………………………………………………………………….

v). Ester………………………………………………………………………….

Q4.Give the IUPAC names to the following compounds:

i). $CH_3CH(CH_3)CH_2CH_3$……………………………………………………………..

ii). CH_3COOH……………………………………………………………………

iii). CH_3CCCH_3…………………………………………………………………..

iv). $CH_3CH(OH)CH_2CH_2CH_3$………………………………………………………

v). $CH_3COOCH_2CH_3$…………………………………………………………………

Q5.Explain the following terms:

i). IUPAC………………………………………………………………………………

ii). Nomenclature…………………………………………………………………

Q6.Name the following substituents:

i). CH_3CH_2……………………………………………………………………..

ii). Cl……………………………………………………………………………

iii). CH_3…………………………………………………………………………..

iv). Br……………………………………………………………………………

v). F……………………………………………………………………………

Q7. Draw the structural formula for the following compounds:

i).2-methylpropane……………………………………………………………

ii). Butan-2-ol…………………………………………………………………

iii). Methyl propanoate………………………………………………………

iv). 3-methylpent-1-ene………………………………………………………

v). Ethanoic acid………………………………………………………………

Q8. Write the condensed formula for the following compounds:

i). 2-chlorobut-2-ene…………………………………………………………

ii). 3-fluorobutanoic acid……………………………………………………

iii). 2,2-dimetylheptane………………………………………………………

iv). Propan-2-ol…………………………………………………………………

v). Ethyl butanoate……………………………………………………………

Q9. Write the molecular formula for the following compounds:

i). 2-chlorobutane……………………………………………………………

ii). Propanoic acid……………………………………………………………

iii). 2-butanol…………………………………………………………………

iv). 2-penthyne…………………………………………………………………

v). Hexane………………………………………………………………………………

Q10.How many atom(s) of carbon, oxygen and hydrogen will you use to build the following compounds using the molecular model kits?

i). Ethanol…………………………………………………………………………

ii). But-2-yne………………………………………………………………………

iii). Methanoic acid……………………………………………………………..………

iv). Ethyl methanoate…………………………………………………………………..

v). Pentane……………………………………………………………………………….

APPENDIX C

MARKING SCHEME FOR BOTH PRE-TEST AND POST-TEST

Q1. Identify the functional group in the following compounds:

i). $CH_3CH_2CHCHCH_3$.	Alkene, C=C	(1 mark)
ii). CH_3CCH	Alkyne, C≡C	(1 mark)
iii). $CH_3CH_2CH(OH)CH_3$	Alkanol, Hydroxyl,-OH	(1 mark)
iv). $CH_3CH_2COOCH_3$	Ester, COO	(1 mark)
v). $CH_3CH_2CH_2COOH$	Carboxylic Acid, COOH	(1 mark)

Q2. Classify the following compounds as alkane, alkene alkyne, alkanol, carboxylic acid or ester.

i). $CH_3CH_2CH_2OH$	Alkanol	(1 mark)
ii). $CH_3CH_2CH_3$	Alkane	(1 mark)
iii). $CH_3CH_2COOCH_2CH_3$	Ester	(1 mark)
iv). CH_2CH_2	Alkene	(1 mark)
v). CH_3COOH	Carboxylic Acid	(1 mark)

Q3. Draw the functional group for the following compounds:

i). Carboxylic acid…………………	COOH	(1 mark)
ii). Alkyne……………………………	C≡C	(1 mark)
iii). Alkanol…………………………	-OH	(1 mark)

iv). Alkene………………………… C=C (1 mark)

v). Ester…………………………… COO (1 mark)

Q4.Give the IUPAC names to the following compounds:

i).$CH_3CH(CH_3)CH_2CH_3$.............. 2-Methylbutane (1 mark)

ii). CH_3COOH…………….. Ethanoic acid (1 mark)

iii). CH_3CCCH_3........................ 2-butyne or But-2-yne (1 mark)

iv). $CH_3CH(OH)CH_2CH_2CH_3$... 2-pentanol or Pentan-2-ol (1 mark)

v). $CH_3COOCH_2CH_3$……… Ethyl ethanoate (1 mark)

Q5.Explain the following terms:

i). IUPAC……International Union of Pure and Applied Chemistry. (2½ marks)

ii). Nomenclature…… Systems of Naming Chemical Compounds. (2½ marks)

Q6.Name the following substituents:

i). CH_3CH_2………… ethyl (1 mark)

ii). Cl………………… Chloro (1 mark)

