UNIVERSITY OF EDUCATION, WINNEBA

THE EFFECT OF HANDS-ON ACTIVITY ON STUDENTS' SKILL PERFORMANCES AND ATTITUDES TOWARD CHEMISTRY

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JANUARY, 2023

DECLARATION

STUDENT'S DECLARATION

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

Signature: ……………………………………………

Date: ……………………………………..…………

SUPERVISOR'S DECLARATION

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

NAME: DR. CHARLES K. KOOMSON

Signature: ……………………………………………

Date: ……………………………………..…………

DEDICATIONS

I dedicate this piece of academic work to my parents Mr. and Mrs. Asamany for their love and support.

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LIST OF ABBREVIATIONS

STEM	**:**	Science Technology Engineering and Mathematics
GES	**:**	Ghana Education Service
SHS	**:**	Senior High School
JHS	**:**	Junior High School
TLM	**:**	Teaching and Learning Material
MoE	**:**	Ministry of Education
SPS	**:**	Science Process Skills

ABSTRACT

The purpose of this study was to examine the effect of hands-on activity on students' skill performance and attitude towards chemistry. The action research design was adopted with an intervention covering four weeks. The study sought answers to these research questions: 1. What is the attitude of students toward chemistry before and after the use of hands-on activity? 2.What is the effect of hands-on activity on the levels of skill performance among students in chemistry? 3.What is the effect of hands-on activity on the retention ability of students in chemistry? Thirty-four chemistry students from Bisease Senior High School, Central Region – Ghana were purposively selected as the sample for this study. Chemistry Achievement Tests, CAT and questionnaire were the instruments used to collect data for analysis. Data were collected from students who participated in this study both before and after the intervention. Descriptive and inferential statistics were used to analyse the data. The findings of the research revealed that students exhibited more positive attitudes toward teaching and learning of chemistry after hands-on instructional approach was used. Also, the findings revealed that students exhibited improvement in science process skills when hands-on approach was used to teach chemistry – the mean score obtained on the pre-intervention test was 9.71 compared to 20.41 on the post-intervention test. The t-test conducted showed the difference to be statistically significant ($p = 0.00$, sig. at 0.05). additionally, a large effect size ($\Theta = 1.78$) indicated that the difference between the pre-test mean and the post-test mean is significant in practical scenarios. Further, the findings revealed that the performance of the students on the post-intervention test and the retention test, conducted two weeks after the intervention did not differ significantly ($p = 0.31$. not sig. at 0.05). However, students' performance on both the post-intervention test and the retention test were significantly different from the pre-intervention test as revealed by a post hoc test. Based on these findings, it was recommended that teacher training institutions such as colleges and universities should emphasise hands-on activity instructional methods as part of their chemistry training curriculum. Chemistry teacher trainees should be subjected to external assessment on the use of hands-on activity instructional methods during their teaching internship programme. Also, the Ministry of Education, through the Ajumako Essiam Enyan District Education Directorate, should allocate more time for in-service training of chemistry teachers on the integration of hands-on activity to empower them, thus, enabling its application in the classroom.

CHAPTER ONE

INTRODUCTION

1.0 Overview

This action research sought to investigate the impact of hands-on activity on student academic achievement and interest in chemistry. In this chapter, the background to the study was discussed. The problem and rationale for the research were stated. The specific objectives that guided this study were outlined and research questions posed. The benefits of the study as well as limitations and delimitations were presented also in this chapter. Finally, the organisation of the study report for the chapters that follow was detailed.

1.1 Background to the Study

Pieces of research focusing on theories of knowledge acquisition in the past few years (Chinn & Brewer, 2013; Dreyfus, Jungwirth, & Eliovitch, 2010; Duschl & Gitomer, 2011; Dykstra, Boyle, & Monarch, 2012; Hewson & Hewson, 2014; Niaz, 2015; Posner, 2012; Smith, Blakeslee, & Anderson, 2013) have evoked changes in educational practise. Studies have shown that the traditional textbook and lecture paradigm involving students as passive recipients of facts is not the most effective way to teach chemistry (Dykstra, Boyle & Monarch, 2012; Yager, 2011). By understanding the process of learning, chemistry instruction can evolve into a model in which students become active participants in the development of their conceptual frameworks. As a practical result of these research efforts, a series of student-centred teaching strategies have been introduced in classroom settings, including: group discussions, problem-based learning, student-led review sessions, think-pair-share, student-generated examination questions, mini-research proposals or projects, a class research symposium, simulations, case studies, role plays, journal writing, concept mapping, structured learning groups, cooperative learning, collaborative learning, enquiry-based approach, and a hands-on/minds-on approach to teaching and learning. The last two strategies are especially suitable for learning experimental sciences (Vrtačnik & Gros, 2005; Weaver, 2016). Flick (2013) defines hands-on science on the one hand as a philosophy guiding the usage of different teaching strategies needed to address diversity in classrooms, and on the other hand as a specific instructional strategy in which students are actively involved in manipulating materials and instruments.

In teaching and learning chemistry, hands-on supported laboratory work is of special importance, due to the abstract language and symbolism of science which calls for establishing links between the theoretical (abstract) and observable (practical) contents of topics taught (Flick, 2013). In addition, through hands-on laboratory work, learning goals such as: subject-matter mastery; improved scientific reasoning, an appreciation that experimental work is complex and can be ambiguous, and an enhanced understanding of how science works, can be achieved (Moore, 2006). The hands-on approach to laboratory work enables also the development of a series of generic competences and skills: manipulation with the equipment, experiment design, observation and interpretation, data collection, processing and analysing, problem solving and critical thinking, communication and presentation, developing safe working practices, time management, ethical and professional behaviour, application of new technologies and team work (Buntinea *et al*., 2007).

Nonetheless, results of the studies on the effects of hands-on science teaching and enquiry-based approaches versus the textbook approach are contradictory, with some studies showing little or no curricula effect (Pine *et al*., 2006). However, it was not completely clear whether the lack of difference in the performance assessments were a consequence of the assessment, the curricula and/or the teaching approach (Pine *et al*., 2006). Results of a study in which 18 middle school students with serious emotional disturbance were instructed over the course of 8 weeks on “Matter” by two different approaches, indicated that students in the hands-on instructional programme performed significantly better than students in the textbook programme on two of the three measures of science achievements: a hands-on assessment, and a short-answer test (McCarthy, 2005). Also, the research findings of O’Neill and Polman (2004) found hands-on activities substantially contribute to the achievement of the scientific literacy goals and competencies as promoted in the educational standards.

A combination of the aforenamed pieces of research and the desire of the researcher to improve the performance of his students in chemistry using hands-on activities necessitated a further investigation into the effect of hands-on instructional strategies on students’ academic performance and interest in chemistry.

1.2 Statement of the Problem

One of the most important and pervasive goals of schooling is to teach students to think. Science contributes its unique skills, with its emphasis on observation, manipulating the physical world and reasoning from data. The scientific method, scientific thinking and critical thinking have been terms used at various times to describe these science skills. Today, the term “science process skills” is commonly used.

The chemistry syllabus for senior high schools in Ghana emphasise the acquisition of science process skills in accordance with the national science education policy. However, observations made by the researcher revealed that chemistry students in

Bisease Senior High School exhibited poor science process skills and lukewarm attitude during practical lessons. It was observed that science process skills like: Observing, classifying, formulating models and communicating were poorly demonstrated by students.

Numerous research projects have focused on the teaching and acquisition of science process skills. For example, Padilla, Cronin and Twiest (2016), Thiel and George (2015) and Tomera (2014) found that science process skills can be taught, and that teaching increases levels of skill performance. Teaching strategies which proved effective were: (1) using activities and pencil and paper simulations to teach, and (2) using a combination of explaining, practise with models, discussions and observation with feedback. Guided by this, the present study sought to examine the effect of hands-on activity on the levels of skill performance and students' attitude towards chemistry.

1.3 Purpose of the Study

The purpose of this research was to examine the effect of hands-on activity on students' skill performance and attitude towards chemistry.

1.4 Objectives of the Study

The objectives of this research were to:

1. Examine the attitudes of students toward chemistry before and after the use of hands-on activity.
2. Determine the effect of hands-on activity on the levels of skill performance among students in chemistry.

3. Assess the effect of hands-on activity on the retention ability of students in chemistry.

1.5 Research Questions

This research sought answers to the following research questions.

1. What is the attitude of students toward chemistry before and after the use of hands-on activity?
2. What is the effect of hands-on activity on the levels of skill performance among students in chemistry?
3. What is the effect of hands-on activity on the retention ability of students in chemistry?

1.6 Null Hypotheses

H_{o1}: There is no statistically significant difference between the performance of students on the pre- and post-intervention tests.

H_{o2}: There is no statistically significant difference between the mean scores of students on the pre-intervention test, the post-intervention test and the retention test.

1.7 Significance of the Research

This study allowed the researcher to draw conclusions regarding the use of hands-on activity and establish whether or not this approach causes a change in the students' attitude and levels of skill performance in chemistry. This provides useful information on the integration of hands-on activity into the senior high school chemistry curriculum.

Furthermore, the results of the current research could add to the body of research done on the significance and importance of incorporating hands-on activity into high school chemistry classes.

1.8 Limitations of the Study

The health status, mood, and test anxiety of the research participants may influence their response to the data collection instruments.

1.9 Delimitations of the Study

This study only sought to examine the effect of hands-on activity on students' skill performance and attitude toward chemistry. Also, only the following skills were covered in this study: observing, communicating, classifying, and formulating models.

1.10 Operational Definition of Terms

Terms applicable to this research were defined as follows:

Attitudes: Attitudes are students' beliefs about science in the area of willingness, self-efficacy, and science anxiety. Attitudes were measured using a pre- and post-anxiety survey, focus group interviews and teacher field notes.

Hands-on Activity: Hands-on activity means that students utilised strategies such as cooperative groups, learning games and manipulatives.

Science Anxiety: Science anxiety is a students' feeling of fear, dread, tension, apprehension, or general discomfort that interferes with science performance.

Focus group: A group composed of six to ten participants that is led by a moderator, for the purpose of discussing one topic or issue in depth (Atkeson & Alvaraz, 2018).

Relationship: Relationship from a research perspective, means that an individual's status on one variable tends to reflect his or her status on another variable (Creswell, 2013).

Science Process Skill: These are a set of broadly transferable abilities, appropriate to many science disciplines and reflective of the behaviour of scientist. They are classified into basic and integrated science process skills.

1.11 Organisation of the Study Report

This research report was organised into five (5) chapters. Chapter one of the report has already been presented. Chapter two comprises the review of related literature. It begins with an overview of the chapter and then a review of relevant literature under various strands. Chapter three consists of the research methodology. It covers the overview, the design of the study, population, sample and sampling procedure, instrumentation, the validity of the instruments, the reliability of the instruments, data collection and data analysis techniques. Chapter four presents the results of the study according to research questions posed in chapter one. The chapter also includes the analyses and discussions of the findings. Chapter five of the report includes the summary of the study, conclusions drawn and recommendations made.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

In this chapter literature related to the study was reviewed. The literature mainly concerns the hands-on learning approach in chemistry education. The review was meant to explore the extent to which hands-on approach to teaching chemistry, could motivate learners and improve performance in the study of the concept of hydrocarbons. This was followed by the empirical review of literature on the effectiveness of hands-on learning in chemistry and a discussion on the use of hands-on learning in chemistry classrooms. Finally, the educational theory on which this study is premised was presented and discussed. The literature is presented under the following strands:

Conceptual Framework

Hands-on Learning; the Case of Ghana

Student Attitude towards Chemistry

The Science Process Skills [SPS]

Methods of Teaching Chemistry

Hands-On Activity in Chemistry

Hands-on Learning Methods

Effectiveness of Hands-on Activity in Chemistry Education

Theoretical Rationales for Effect of Hands-on Science on Student Achievement

Learning about Hydrocarbons

The Use of Teaching and Learning Materials in Chemistry

Molecular Model Toolkit as a TLM for Teaching Hydrocarbons

Impact of Molecular Model Toolkit on Students Understanding

Effects of Molecular Model Toolkits on Student Academic Performance

How People Learn

Empirical Framework

Experiential Theoretical Framework

2.2 Conceptual Framework

The conceptual framework of this study is represented diagrammatically in Figure 1.

The relationships between variables of this study are shown in Figure 1. In an ideal situation, the teaching approach would affect the students' achievements and attitude towards chemistry. In practical situations the students' achievement and attitude to towards chemistry would be influenced by various factors which include, teacher training, teachers' epistemological views on teaching, learning, and teaching resources. These are extraneous variables which need to be controlled. Hands-on learning is one instructional approach to help students construct knowledge through a discovery process that supports continuous learning. Theoretically, hands-on learning represents constructivist perspectives. It can engage students in individual and social activities such as experiments, discussions, and learning projects. Driver (2017) stated that meaningful activities can support students to make sense of scientific conceptions and the processes of scientific methods.

Hands-on learning leads to experiential learning, exposing learners to useful learning activities that facilitate meaningful and long-term learning. This invariably leads to improved process skills and performance in chemistry and promotes a positive attitude towards the subject among learners.

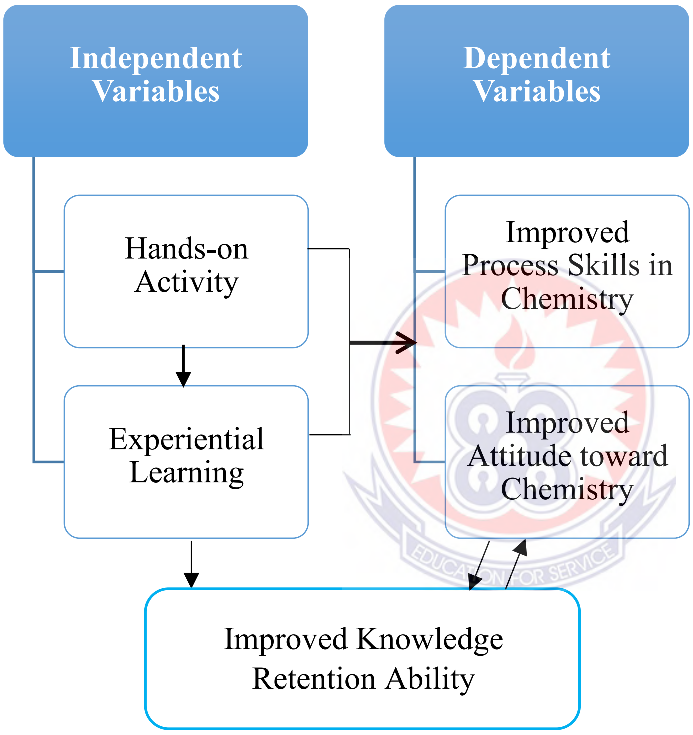


Figure 1: Conceptual Framework Showing the Interaction of Variables

2.3 Hands-on Learning; the Case of Ghana

In Ghana, students use the phrase "chew and pour, pass and forget" to describe their experience of learning in school. This phrase dramatically portrays how students are asked to memorise information, repeating facts repeatedly, and reproduce the same during an examination, in an attempt to pass the exams, and then promptly disremember the concepts (Blench & Dendo, 2016; Quansah & Asamoah, 2019). The dominance of this phrase in the Ghanaian educational arena coupled with its distasteful effect on the quality of education has occasioned several research into alternative teaching and learning pedagogies that are meaningful. Researchers have noted the detrimental effects that "chew and pour" has on students' creativity (Haffar, 2016) and ability to translate theory to useful outcomes (Adomako-Ampofo & Kaufmann, 2018). The future world of work in Africa is technology-based (World Economic Forum, 2017). For the growing youth population in Africa to rise to these demands, the education system needs to be able to engage students, drive meaningful learning, and build their interest in Science Technology, Engineering and Mathematics [STEM] especially chemistry, the building block of STEM. Stakeholders of education in Ghana strongly express that a shift in teaching practice is key to achieving this. The new national curriculum states "Ghana believes that an effective science education needed for sustainable development should be inquiry-based" (Ministry of Education, 2019). Interventions that can create lasting, transformative change in chemistry teaching in Ghana should be hands-on, providing learners with activity that are meaningful and engaging. This way, the learners create their knowledge with the guidance of a facilitator.

Survey data collected from a few hundred Ghanaian public Junior High School (JHS) teachers revealed that virtually all teachers see the benefit of using hands-on activity, but eighty percent (80 %) cited the lack of resources as the main challenge they face in teaching more experientially (Practical Education Network [PEN], 2016). Furthermore, less than 5% reported having attended any relevant training towards this challenge within the last year (PEN, 2016). With minimal resources and training available, most Ghanaian teachers feel there are no realistic alternatives to the "chew and pour" approach. The present study sought to tackle this challenge by using low-cost materials for the deployment of hands-on activity in teaching the chemistry of hydrocarbons, which are aligned to the national curricula. The aim of this study is to determine the impact of hands-on approach on the performance of students in chemistry, and their attitude towards the subject. The study hypothesizes that regular use of low-cost, hands-on activity in the chemistry classroom will improve students' assessment scores, attitudes towards learning chemistry, and their interest in pursuing chemistry in the future.

2.3.1 Effects of hands-on activity on science process skills [SPS] acquisition and retention in chemistry

Previous studies have been carried out to investigate how hands-on activity affect students' acquisition of process skills and retention ability. For example, a study was conducted by Supriyatman and Sukarno (2014) on the role of hands-on activity in skills performance and knowledge retention among senior high school students. The findings indicated that students improved basic SPS in observation, prediction, communication and in making conclusions. Retention ability was also greatly enhanced. Çelik (2022) explored the role of hands-on activity in improving science process skills and retention in chemistry, the findings indicated that although hands-on activity improve science process skills and content retention, the effect on high achievers was relatively low compared to low achievers. Furthermore, Stieff (2011) examined the effect of hands-on activity in enhancing students' basic SPS in learning the states of matter at microscopic, macroscopic, and symbolic levels among students in senior high schools. It was found that hands-on activity improved students' skills in making observations, predictions, analysing patterns, and making inferences, which are basic SPS. Further, Ardac and Sezen (2002) explored the effectiveness of hands-on activity on process skills for controlling variables of boiling point elevation and freezing point depletion among students in secondary schools. The findings indicated that students learning with hands-on activity improved SPS by developing the ability to control different variables. Similarly, Saat (2004) investigated students' ability to acquire SPS among students learning science using

hands-on activity. The findings indicated that students could develop skills for controlling variables. Saputri (2021) and Siahaan *et al*. (2017) indicated that hands-on activity can be used as a solution to deal with students' low science process skills in chemistry teaching. Generally, hands-on activity has been shown to be beneficial in helping students to acquire relevant basic SPS and improved retention ability. However, little is known on how hands-on activity enhance integrated science process skills in chemistry context.

2.4 Student Attitude towards Chemistry

Attitudes, as constructs of affective domain, have been in the research forum for several years. Attitudes have determined the power to predict future behaviours like subject and career preferences of students, and the relationship existing between attitude and academic achievement. In their meta-analysis of attitude related factors that predict future behaviours, Glasman and Albarracín (2006) concluded that there is a correlation between attitudes and future behaviours; that is, attitudes are a potential for predicting future performances, especially if there is a direct interaction between participants and the attitude object (i.e., objects that are related to attitude like chemistry lessons). A review of the literature suggests that studies that examined the correlation between attitude and academic achievements did not provide consistent results. Schibeci (2014), for instance, found a strong relationship between attitude and achievement. Shrigley (2016), on the other hand, argued that there is only moderate relationship between attitudes toward chemistry and chemistry achievement. The literature deals extensively with the factors affecting attitude toward chemistry. Grade and skill levels achievement are some of the most investigated factors affecting senior high school students' attitudes toward chemistry.

Research shows that self-regulated students are more engaged in their learning. These students commonly seat themselves to study, voluntarily offer answers to questions, and seek out additional resources when needed to master content (Clarebout, Horz, & Schnotz, 2010). Most importantly, self-regulated learners also manipulate their learning environments to meet their needs. For example, researchers have found that self-regulated learners are more likely to seek out advice and information and pursue positive learning climates (Labuhn, Zimmerman & Hasselhorn, 2010), than their peers who display less self-regulation in the classroom. Due to their inquisitive attitude and engagement, it is not then surprising that findings from recent studies suggest that self-regulated learners also perform better on academic tests and measures of student performance and achievement (Zimmerman, 2018). To promote self-regulated learning [SRL] in chemistry classrooms, teachers must teach students the self-regulated processes that facilitate learning. These processes often include: goal setting, planning, self-motivation, attention control, flexible use of learning strategies, self-monitoring, appropriate help-seeking, and self-evaluation. Hands-on activity involves all these processes. Creating SRL environments for the complex and diverse range of backgrounds, skill sets, and personalities that many students encompass poses challenges to the most experienced teachers too. Fortunately, a great deal of literature showcases a variety of effective instructional strategies for encouraging self-regulation in the classroom. Some of these strategies include direct instruction and modelling, guided and independent practice, social support and feedback, and reflective practice. All these instructional strategies are included in hands-on activity.