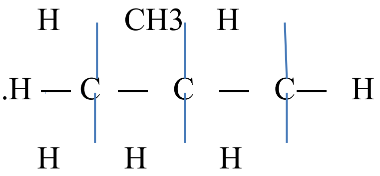
iii). CH3……………..methyl (1 mark)

iv). Br………………… bromo (1 mark)

v). F………………… fluoro (1 mark)

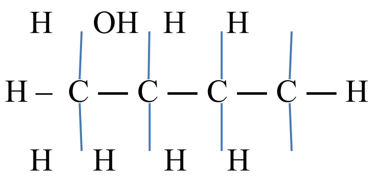
Q7. Draw the structural formular for the following compounds:

i). 2 – methylpropane….



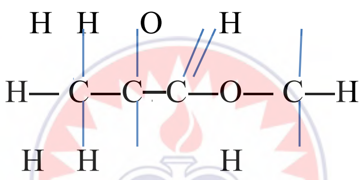
(1 mark)

ii). Butan -2- ol



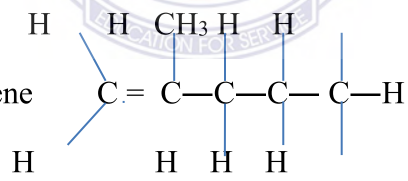
(1 mark)

iii). Methyl propanoate



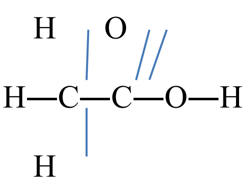
(1 mark)

iv). 3 – methylpent -1- ene



(1 mark)

v). Ethanoic acid



(1 mark)

Q8. Write the condensed formula for the following compounds:

i). 2-chlorobut-2-ene...... $CH_3C(Cl)CHCH_3$ (1 mark)

ii). 3-fluorobutanoic acid... $CH_3CH(F)CH_2COOH$ (1 mark)

iii). 2, 2-dimethylheptane... $CH_3C(CH_3)_2CH_2CH_2CH_2CH_2CH_3$ (1 mark)

iv). Propan-2-ol......... $CH_3CH(OH)CH_3$ (1 mark)

v). Ethyl butanoate...... $CH_3CH_2CH_2COOCH_2CH_3$ (1 mark)

Q9. Write the molecular formula for the following compounds:

i). 2-chlorobutane......... C_4H_9Cl (1 mark)

ii). Propanoic acid......... $C_3H_8O_2$ (1 mark)

iii). 2-butanol........... $C_4H_{10}O$ (1 mark)

iv). 2-penthyne......... C_5H_8 (1 mark)

v). Hexane........... C_6H_{14} (1 mark)

Q10. How many atom(s) of carbon, oxygen and hydrogen will you use to build the following compounds, using the molecular model kits?

i). Ethanol... (2 Carbon atoms, 6 Hydrogen atoms and 1 oxygen atom). (1 mark)

ii). But-2-yne...(4 Carbon atoms and 6 Hydrogen atoms). (1 mark)

iii). Methanoic acid.(1 Carbon atom, 2 Hydrogen atoms and 2 Oxygen atoms)(1 mark)

iv). Ethylmethanoate. (3 Carbon atoms, 6 Hydrogen atoms and 2 Oxygen atoms) (1 mark)

v). Pentane. (5 Carbon atoms and 12 Hydrogen atoms). (1 mark)

APPENDIX D

Raw Scores for Pre-test and Post-test on Functional Groups

PRE-TEST	POST-TEST
8	12
9	10
7	9
10	15
8	10
9	12
6	10
9	15
6	12
7	13
11	15
10	15
7	12
15	15
9	14
12	15
9	11
13	15
8	13
5	9
7	15

8	13
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5	15
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8	12
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6	8
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9	14
13	15
9	13
10	12
13	15
13	15
10	13
7	10
12	12
7	12
9	12
6	15

5	13
5	10
9	12
14	15

APPENDIX E

Analysis of Scores With Respect to Functional Groups

PRE-TEST		POST-TEST	
Mean	8.94	Mean	13.16
	0.42991218		0.36851605
Standard Error	8	Standard Error	3
Median	8.5	Median	13
Mode	9	Mode	12
	3.03993823		2.60580200
Standard Deviation	8	Standard Deviation	4
			6.79020408
Sample Variance	9.24122449	Sample Variance	2
	1.80543910		0.06932542
Kurtosis	9	Kurtosis	9
			0.36535075
Skewness	1.28985265	Skewness	8
Range	10	Range	7
Minimum	5	Minimum	8
Maximum	15	Maximum	15
Sum	447	Sum	658
Count	50	Count	50