2.5 The Science Process Skills

The science process skills are defined as a set of broadly transferable abilities, appropriate to many science disciplines and reflective of the behaviour of scientists. They are grouped into two types-basic and integrated. The basic (simpler) process skills provide a foundation for learning the integrated (more complex) skills. These skills are listed and described below.

2.5.1 Basic science process skills

Observing: using the senses to gather information about an object or event. Example, describing a pencil as yellow.

Inferring: making an "educated guess" about an object or event based on previously gathered data or information. Example, saying that the person who used a pencil made a lot of mistakes because the eraser was well worn.

Measuring: using both standard and nonstandard measures or estimates to describe the dimensions of an object or event. Example, using a meter stick to measure the length of a table in centimetres.

Communicating: using words or graphic symbols to describe an action, object or event. Example, describing the change in height of a plant over time in writing or through a graph.

Classifying: grouping or ordering objects or events into categories based on properties or criteria. Example, placing all rocks having certain grain size or hardness into one group.

Predicting: stating the outcome of a future event based on a pattern of evidence. Example, predicting the height of a plant in two weeks' time based on a graph of its growth during the previous four weeks.

2.5.2 Integrated science process skills

Controlling variables: being able to identify variables that can affect an experimental outcome, keeping most constant while manipulating only the independent variable. Example, realising through past experiences that amount of light and water need to be controlled when testing to see how the addition of organic matter affects the growth of beans.

Defining operationally: stating how to measure a variable in an experiment. Example: stating that bean growth will be measured in centimetres per week.

Formulating hypotheses: stating the expected outcome of an experiment. Example: the greater the amount of organic matter added to the soil, the greater the bean growth.

Interpreting data: organizing data and drawing conclusions from it. Example: recording data from the experiment on bean growth in a data table and forming a conclusion which relates trends in the data to variables.

Experimenting: being able to conduct an experiment, including asking an appropriate question, stating a hypothesis, identifying and controlling variables, operationally defining those variables, designing a "fair" experiment, conducting the experiment, and interpreting the results of the experiment. Example: The entire process of conducting the experiment on the effect of organic matter on the growth of bean plants.

Formulating models: creating a mental or physical model of a process or event. Examples: The model of how the processes of evaporation and condensation interrelate in the water cycle.

2.5.3 The Role of Skills Performance in Chemistry Learning

The development of students' SPS is emphasised in various nations' chemistry curriculum. Moreover, in Ghana, the development of students' SPS is considered a priority in the chemistry curriculum by allowing students to address practical issues. In a similar vein, chemistry syllabus for senior high schools incorporates SPS to inculcate real life applications in students. This emphasis is based on the importance of SPS in scientific knowledge and an individual's life. SPS allow students to investigate the environment and build their own meaning during the learning process (Athuman, 2017). When students are engaged in inquiry learning activities that are investigative, such as experiments, hands-on activities, and discussion, they can construct meaning for themselves (Williams, 2017). Students have the chance to create and test hypotheses, gather and analyse data, make observations, and draw conclusions while participating in these activities. Students develop their own meaning about the world around them through these inquiry activities, which are scientific process skills. As a result, learning chemistry is made simple and relevant by incorporating SPS into the teaching and learning process. Furthermore, scientists employ SPS to perform scientific studies. Thus, they are used as research skills. In addition, scientists identify the problem, formulate hypotheses, conduct experiments including the identification and control of factors, collect, analyse and interpret data. To explain the results and reach a conclusion, students may use graphs, tables, phrases, and diagrams to portray the data. Therefore, learning of SPS becomes critical among the primary goals of chemistry instruction. Once students have learned these skills, they may be transferred from one learning setting to another. Consequently, students may use them to address issues in real-life situations. In addition, according to Athuman (2017), engaging students in SPS improved their attitudes and enthusiasm in learning chemistry.

2.6 Methods of Teaching Chemistry

Research on concept acquisition (Williams, 2017) has revealed that children learn by active interaction initially with concrete objects and later with abstract entities. Additionally, Ekon (2017) suggested that cognitive development occurs through active involvement; interaction of the child with objects and phenomena that leads to cognitive conflicts and subsequently to equilibration or self-regulation. Chemistry as a way of acquiring knowledge includes a set of unique procedures or processes which are regarded as 'standard' or acceptable in generating new knowledge. Chemistry is characterized and differentiated from other ways of knowing by the nature of its knowledge and the procedures by which new knowledge is generated. The importance of using a variety of learning models in teaching chemistry probably cannot be over-emphasized from a psychological point of view. One of the principal causes of students' losing interest in chemistry, according to Williams (2017) is the approach adopted by the teacher in teaching the subject. The chemistry teacher should be well acquainted with the use of a variety of instructional approaches in teaching chemistry content.

According to Atiku (2014), approaches or strategies that one uses to communicate to learners in the teaching and learning process are referred to as the teaching method. Appropriate styles through which one can present a lesson are also referred to as teaching methods or styles. Teaching methods can otherwise be described as instructional methodology, which includes all special ways through which an instructor imparts or inculcates knowledge into the learner. Such instructional methods may vary from teacher to teacher and from subject to subject. Every instructional method aims at involving the learner in meaningful activities which will result in the successful attainment of learning objectives (Talabi, 2018).

Erinosho (2019) defined teaching method or style as the manner in which a teacher effectively and efficiently interacts within the classroom environment to bring about quality subject matter among students. According to Woods, there are three teaching methods identified in the teaching and learning of chemistry. These are: discipline-centred, teacher-centred, and student-centred methods of teaching.

Discipline-centred method of teaching chemistry aims at the subject matter rather than what the teacher does. Contents of the syllabus or textbook must be covered regardless of what the student absorbs. This method is mostly used in senior high schools as the content must be given to students before they write their final external examinations.

The teacher-centred method of teaching is also known as the 'chalk and talk' method of teaching. The teacher acts as an authoritative expert, the main source of knowledge and the central point of every activity in the teaching and learning process. In this teaching arena, students are passive and they merely regurgitate content. Teaching in this context is to transmit information and help student to master facts for examination purposes only. Teacher-centred methods of teaching include lectures, explanations and illustrations. This allows minimal teacher-student interactions though much information is given to students. The lecture method is mostly effective at the tertiary level of education and during introduction, demonstrations and summary of a lesson at the primary and secondary levels of education.

The learner–centred method is the most effective teaching method for creating a dynamic classroom environment. The prior concern of the teacher is how to engage students in activity so as to develop their own ideas, and share them with others through collaborative work. Students are able to develop skills and have cognitive understanding of concepts. Classroom activities, instructional contents and teaching methods are selected to facilitate active learning, critical thinking, stimulate interest and promote positive attitude towards science. The teacher in this situation is a facilitator; hence he or she uses approaches that encourage flexibility and more student engagement. Learner–centred methods of teaching include, questioning, collaborative learning, cooperative learning, discussions and activity- based methods.

Teacher-centred process raises a series of related questions for teachers: How well do we know what our students already know? What are their interests? What do they want to learn? And what lessons they walk away with from our teaching (Ogle, 2016). The best way to learn the answers to these questions is to ask them often. Instructors should often ask their students to list what they know, what they want to know, and what they learned in each class (Ogle, 2016). These data are exceptionally helpful in adjusting the content of lessons to ensure that you meet the needs of the greatest number of students. Other classroom assessment techniques that are easy to use include asking students how the material relates to them or their interests, inquiring about what remains confusing, or allowing students to provide feedback to the instructor via clickers (Ekon, 2017). These methods complement the helpfulness of frequent quizzes and written assignments that regularly monitor students' performance. Teachers who use differentiated instruction (Chapman, Bettinger & Due, 2012) give students different options during class time (e.g., students form flexible groups that have complementary tasks centring on the topic of the lesson). Similarly, students have the opportunity to select from a range of options for evaluation (e.g., research paper, oral presentation, applied project, traditional exam). This approach builds on students' strengths and interests in learning chemistry.

According to Dosoo (2016), it is important for teachers to know how students learn; this will enable teachers to put what they want to teach in suitable ways for learning to occur easily and also to expose learners to the techniques that make learning easier. According to Mckeachie (2014), all teaching styles 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. Examples of teaching methods used in Ghanaian schools are discussion, discovery activity, lecture, brainstorming, project, demonstration, etc. The fact that learning to "explain ideas in chemistry" as well as to "evaluate arguments based on scientific evidence" is given little emphasis at all levels suggests that, students may be learning chemistry without understanding what they learn (Williams, 2017). It could also mean that chemistry teachers are relying on teaching methods or strategies that are ineffective in promoting understanding of the subject. The teaching of chemistry in senior high schools can be made easy and interesting or difficult and boring depending upon the teacher's approach to teaching. Some teaching methods that can be used to make the teaching and learning of chemistry more effective are discussed next.

2.6.1 Question and answer (citation)

Question and answer is defined as a method both for teaching and oral testing based on the type and use of questions. Questioning techniques are one of the basic and successful ways of stimulating students thinking and learning (Ndirangu, 2017). It is applicable to all teaching approaches and methods.

2.6.2 Discussion

Discussion approach to instruction is an important component of any teaching or learning situation which allows students to share their ideas (Ndirangu, 2017). It can be used at the beginning of a topic to ascertain students' preconceived notion of the subject matter. Or toward the end of a subtopic by presenting the student with a new situation and asking them to explain it in terms of what they have just learned. Discussion method is a teaching and learning strategy that entails sharing and exchange of ideas, experience and opinion (Kimweri, 2014). Strengths of discussion method are that; increases the depth of learners' understanding, enhances motivation and generates greater involvement of the learners, promotes leadership role skills, develops skills of organizing and presenting ideas to others in a logical form and develops a spirit of cooperation among learners. In spite of the strengths, there are also limitations of discussion method which includes; time-consuming, can be used effectively with a limited number of learners, if not well handled some extrovert learners may dominate the discussion.

2.6.3 Brainstorming

Brainstorming is a teaching technique in which every pupil's response that applies to a given topic is acceptable (MIE, 2014). The strengths of brainstorming are that; promotes exploration, analysis and problem-solving skills, develops the sense of cooperation and group cohesiveness in problem-solving, encourages the generation of creative ideas, and promotes the generation of initiatives in searching for solutions to problems. The limitations of brainstorming are that; it is time-consuming if not planned, more useful to a limited number of learners and needs thorough preparation.