APPENDIX F

Raw Scores for Nomenclature

(PRE-TEST)	(POST-TEST)
8	10
9	9
10	13
9	12
6	13
9	13
7	10
10	15
7	13
6	15
9	12
10	15
8	10
12	14
14	15
10	12
7	10
10	13
9	13
6	11
6	9
10	14

5	12
6	14
8	12
8	12
6	11
6	10
10	13
5	8
7	10
8	9
5	10
6	8
10	12
8	11
7	10
7	10
12	15
12	14
10	13
5	14
9	11
5	9
7	9
5	14
6	15

6	13
7	10
12	14

APPENDIX G

Analysis of Scores With Respect to Nomenclature

PRE-TEST		*POST-TEST*	
Mean	7.9	Mean	11.98
Standard Error	0.3	Standard Error	0.314921435
Median	7.5	Median	12
Mode	6	Mode	10
Standard Deviation	2.121320344	Standard Deviation	2.226830822
Sample Variance	4.5	Sample Variance	4.95877551
Kurtosis	-0.75749827	Kurtosis	-0.856102882
Skewness	0.45697377	Skewness	0.106999884
Range	7	Range	7
Minimum	5	Minimum	8
Maximum	12	Maximum	15
Sum	395	Sum	599
Count	50	Count	50

APPENDIX H

Raw Scores for Writing of Formulae

WRITING OF FORMULAE PRE-TEST	WRITING OF FORMULAE POST-TEST
9	10
10	11
7	13
9	13
6	12
9	11
6	10
7	11
5	10
7	13
9	17
11	14
7	11
13	16
11	10
13	13
11	13
9	16
8	12
5	11

7	16
14	15
7	10
8	10
4	13
7	10
9	13
6	10
8	12
8	12
5	10
8	12
6	10
8	12
9	10
10	13
9	15
11	14
8	10
12	17
9	12
8	14
7	16
6	13
8	11

10	11
5	10
4	11
5	12
10	13

APPENDIX I

Analysis of Scores With Respect to Writing of Formulae

PRE-TEST		*POST-TEST*	
Mean	8.16	Mean	12.28
Standard Error	0.32994742 9	Standard Error	0.29282572
Median	8	Median	12
Mode	9	Mode	10
Standard Deviation	2.33308067	Standard Deviation	2.07059094
Sample Variance	5.44326536	Sample Variance	4.28734699
Kurtosis	0.07119038	Kurtosis	0.34419497
Skewness	0.40136321	Skewness	0.72902863
Range	10	Range	7
Minimum	4	Minimum	10
Maximum	14	Maximum	17
Sum	408	Sum	614
Count	50	Count	50

APPENDIX J

Overall raw Scores for Pre-test and Post-test

PRE- TEST	POST-TEST
25	32
28	30
24	35
28	40
22	35
27	36
19	30
26	41
18	35
20	41
29	45
31	44
22	33
40	48
32	41
35	40
27	34
32	46
25	38
16	31
20	40

30	42
19	36
21	40
17	40
27	42
23	37
18	34
26	41
19	30
20	32
25	31
17	28
24	32
28	36
31	39
25	38
28	36
35	41
42	48
26	41
20	38
30	39
18	34
24	32
21	40

16	38
15	33
21	34
36	42

APENDIX K

Overall Analysis of Pre-test and Post-test

t-Test: Paired Two Sample for Means

	PRE-TEST	*POST-TEST*
Mean	24.96	37.38
Variance	39.59020408	23.46489796
Observations	50	50
Hypothesized Mean Difference	0	
Df	49	
t Stat	-18.09538659	
P(T<=t) one-tail	1.22401E-23	
t Critical one-tail	1.676550893	
P(T<=t) two-tail	2.44802E-23	
t Critical two-tail	2.009575237	

APPENDIX L

Reliability Coefficient for Pilot Tests

Test 1	Test 2
25	40
30	42
19	36
21	40
22	40
27	42
23	37
20	34
26	41
19	30
20	32
25	31
17	36
24	32
28	36
31	39
25	38
28	36
35	41
42	48
26	41
20	38
30	39
18	34
24	32
21	40
16	38
15	33
21	34
36	42

	Test 1	Test 2
Test 1	1	
Test 2	0.646	1