2.6.4 Peer instruction

Peer Instruction (PI) is a research-based pedagogy for teaching large introductory science courses (Fagen & Mazur, 2013). It is a method created to help make lectures more interactive and to get students intellectually engaged with what is going on. PI provides a structured environment for students to voice their idea and resolve individual misunderstandings by talking with their peer (Gok, 2012). Peer instruction is a cooperative learning technique that promotes critical thinking, problem-solving, and decision-making skills (Rao & Dicarlo, 2019). This method has the advantage of engaging the student and making the lesson more interesting to the student. It also has the tremendous importance of giving the teacher significant feedback about where the class is and what it knows.

Despite these arrays of teaching methods being advocated in literature, there is no one universally accepted method. Both learners centred and teacher centred methods of teaching are important in teaching and learning (Haas, 2012; Gulobia, Wakadala & Bategeka, 2018), and each is appropriate depending on the environment within which they are used. For teaching to be more effectively done, a combination of these methods should be employed since education has many different types of approaches and contexts.

2.7 Hands-On Activity in Chemistry

Hands-on activity has long been documented as a crucial factor in motivating students to learn (Satterthwait, 2018). Students may learn to reflect methodically through trial and error, and hands-on learning processes can increase students' motivation and learning outcomes (Larkin, Seyforth & Laskey, 2021). According to research on the influence of hands-on activity on student performance, students can achieve seventy-five percent (75%) of knowledge uptake through hands-on activity and about ninety percent (90%) uptake through the instantaneous application of what they have learned (Dale, Dull & Mosher, 2019). Hands-on activity can reinforce students' ability to integrate their knowledge and apply it. Through design and hands-on activity, learners can merge their knowledge acquired in different subjects, appreciate the link between theory and real life, and have the occasion to design solution to problems. Students' creativity in hands-on activity motivates their participation in hands-on processes. The problem-solving ability of students can also be cultivated through hands-on activity (Lin *et al*., 2021; Klopp, Rule, Schneider & Boody, 2014).

Creativity is defined as an ability that can be improved through learning and training (Lou, Chou, Shih & Chung, 2017). Guilford (2019) first proposed the concept of "creativity", which he described as the ability to invent or create something unprecedented. He also developed the Structure of Intellect (SOI) model, which states that divergent and convergent thinking practices and training should be incorporated into instruction in order to stimulate creativity. Williams (2017) stated that cognitive and affective behaviours in the classroom setting are essential for stimulating creativity.

Hands-on activity is a technique of teaching where students are guided to gain knowledge by experience. This implies giving the student the opportunity to manipulate objects they are studying, for instance, plants, insects, rocks, water magnets, scientific instruments, etc (Williams, 2017). Hands-on activity is a process of teaching science where students become dynamic participants in the classroom. Haury and Rillero (2015) posit that hands-on approach to teaching science involves the learner in a total learning experience which enhances the learner's ability to think critically. It is understandable, therefore, that any instructional strategy that is skilled towards this direction can be seen as an activity-oriented teaching method (Hands-on activity). Hands-on activity has been shown to improve students' academic achievement and attitude toward science through the manipulation of objects which may make abstract knowledge more concrete and vibrant. Through hands-on activity, learners are able to engage in real life illustrations and observe the effects of changes in different variables. Hands-on activity offers concrete illustrations of concepts. Hands-on learning approach offer learners the opportunity to see, touch and manipulate objects while learning as science is more of seeing and doing than hearing (Obanya, 2012). Obanya obseverd that the average retention rate of learning by lecture is 5% while that of practice by doing (Hand-on activity) is about 75%. It can be seen that retention rate increases progressively with the use of more interactive and activity-oriented teaching methods (NEA, 2008).

On the contrary, Ekwueme and Meremikwu (2010) observed in their study that some teachers object to the use of interactive activity-oriented method stating that it is time consuming and do not permit total coverage of the syllabus. Science syllabus coverage should be determined by how much skills/knowledge students' have acquired rather than how much of the content is covered as learner-centredness is highly advocated (Obanya, 2012).

Past research works have stated their findings that one of the major causes of students' failure in chemistry is the lack of good teaching method (Lin *et al*., 2021; Driscoll, 2014; Ekon, 2017). This study therefore, focuses on the possible impact of Hands-on activity in chemistry on students' academic performance in the chemistry of hydrocarbons, and also their attitude towards the subject.

2.8 Hands-on Learning Methods

Four methods appear to be used most often, and while all four of these methods tend to overlap in some respects, there are distinctions among them.

2.8.1 Experimental projects

One way for students to understand how scientists think and work, and to acquire the skills and knowledge to think and act scientifically is for them to engage in long-term experimental projects. In one study, an instructor replaced the ecology and environmental science unit with a five-week long class project (Petersen, 2014), during which students conducted an experiment and analysed their results statistically. Students in these classes were required to perform all the tasks faced by contemporary scientists, including balancing a fictitious budget, and applying for collection permits. Students showed development and improvement in interdisciplinary skills related to science.

Having students engage in experimental projects allows the students to be more actively involved in their learning and discovery by owning the process. They also learn in context, which provides students with a better mental framework in which to incorporate new knowledge (Seago, 2020). Once students engage in protracted experiments, they begin to learn how science is done, and thus gain an appreciation for science. Students also get an opportunity to practice thinking analytically and scientifically, which is what one must do while conducting experiments (Seago, 2020).

2.8.2 Problem-based learning

In problem–based learning (PBL) the instructor presents students with a problem, query, or puzzle that the learner wants to solve (Allen & Duch, 2018). What are presented to students are complex, real-world problems that motivate students to identify and research concepts and principles they need to know to solve the problem. PBL was started in medical schools where students solved real patient problems using case studies (Herreid, 2013). This model was subsequently modified and applied in science courses (Herreid, 2013). The process of problem–based instruction (Boud & Feletti, 2016) is as follows:

A) Students are presented with a problem, and working in permanent groups, organise their ideas and previous knowledge related to the problem. The problem could be a case study, research paper, or videotape. Within their groups, the students attempt to define the broad nature of the problem. Problems are generally started with a brief introductory lecture (Allen & Duch, 2018). Then each group is presented with the first part of a problem. Groups are then asked to start identifying the broad nature of the problem and the major factors or issues involved.

B) During the initial brainstorming session groups organize their thoughts about the problem and critically analyse their initial ideas and solutions to the problem. Throughout these steps, members within the group recognize issues and concepts that they do not understand; these "learning issues" are recorded. In their discussion, students pose questions about aspects of the problem that they do not understand. In this, students start to define what they know and, more importantly, what they don't know. Learning issues are recorded by the group and help generate and direct discussion.

C) The group will reach a point where no further progress can be made until the group learns more about specific topics. Learning issues are prioritized, and the most effective ways of researching the learning issues are discussed. The first session ends and students are expected to return to the groups having investigated their learning issues. Before groups leave, learning issues are ranked in order of importance. Students then decide which questions the whole group will follow up on and which issues can be assigned to individuals. Individuals who are assigned issues are expected to teach the rest of the group later. A discussion with the instructor outlines what resources are needed to research the learning issues and where they can be found.

D) The second session begins with group members communicating what they have learned. The learning issues can then be revisited from a perspective of deeper understanding, integrating new knowledge into the context of the problem. While students discuss in groups, they continue to define new learning issues as they progress through the problem. During any of the above activities, the problem–solving process can temporarily be interrupted by short lectures, discussions, or group assignments to help clarify concepts. Once the instructor is satisfied that the student groups have arrived at a conclusion, the solution to the initial problem can be summarized in a wrap-up discussion. Students are also encouraged to summarize their knowledge and connect new concepts to old ones. For complex problems, additional stages may be added that require a more in–depth analysis, and the cycle of activities described above continues.

The PBL process fosters the ability to identify information that is needed for an application, where and how to seek information, how to organize information into a meaningful conceptual framework, and how to communicate that information to others (Allen & Duch, 2018). Students also begin to recognize that knowledge transcends artificial boundaries because problem–based instruction highlights interconnections among disciplines and the integration of concepts (Allen & Duch, 2018).

2.8.3 The learning cycle method

The learning cycle approach to teaching consists of three to five phases. In the three-phase model, the first phase is the Exploration Phase, where students generally interact with each other to solve a problem or complete a task (Allard & Barman, 2014). The problem is open-ended to allow students to be creative yet directed in their problem solving. In other words, the problem does not have just one answer or one way of arriving at the answer; however, the instructor can narrow the field of possibilities. This phase also allows students to share ideas about something that is familiar to them, and try to relate the problem to different concepts (Beisenherz *et al*., 2011). For example: to begin a unit on cells, students may investigate the differences between plant and animal cells by observing different specimens with a microscope, then draw and discuss observed differences (Allard & Barman, 2014).

During the second phase, concept introduction, students are introduced to the main concepts of the lesson, and any pertinent vocabulary. Here, students report findings accumulated during the exploration phase. The instructor then uses the information provided by the students as a springboard to discussions (Allard & Barman, 2014).

The final phase of the learning cycle is concept application. During this phase, students study additional examples of the main concepts. This may lead to a new task where students are asked to apply concepts they have learned to new situations, for instance: identifying unknown cell specimens (Allard & Barman, 2014).

In an example in plant nutrition (Lee, 2013), the instructor started the lesson with the open-ended question, "What do plants need to live?" After a period of open discussion, the instructor started to guide students to think about the raw materials necessary for plant growth. The exploration phase could then begin with students setting up a host of experiments to determine what nutrients may be necessary for plants to live and grow. Students were expected to collect data for several weeks. After the experimental phase was complete, the instructor introduced reading assignments on nutrient effects on root and shoot growth. Applications from this point could vary widely from chemical testing in soils, to the use of different types of fertilizers (Lee, 2013). In the 5-E model, two more phases have been added to the learning cycle (Llewellyn, 2012). In the 5-E model, the first phase is Engagement. Here the teacher sets the stage for the lesson, explains the objectives, and focuses the students' attention. During the Engagement phase, the instructor can also assess prior knowledge, and have students share their experiences, in a true constructivist fashion (Llewellyn, 2012).

The second phase is the Exploration phase. Here students raise questions and develop hypotheses to test. The instructor is not directly involved with the students, while they gather evidence and data and share it with other groups.

The third phase, Explanation, is more instructor-directed. Here the students are guided through data-processing techniques, and how their data relate to scientific concepts. The instructor may introduce more details and vocabulary to provide a common language for discussion of their results (Llewellyn, 2012).

The fourth phase is the Elaboration or Extension phase. The instructor reinforces concepts by applying gathered evidence and data to new and real-world situations. This places the new knowledge within the students' conceptual framework.

The final phase of the 5-E method is the Evaluation phase. During this phase the instructor and the students summarize the relationships among the variables in the experiment. In addition, the instructor poses questions to the students to get them to make judgments and analyse their own work (Llewellyn, 2012). The instructor can make comparisons between knowledge shared in the Engagement stage and new knowledge acquired throughout the lesson. This evaluation then may lead to another Engagement.

The most noticeable difference between the learning cycle and traditional teaching methods is that in the learning cycle the laboratory, or exploratory, experiences come first. In traditional lecture/lab situations, the labs are performed after the lecturer has discussed the topic and the laboratory is purely for verification and reinforcement. In these traditional exercise students are rarely engaged mentally (Colburn & Clough, 2017), rather they are performing steps in a cookbook with a predetermined outcome.

2.8.4 Scientific inquiry method

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work (NRC, 2016). The inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as, an understanding of how scientists study the natural world. Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyse, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (NRC, 2016).

The American Association for the Advancement of Science, AAAS (2013) defines scientific inquiry similarly:

Scientific inquiry is not easily described apart from the context of investigations. There simply is no fixed set of steps that scientist always follow, no one path that leads them unerringly to scientific knowledge. There are, however, certain features of the science that gives it a distinctive character as a mode of inquiry. Although those features are especially characteristic of the work of professional scientists, everyone can exercise them in thinking scientifically about many matters of interest in everyday life (p. 4).

Scientific inquiry learning can also be viewed as a cycle (Llewellyn, 2012):

1) Inquisition: The lesson starts with a question to be investigated.
2) Acquisition: Students brainstorm possible solutions to the problem.
3) Supposition: Students select which solution to test.
4) Implementation: Students design and carry out an experiment.
5) Summation: Upon collecting evidence, students draw conclusions.
6) Exhibition: Students communicate their findings to other students.

During the exhibition phase, students may discover more questions to be answered, and thus start back at the inquisition phase. One difference from the learning cycle is that during the learning cycle, the second step is devoted to learning the terminology and the main concepts. This is absent in the scientific inquiry method and could be done before, during, or after the inquiry process. The scientific inquiry method more closely models the scientific method and those which scientists do every day (Windschitl & Buttemer, 2010), than does the learning cycle. The scientific inquiry method develops science process skills; this is an intellectual ability (Basaga *et al*., 2014). These process skills, once learned, can then be used to formulate responses to questions, justify points of view, interpret data, and explain events and procedures (Basaga *et al*., 2014). The scientific inquiry method is more flexible than the learning cycle, and is more representative of how scientists engage in problem solving. While some instructors may use the structured steps, as outlined above, others may wish to leave the process more flexible.

To be sure, the differences between the four outlined methods are subtle, yet may be outlined as follows: The experimental projects method involves more long-term projects that may have research teams and even fictitious budgets. Problem-based learning generally employs case studies. The learning cycle is a structured method that may give inexperienced students a better idea of the process of science. Finally, the scientific inquiry method is somewhere in between these methods. It allows for the flexibility of short and long-term projects, it may follow defined steps, or allow students the freedom to jump around within the process, and it may start off with a case study.

2.9 Effectiveness of Hands-on Activity in Chemistry Education

Research in chemistry education has established strong positive effects when students are taught using experiential pedagogies such as hands-on activity (Gormally, Brickman, Hallar & Armstrong, 2019; Abdi, 2014; Ergul *et al*., 2011). These approaches have been shown to enhance student attitudes (Gormally, Brickman, Hallar & Armstrong, 2019), improve assessment scores (Abdi, 2014), increase scientific process skills (Ergul *et al*., 2011), and potentially encourage more students to pursue chemistry-related careers (van den Hurk, Meelissen & van Langen, 2019). The body of literature has largely been developed in some East African countries, but a recent study (Bando *et al*., 2019) compiled the results of randomized controlled trials deployed across four West African countries, assessing the efficacy of the hands-on activity approach on teaching chemistry across a total of seventeen-thousand (17,000) students. Their results showed a 0.16 standard deviation increase in chemistry test scores after seven (7) months of hands-on chemistry learning. There is a pressing need to understand how to contextualize findings of Bando *et al*. (2019), given the low learning outcomes presently being recorded here in Ghanaian senior high schools. In the early 2000's, Ghana began participating in the Trends in International Mathematics and Science Study (TIMMS). Ghana has continually ranked near or at the bottom of the participating countries (Buabeng, Owusu & Ntow, 2018). Despite Ghanaian education stakeholders' recognition that improvements in learning outcomes are needed, only a few studies have been conducted to determine the efficacy of experiential pedagogies in the local science education context. One study at the senior high school level (Aboagye, 2009) compared the effectiveness of a particular constructivist approach (the three-phase learning cycle) with the traditional approach used in Ghanaian science classrooms. It was used in the context of teaching one specific topic (direct current electricity). In South Africa, Kibirige, Rebecca and Mavhunga (2014) studied sixty (60) high school students, half of whom were undergoing three weeks of experimental work (using standard laboratory equipment) and the other half were undergoing traditional lecture methods. In both cases, they measured improvement on process skills and assessment scores as a result of the hands-on activity. These studies indicate that hands-on activity can improve learning outcomes in the African science classroom. More such studies should be done to understand details of implementation, and they should also be carried out in different disciplines.

In Ghana, less than ten percent (10%) of public senior high schools contain any laboratory equipment (Williams, 2017). For hands-on experiential lessons to be widely deployed, teaching and learning materials must be available or made from low-cost materials. Davis and Chaiklin (2015) studied the use of classroom objects, such as tables and chairs, as teaching and learning resources for Ghanaian students to learn measurement. With over 500 hands-on activities made from materials available locally in Ghana (PEN, 2020), PEN's content is one of the most extensive and relevant resources currently available to the Ghanaian science teacher. Its alignment with the Ghanaian national curriculum also warranted its infusion into the latest revision of the primary school science curriculum (Ministry of Education Ghana,

2019) and the accompanying Teacher Resource Pack's list of "Practical Science Lesson Resources" (National Council for Curriculum & Assessment, 2019). In addition to the content itself, teacher training is a key component in enabling a shift from rote to experiential pedagogies. In Ghana, where teacher-centred approaches tend to dominate chemistry teaching (Buabeng, Ossei-Anto, & Ampiah, 2014), teacher training has been pointed out as a key factor to improving student outcomes (Buabeng, Owusu, & Ntow, 2014). The details of how a teacher implements practical content also affects the efficacy of the approach (Abrahams & Millar, 2018). Various teacher training interventions have been successfully carried out in Ghana, but they have mostly been focused on literacy and numeracy (Aizenman & Warner, 2018; Johnston & Ksoll, 2017). The role of gender as it relates to chemistry education in Ghana has been subject to some enquiry. Donkor and Justice (2016) sought to uncover the reasons behind the gender gap in students pursuing chemistry in the Upper West Region of Ghana. Further research is needed to elicit key mechanisms that can close the gap. The study in South Africa mentioned above (Kibirige et al., 2014) found no difference in results across gender lines.

2.10 Theoretical Rationales for Effect of Hands-on Science on Student Achievement

A set of theories have been proposed to explain how hands-on science benefits student learning of science. Since scientific knowledge is often complex and abstract, physically manipulating objects can help bridge the gap between the concrete and the abstract (Ruby, 2015). Developmental theorists posit successive stages of development through which humans progress. Since thinking during the second stage of development depends on concrete matters and advancement to the third, abstract stage, is facilitated through interaction with the environment, hands-on activities must help students progress to the final level (Darling-Hammond, Flook, Harvey, Barron & Osher, 2019). Relatedly, information processing in cognitive theory designates long-term memory for storage and short-term memory for immediate use. The ability to access information stored in long-term memory depends on how the knowledge is organized and the strength of the associations. Participating in tactile experiences adds a physical component to abstract knowledge, creating additional connections and improving retrieval (Ruby, 2015).

Another component of cognitive theory purports that information is filed away in long-term memory using organizing themes called schema. When learning, students may form schema which do not correspond to the real world. However, hands-on activities that require students to use knowledge to conduct experiments and achieve outcomes reduce the likelihood of the student having misconceptions about the knowledge and consequently filing the information in the wrong schema (Ruby, 2015). Adding to these rationales, Darling-Hammond *et al*. (2019) in their research on developmental outcomes and the experiences needed to support them, cited the following as necessary elements: Meaningful work that builds on students' prior knowledge and experiences and actively engages them in rich, engaging tasks that help them achieve conceptual understanding and transferable knowledge and skills; inquiry as a major learning strategy, thoughtfully interwoven with explicit instruction and well-scaffolded opportunities to practice and apply learning; well-designed collaborative learning opportunities that encourage students to question, explain, and elaborate their thoughts and co-construct solutions; (p. 104). Each of these can be achieved in the chemistry classroom through the use of hands-on activity, engaging, collaborative, laboratory experiences. Protagonists of the rationales for including hands-on activities in chemistry cite studies that seem to indicate that hands-on activities may reduce learning (Bohr, 2014: Dyrberg, Treusch, & Wiegand, 2017). Today, traditional laboratory method is used widely. Concannon and Brown (2008) mention that traditional labs only focus on scientific terminology, concepts, and facts. Furthermore, Concannon & Brown (2008) note that these labs contain detailed procedures that tell students what they will observe during experiments. In this method, students follow instructions written in the lab manual step by step and the outcome is pre-determined. Students already know the scientific theory when they start doing their experiments. In this format, students only think about following the directions written in the lab manual. For this reason, students cannot develop higher-order cognitive skills. Despite the traditional laboratory method having some advantages like conducting many experiments in crowded classes within a limited time and using limited sources, this method has many disadvantages. The following research supports the assertion that students often cannot learn effectively since they just concentrate on the lab manual and they generally do not have real-life connections. Donaldson and Odom (2011) state that in a traditional laboratory, students' ability to follow instructions has been considered instead of their questioning, designing, conducting and analysing an experiment. According to Madhuri, Kantamreddi, and Prakash (2012), the most important negation of a cookbook-style laboratory is it does not help students translate scientific outcomes into meaningful learning. The traditional laboratory method is inadequate for supporting the development which is its aim. According to Baseya and Francis (2011) changes in lab style can help students develop scientific processing skills and understand the nature of science. Teachers should move away from traditional lecturing and cookbook-style laboratories to active learning strategies such as problem-based learning, cooperative learning, and hands-on learning which help students to develop their cognitive processes and help them to become lifelong learners (Tessier & Penniman, 2016). Hands-on learning promotes cohesiveness and supports students' as they apply their knowledge, understand real-world situations, and discover (Ketpichainarong, Panijpan, & Ruenwongsa, 2010; Toth, Ludvico, & Morrow, 2012). Hands-on learning helps educators to increase students' self-confidence and learning (Wall, Dillon, & Knowles, 2015). According to Arnold, Kremer and Mayer (2014) students need to develop scientific inquiry skills while learning scientific facts and principles. In hands-on learning environments, students are more active and they are guiding their own learning processes.

2.11 Learning about Hydrocarbons

Chemistry is one of the important branches of science and occupies a central position in preparing students who wish to pursue careers in medicine, industrial chemistry, food science, engineering and other related disciplines. The chemistry curricula in senior high schools have many abstract concepts that cannot be easily understood if these underpinning concepts are not sufficiently grasped by the student. The abstract nature of chemistry concepts along with other learning difficulties means that chemistry classes require a high-level skill for proper application (Talabi, 2018). One of the essential characteristics of chemistry is the constant interplay between the macroscopic and microscopic levels of thought, and it is this aspect of chemistry learning that presents a significant challenge to novices (Talabi, 2018). The abstract concepts of chemistry require thinking on several levels and organic chemistry is no exception. Beginners in the learning of organic chemistry usually have confusion and difficulty because there are no problem-solving algorithms, it requires three-dimensional thinking and has an extensive new vocabulary (Atiku, 2014). One of the major difficulties for students in organic chemistry is the understanding of the three-dimensional nature of molecules which they have great difficulty converting between the two-dimensional drawings used in textbooks and on classroom boards to represent molecules and their three-dimensional structures (Atiku, 2014). Without this understanding, to survive the course, students have to memorize a large vocabulary of molecules and rules to pretend they understand the three-dimensional structures (Atiku, 2014). The difficulty encountered by Senior high school students in understanding the subject prevents many of them from continuing with this career path (Kimweri, 2014). Educational researchers have recently begun to concentrate on the development of a wide variety of visualization tools and novel pedagogies to aid students in science learning at all levels. These tools describe a spectrum of learning environments that support many different types of visualization from concretizing abstract concepts to understanding spatial relationships. Tools are now available that allow students to visualize experimental data sets, simulate experiments, or construct models of imperceptible entities. Visualization is any technique for creating images, diagrams, or animations to communicate a message (Dickinson, 2013). Visualization which involves visual imagery has been an effective way to communicate both abstract and concrete ideas since the dawn of man (Dickinson, 2013). Scientific visualization is the use of interactive, sensory representations, typically visual, of abstract data to reinforce cognition, hypothesis building, and reasoning.

2.12 The Use of Teaching and Learning Materials in Chemistry

Materials that are used to aid in the transference of information from one person to another are referred to as instructional materials or learning or teaching aids. Teaching materials (aids) may be described as the materials used in teaching for illustrative purpose. Its ultimate goal is to facilitate and demonstrate an understanding of a lesson. Teaching and learning materials are also defined to include materials which can be seen or heard and contribute to the teaching and learning process. Learning is done through the use of the five senses. Any medium which gives learners the opportunity to use as many senses as possible is the best medium in learning (Atiku 2014). According to Talabi (2018) there are some specific values for which teaching and learning materials should be involved in the teaching of chemistry in order to change students' perception towards the subject. He further stated that teaching and learning materials (TLMs) help to clarify and illustrate concepts, thus making abstract ideas more concrete.

Education is a fundamental human right (Pavio, 2016). The key to sustainable development, peace and stability within and among countries is the provision of education to the populace of such countries. Availability of teaching/learning resources enhances the effectiveness of schools as these are basic things that can bring about good academic performance in the students. Ruby (2015) opined that all institutions or organization are made up of human beings (workers) and other non-human resources. He further asserts that when the right quantity and quality of human resources is brought together, it can manipulate other resources towards realizing institutional goals and objectives. Consequently, every institution should strive to attract and retain the best of human resource. The implication of these opinions is that well trained teachers in chemistry, if well deployed to the secondary schools will bring about well-rounded students who will perform academically well in chemistry.

Talabi (2018) is of the view that the failure or poor performance of some students in chemistry is as a result of lack of concrete teaching and learning materials in chemistry lessons. He remarks that, no subject is taught in isolation and that, carefully selected teaching materials will link up with other subject areas, and show the relevance of the subject being taught to a much wider picture. Students who do not like, or are not particularly good, at a subject may respond with more interest and enthusiasm when the relevance of what they are being taught is brought to bear on them. The use of TLMs aid in the retention of factual knowledge and brings variety, curiosity, and interest among learners which reinforce their interaction with the learning experience. Human minds approach learning situations in practical terms (Bass, Yumol & Hazer, 2015).

The use of teaching and learning materials in the teaching and learning process attracts students' attention and arouse their interest in what is being taught, making understanding and remembering of concepts easy. No matter how well the lessons are prepared and delivered, the students soon become tired of having nothing to attend to or interest them except the teacher and themselves. TLMs make a refreshing change by keeping both the teacher and student busy. TLMs also create interest and save the teacher the trouble of explaining at length and also encouraging student to find out more on their own and thereby stimulating self-learning. They can effectively show the interrelationships among a complex whole. For example, a diagram showing parts of an alkane can be well made to show the interrelationship between the component parts, thus making it seem less complex to benefit both the teacher and the students.

Finally, one of the best ways to understand something is to get one's hand on it and actually experiment with it. Dickinson (2013) agrees with the view that learners should be engaged in hands-on activity during chemistry lessons, and the use of TLMs encourages hands-on activity amongst students, instilling positive attitudes in students can be achieved by giving students more opportunities to explore and to develop their creative skills through hand-on activity (Bass, Yumol & Hazer, 2015).

Teachers must help students to develop high self-awareness, positive belief, learning goals, and positive expectations for success since these are the ingredients of intrinsic motivation of learning (Bass, Yumol & Hazer, 2015). The use of teaching and learning materials goes a long way in helping students develop interest towards the study of chemistry.

2.13 Molecular Model Toolkit as a TLM for Teaching Hydrocarbons

Molecular model toolkit helped decrease the time to retrieve information from long-term memory and then subsequently reconstruct it in short-term memory (Ruby, 2015). Ruby (2015) explained that model toolkits facilitate the reconstruction process during retrieval by encouraging organization. Mayer (2017) in his study showed that hands-on activity involving the use of molecular model toolkits can be used to promote chemistry learning and teaching. Mayer also found that students performed better on recall and problem-solving test when hands-on activity instructional approaches were utilized. Ruby (2019) in his study found that students with different genders and learning styles perform on the ability to solve learning problems when hands-on activity was used. Molecular model kits with a support of text had reduced cognitive load of a student's (Mayer, 2017). Mayer's research found that manipulations complemented with a textual explanation enabled students to take greater advantage of their capability to process information on two levels by stimulating the visual system and by reducing the load placed on the verbal processing system. This re-shuffling of information in working memory increased their ability to make meaning out of the information in preparation for storage in long-term memory. The placement of the supporting textual explanation next to the model kits further reduced cognitive load and enhanced performance (Lee, 2013). Students will be guided to learn by sifting the relevant from the irrelevant information and can relate new information to real world situations (Boud & Feletti, 2016).

2.14 Impact of Molecular Model Toolkit on Students Understanding

Over the last decades, studies from many countries have pointed out the decreasing interest of senior high school students towards chemistry (Ekon, 2017). Many reasons have been observed as the cause of this. Respectively, the proposed resolution strategies to make chemistry more attractive to students also vary. Some researchers primarily focus on methodological innovation and diversification and has indicated the necessity to apply innovative methodology and technology such as videos, molecular model kits and animations – to promote hands-on learning and enhance learning outcomes, motivation and application skills (Smith, Blakeslee & Anderson, 2020).

Others while recognising the importance of methodological considerations, attempt to go deeper and focus primarily on the teachers' general attitudes and beliefs. Differences in teaching practice in this case is not reducible to methodological issues, but rather to the differences in teachers' aims at some more general chemistry learning goals that lie beyond the subject itself (Gulobia, Wokodola & Bategeka, 2018). Working within and elaborating the theoretical model of Haas (2012), Gulobia, Wokodola and Bategeka (2018) have distinguished chemistry teachers' attitudes towards the aims of chemistry teaching. These aims, or 'curriculum emphases', may vary from stressing chemistry as cumulative, reliable and valid knowledge (a traditional science curricula) to using chemistry as a way to understand and to explain both technology and everyday occurrences.

2.15 Effects of Molecular Model Toolkits on Student Academic Performance

Several studies in the literature show that the use of molecular model kits which involves hands-on activity helps students to outperform students who follow traditional, text-based programmes (Turpin, 2021). Hands-on activity was found to enhance students conceptual understanding and replace their misconceptions with the scientific ones (Ünal, 2018). Hands-on activity involving molecular model toolkit also improved students' attitudes toward chemistry positively (Bilgin, 2016) and encourage their creativity in problem solving, promote student independence, improves skills and communication (Haury & Rillero, 2015). Lebuffe (2014) emphasized that children learn better when they can touch, feel, measure, manipulate, draw, and make charts, record data and find answers for themselves rather than being given the answer in a textbook or lecture.

Ekwueme and Meremikwu (2010) posited that hands-on learning approach involves the child in a total learning experience which enhances the child's ability to think critically. It is obvious therefore, that any teaching strategy that is skewed towards this direction can be seen as an activity-oriented teaching method (Hands-on-approach). Hands-on-approach has been proposed as a means to increase students' academic achievement and conceptual understanding of chemistry concepts by manipulating objects which may make abstract knowledge more concrete and clearer. Through hands-on-approach, students are able to engage in real life illustrations and observe the effects of changes in different variables. It offers concrete illustrations of concepts. This method is learner-centred which allows the learner to see, touch and manipulate objects while learning as chemistry is more of seeing and doing than hearing (Ekwueme & Meremikwu, 2010).

The uses of molecular model kits develop critical thinking skills (Turpin, 2018). By investigating the subject matter through hands-on activity, students learn both content and thinking strategies (Hmelo-Silver, 2019). Hands-on activity support problem-based approaches to learning by focusing on the experience and process of investigating, proposing and creating solutions. As a result, students learn how to gather information and solve problems.

Molecular model toolkits are real objects used to support multiple modes of learning, linking visual learning to what is being said and discussed (Lee, 2013). Hands-on activities enable students to discuss, debate, verbalize and explain processes and concepts while working together. An observation of hands-on learning noted that students demonstrated strong interest tied to working in teams (Bass, Yumol & Hazer, 2011). Bass, Yumol and Hazer (2015) opined that with the right kind of planning and presentation, hands-on teaching can restore focus and spark engagement. An independent observation of teachers using hands-on learning noted that students were enthusiastic and generally stayed on-task during guided hands-on activities.

It has been demonstrated that students who are disadvantaged economically or academically gain the most from activity-based programmes (Bredderman, 2012). Every learner is provided with the same materials and guidance, and can interact with the lessons in the way that builds on their unique level of prior knowledge, past experiences and current abilities. Hands-on learning inspires all students to meet and exceed high standards for learning and participation, while engaging multiple senses (sight, sound, touch, etc.). The learner can interact with the materials in a way that makes sense to them (e.g., students who tend to learn visually may connect with the colours and sights while tactile learners can appreciate being able to manipulate objects).

2.16 How People Learn

Knowledge concerning human learning and development has grown rapidly, but much of what we know from research on learning and instruction has yet to affect the design and enactment of everyday schooling in the form of curriculum, instruction, and assessment (Goldman & Pellegrino, 2015). Suggestions for improving school and classroom practices have emerged from a consensus about the science of learning and development, outlined in a recent synthesis of the literature (Cantor, Osher, Berg, Steyer, & Rose, 2020). When the review is put into the context of a developmental systems framework, evidence of how students learn chemistry can be better understood (Darling-Hammond, Flook, Cook-Harvey, Barron & Osher, 2019). The developmental systems framework makes it clear how children's development and learning are shaped by interactions among the environmental factors, relationships, and learning opportunities they experience both in and out of school. These factors, along with the child's physical, psychological, cognitive, social, and emotional processes can either enable or undermine learning (Fischer & Bidell, 2016; Rose, Rouhani & Fischer, 2013). Critical information garnered from the science of learning and development asserts that the brain and the development of intelligences and capabilities have a capacity for adaptive change, and the "development of the brain is an experience-dependent process" (Cantor *et al.*, 2020, p. 5). When people have experiences, new neural connections are made that create different ways of thinking and performing. The National Research Council's review (Pellegrino, Hilton, & National Research Council, 2012) indicates that the kind of learning that supports higher-order thinking and performance skills needed for the 21st-century is best developed through hands-on activity and investigation, application of knowledge to new situations and problems, production of ideas and solutions, and collaborative problem-solving. Students need an important and relevant activity that scaffolds on their prior learning and experiences and actively engages them in differentiated tasks that facilitate an integrated and functional grasp of concepts that the student can apply in new contexts. Since the goal is to have students understand conceptual knowledge at a depth where they can facilitate its use and application beyond the classroom, the material should be organized and learned in the context of a conceptual framework. Teachers must structure the objectives to be learned in meaningful ways so that students can assimilate the learning and transfer new skills to new situations. The teaching strategies that allow students to do this require careful integration of direct instruction, integrated with hands-on activities that keeps students engaged in working with the material, build a level of increasingly complex problem solving, and assessed understanding to guide revisions. "Rich environments" that support brain development provides numerous opportunities for social interaction, direct physical contact with the environment, and a changing set of objects for exploration (National Research Council, 2018, p. 119).

2.16.1 Cognitive development

Educators must be aware of cognitive development or the way in which people learn (Lion, 2018). A good way for educators to acknowledge different levels of cognitive development in their lessons is for them to use Bloom's Taxonomy. Bloom's taxonomy is a classification system that recognizes the process that students undergo when learning information and gives educators a tool for measuring the levels of cognitive development that they are reaching with their lessons (Love, 2019). The classification is split into six levels that range from basic knowledge gaining to higher level thinking. The lowest level is called knowledge, and it describes when the student is remembering facts that they were previously taught. The second level is comprehension, and this describes the students' ability to understand the significance of the material that they are being taught. The third level is application; this is when the students can use the information that they have previously learned in an original way. The fourth level is analysis, and this is when students can separate material into ordered parts. The fifth level is synthesis, and it is when students can arrange parts into a new whole. The sixth and highest level of the taxonomy is evaluation, and it is when the students can critique the significance of the material that they had learned (Love, 2019). According to research, the traditional lecture method of teaching typically remains at the lower levels of bloom's taxonomy (Lion, 2018). This means that students are not reaching the higher levels of cognitive development by the traditional method (Lion, 2018). The hands-on method of teaching chemistry had been shown by research as potent in facilitating the attainment of higher cognitive levels of the Blooms Taxonomy (Mysliwiec, Dunbar, & Shibley, 2020).

2.17 Empirical Framework

Research has shown that the implementation of hands-on learning, is more effective than traditional learning, for increasing student achievement (Baker & Robinson, 2018). Saunders-Stewart, Gyles, and Shore (2016) discovered and established twenty-three (23) learning aspects and outcomes through hands-on learning and showed recall and retention of knowledge were more predominant with hands-on learning strategies. Abdi (2014) conducted a study in a fifth-grade primary school in Kermanshah, Iran and found that students who were instructed using hands-on learning had higher academic achievement than students in a traditional learning classroom. Throughout the study, a control group of 20 female students and an experimental group of 20 female students were compared. While the control group was given a lesson through traditional teaching strategies such as direct instruction, the experimental group received a lesson through hands-on learning instruction. Abdi (2014) began the study by giving both groups an academic achievement pre-test. The test contained 30 multiple-choice questions to assess student achievement. Both groups were taught a lesson on three units on the fifth-grade content including topics of the nervous system, human diseases, and environment (Abdi, 2014). Both groups were given a lesson presented by the same instructor and classroom observations were conducted to ensure the implementation of the treatments. Students within the experimental group were given lessons and activities designed around a learning model called the 5E Learning Cycle Model, which consists of five cognitive learning developments including engagement, exploration, explanation, elaboration, and evaluation and is centered around cognitive psychology and practices in science education (Bybee & Landes, 2011, as cited in Abdi, 2014). The control group was given the lesson through direct instruction, lecture, and discussion in order to present the concepts. After the lesson, a post-test identical to the pre-test was given to the students. Based on the results, the mean score from the pre-test to post-test for the experimental group increased by 4.15 points. In contrast, the mean score from the pre-test to post-test for the control group only increased by 3.4 points (Abdi, 2014). Abdi concluded that there was a significant relationship between hands-on learning and student achievement, and those students exposed to hands-on learning had a meaningful understanding of the material and could further interpret the information. Through implementation of hands-on learning, students interact with the scientific material, obtaining long-term knowledge and retention. Science knowledge and information should be transmitted through active and critical thinking of the learner

(Cakir, 2018). Abdi (2014) discussed how hands-on learning can be implemented to increase student achievement as well as longer term retention and application of interpretation.

Hands-on learning allows learners to construct and develop long-term ideas and knowledge through scientific experiences and skills (Schmid & Bogner, 2015). Schmid and Bogner (2015) conducted a study in Bayreuth, Germany with 138 ninth graders from ten (10) classes and four schools to examine the effects of hands-on learning on learning outcomes and long-term knowledge. They hypothesized students who participated in a structured hands-on learning of science unit would have a significant increase to their content knowledge. Their theory was developed around the idea of exposure to hands-on learning and its connection to long-term knowledge retention. With hands-on learning, students could activate prior knowledge, build upon newly gained information, and retain content knowledge based upon relevant and personal connections (Abdi, 2014). Schmid and Bogner (2015) also hypothesized students learning and experiencing hands-on learning would develop a long-term retention of the content material in both genders. Throughout the study, Schmid and Bogner (2015) presented a topic on air and sonic waves to both an experimental and control group. Both groups were instructed by the same instructor to ensure teaching style was consistent. The control group consisted of 64 students from three classes and they did not take part in hands-on learning. The experimental group consisted of 74 students from seven classes and were exposed to hands-on learning for long-term knowledge retention. The experimental group was given four questionnaires which were completed over the course of a 14-week schedule. The questionnaires included a diagnostic test which was presented two weeks prior to the unit lesson, a post-test which was presented directly after the lesson, and a second and third post-test which were given at the six- and 12-weeks mark after the lesson. The unit consisted of three sequential lessons at 45 minutes each, all relating to the topics of how humans hear and the definition of sound (Schmid & Bogner, 2015). In the experimental group, students conducted inquiry-based projects in small groups. Each group member was given a role that was switched between the four members of the group. The roles included reading text out loud, collecting correct experimental equipment from areas, conducting the experiment, and writing the group's analysis and conclusions. Schmid and Bogner (2015) explained that the teacher was only a guide to lead students to a solution when issues were raised, and students' only source of information was the inquiry lesson (Schmid & Bogner, 2015). The results showed through the diagnostic test that there was a mean score of 5.9 and rose significantly on the post-test given directly after the hands-on learning to a mean score of 12.00. The second post-test given six-weeks after the lesson had mean score of 9.9, showing a slight decrease. The post-test given at 12 weeks after the inquiry lesson had a mean score of 9.8 showing a slight decrease from the six weeks post-test (Schmid & Bogner, 2015). These results strongly support the hypothesis hands-on learning promotes formation of long-term retention and recall of knowledge. The control group did not practice content knowledge skills through the repeated completion of the content knowledge tests and there were no significant impacts on their knowledge scores of the four assessments (Schmid & Bogner, 2015).

2.18 Experiential Theoretical Framework

The educational theory on which this study was premised is the experiential learning theory (Kolb, 2013). Kolb drew on the ideas of Jean Piaget, Kurt Lewin, and John Dewey when he developed his seminal work, Experiential Learning (Kolb, 2013). In his experiential learning theory, Kolb synthesized what he called a holistic integrative perspective on learning that combines experience, perception, cognition, and behaviour (Kolb, 2013). He asserted that learning is the process by which knowledge is created through the transformation of experience, and knowledge results from the combination of grasping and transforming experience (Kolb, 2013). A crucial principle of Kolb's experiential learning theory is comprised of concrete experience, reflective observation, abstract conceptualization, and active experimentation, where a learner touches all bases in a cycle.

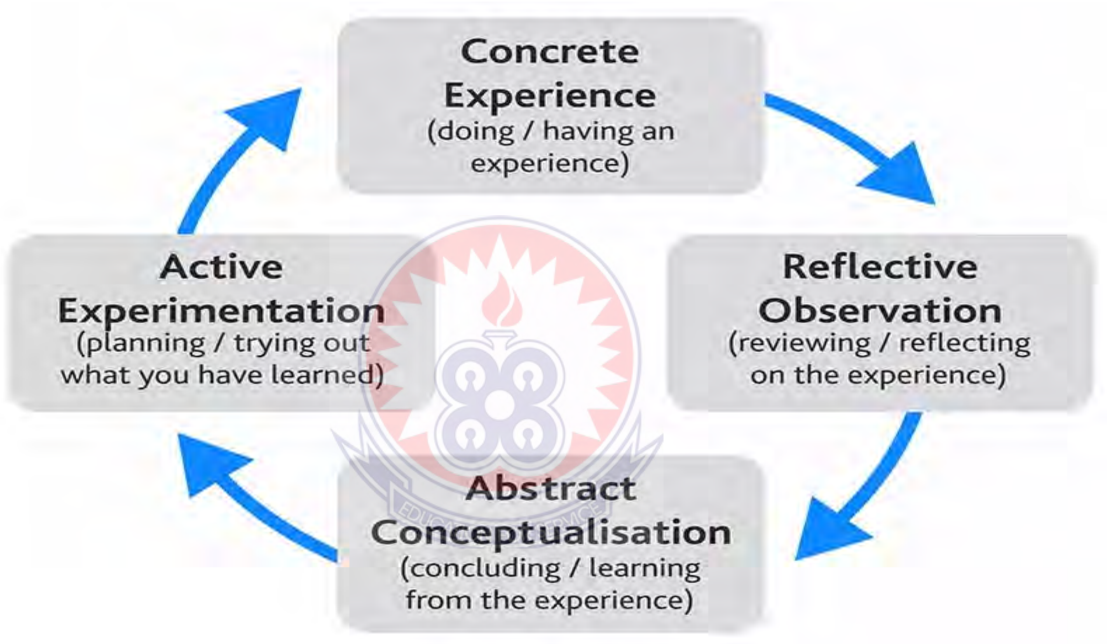


Figure 2: The Experiential Learning Cycle

The first stage in this cycle is concrete learning or concrete experience, where the learner encounters a new experience or reinterprets an existing experience. This could be where the learner is exposed to a new task or a new way of carrying out a learning project, in a way they have not seen before (hands-on activity). This is followed by the next stage, reflective observation, where the learner reflects on the experience on a personal basis. For many people, this is where the metamorphosis from seeing and doing to reflecting can embed the learning into real-time absorption of materials and methodology. It could be where a person is shown how to accomplish a goal and then looks at how it could be applied in differing circumstances. Following reflective observation is abstract conceptualisation, where learners form new ideas, or modify current abstract ideas, based on the reflections that arise from the reflective observation stage. They now have the chance to see how the ideas learned previously can be applied in their real world. The concepts they see can be altered by the results they have seen obtained in observing the ideas formulated in previous stages.

Then, there's the active experimentation stage. This is where the learner applies the new ideas to her surroundings to see if there are any modifications in the next appearance of the experience. By actively experimenting with the whole concept of visible action, we learn to associate what we have experienced with new ideas and innovations. This second experience becomes the concrete experience for the beginning of the next cycle, beginning at the first stage, and this process can happen over a short or long time.

Another renowned work compiled by a group of experts in the fields of learning, psychology, and science, asserts that "people learn to do well only what they practice doing" (AAAS, 2019, para. 1). They continued with, "Students cannot learn to think critically, analyse information, communicate scientific ideas, make logical arguments, work as part of a team, and acquire other desirable skills unless they are permitted and encouraged to do those things over and over in many contexts" (AAAS, 2019, para. 2). The argument that hands-on learning is critical to transferable learning is based on insights from cognitive theories about how people learn and the importance of students making sense of what they are learning and processing content meaningfully so that they truly understand it (Bransford, Brown & Cocking, 2014). Hands-on approaches to learning chemistry require students to take an active role in knowledge construction to solve a problem or probe a question. Hands-on lessons vary in length, design, and implementation, but share the critical component of provoking active learning and student agency through questioning, consideration of possibilities and alternatives, and applications of knowledge (Darling-Hammond, Flook, Cook-Harvey, Barron & Osher, 2019). For epistemologically authentic hands-on learning in schools, the learner is immersed in a collaborative learning environment where problem-solving is connected to real chemistry, alternative strategies are formulated, concepts are questioned, and problem-solving approaches are debated (Lave & Wenger, 2019).

Inquiry has been a clear aim of chemistry education for fifty (50) years (Bybee, 2019). Inquiry, such as hands-on activity, provides a unifying goal that forms a social connection among advocates. Examples of hands-on activity in the chemistry curriculum are one way to make abstract concepts more concrete (Bybee, 2010).

2.19 Summary

The literature showed that several pieces of research were conducted on this topic up to date. However, results of existing studies surprisingly show no reliable empirical evidence supporting the link between hands-on learning and student achievement in chemistry, as the existing studies have produced mixed findings with some suggesting a positive relationship and others suggesting no relationship in various subject areas and various levels of education. Therefore, a conclusion cannot yet be drawn as to whether hands-on learning positively influence students' chemistry achievement at all levels. Further research is, therefore, needed to make conclusive judgement about the link between hands-on learning and students' achievement in chemistry. This study sought to bridge this gap.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Overview

This chapter presents the research design, study population, sampling and sampling procedure, data collecting instruments, validity and reliability of the instruments, pre-intervention activities, intervention activities, post-intervention activities and analytical techniques.

3.2 Research Design

This study sought to examine the effect of the continuous use of hands-on activity in chemistry on the academic performance of senior high school students in the subject. In effect, the study used an action research design. Action research design is the most appropriate approach for this study because it makes for practical problem-solving as well as expanding scientific knowledge and enhances the competencies of its participants (Creswell, 2014). Creswell maintained that action research is designed to bridge the gap between theory and what is practiced in the field of education. Action research is done to improve the quality of practice in the classroom through interventions while learning from the outcome of the resulting changes. Action research aims to practically solve immediate problems of students in a classroom situation and to further the goals of a lesson simultaneously.

3.3 Research Approach

This study adopted the quantitative research approach. Quantitative research methods emphasise the objective measurement of numerical data (Creswell, 2014). To Cohen Manion and Morrison (2018), quantitative research focuses on gathering arithmetic data and generalising it across groups of people or explaining a particular phenomenon. The focus of this study was to gather arithmetic data to explain the effect of hands-on instructional strategy on achievement in chemistry, hence the approach.

3.4 Research Population

A population refers to the group of individuals from whom samples are taken for measurement (Creswell, 2014). For any study, the target population is all the members of a group defined by the researcher's specific interest; for him/her to answer research questions and to whom the findings of a study may be generalized. The target population for this study comprised all the chemistry students in public senior high schools in the central region. The accessible population, however, consisted of chemistry students of Bisease Senior High School.

3.5 Sample and Sampling Techniques

A sample is a subset of people, items, or events from a larger population from whom the researcher collects and analyse data to make inferences (Creswell, 2014). Sampling technique is the method used to select the sample for the study. The purposive sampling technique was utilised in choosing an intact form-two chemistry class of thirty-four (34) students to form the sample of the study. The purposive sampling was employed to conveniently select a chemistry class that the researcher was handling in order that normal class schedules are not disrupted. The thirty-four students selected comprised nineteen males and fifteen female students. The students were aged between fifteen and twenty.

3.6 Research Instruments

In this study, chemistry achievement test [CAT] was the main instrument used for collecting data. Questionnaire was used to collect data on the attitude of the learners before and after the intervention. The selections of these tools were guided by the nature of data to be collected; the time available as well as the objectives of the study.

3.6.1 Test

Chemistry Achievement Tests [CAT] were constructed and used by the researcher to collect data before and after the study. These tests were used to determine the achievements of the thirty-four research participants comprising the sample before and after the intervention. The CAT was reshuffled and used two weeks after the intervention to collect data on the retention ability of the respondents. The test items covered the content of hydrocarbons in chemistry in the SHS chemistry syllabus. CAT comprised 40 multiple choice items focused on five (5) categories of the Bloom's Taxonomy; remember, understand, apply, analyse and evaluate. Four alternative options were provided for each item. Both the pre- and post-CAT were equivalent in terms of number of items and difficulty. However, items were reshuffled in the post-CAT.

3.6.2 Questionnaire

According to Cohen Manion and Morrison (2018), a questionnaire is a collection of written questions which are usually answered in order to obtain information from the participants. The purpose of using the questionnaire was to enable the respondents to answer questions freely as they fill the questionnaire forms. This instrument was necessary for this study as the respondents had time to provide well taught information. The questionnaire contained closed-ended items which aim to get information about attitude of senior high school students toward chemistry. For the closed statements in the questionnaire, each statement was rated on a Likert type scale. Likert scales can have between three and nine choices. The students were required to tick in boxes corresponding to their option. The questionnaire was based on the second objective of the study. The questionnaire also sought background information on gender, and age category of the respondents.

3.7 Validity of the Instruments

The content validity of the data collecting instruments was done by the experts in the field of education who proof read and provided necessary feedback. Colleague chemistry teachers were further requested to rate the ability of each item in the instruments to measure and elicit anticipated data. They were also requested to indicate if the required data was meaningfully related to the stated research questions and objectives. The validity of the instruments was further verified during the piloting of the study in a sister school. Suggestions and pieces of advice offered by assessors were used by the researcher to modify the instruments to make them more adaptable in the study prior to its approval. Moreover, for the test items (CAT) used in this study, a table of specifications [TOS] (Table 2), was employed in their construction.

Table 1: Table of Specification [TOS]

Ability/ Topic	Lesson Duration (in hours)	Cognitive Knowledge (Remember)	Cognitive Comprehension	Cognitive Application	Cognitive Analysis	Cognitive Evaluation	Total
Structure of Alkanes	1.5	2	2	2	2	2	10
Structure of Alkenes	1.5	1	3	2	2	2	10
Structure of Alkynes	1.5	1	2	3	2	2	10
Naming Hydrocarbons	1.5	1	3	1	2	3	10
Total	**6**	**5**	**10**	**8**	**8**	**9**	**40**

3.8. Reliability of the Instruments

To ensure the reliability of the data collection instruments, the first draft of the instrument was presented to a few colleagues for their opinion and suggestions on the format, content and other related issues. Their opinions and suggestions were incorporated into the final draft of the instrument. The researcher used the test-retest technique to measure the reliability of the research instruments by using the following procedure: the research instruments were administered to selected chemistry students of a sister school with identical characteristics to those in the study. The students who took part in the piloting of the study were not involved during the actual study. The answered instruments were then manually scored. The research instruments were administered to the same group of respondents after a period of two weeks and responses scored manually. Pearson's Product Moment Correlation Coefficient (PPMCC) formula was used for the test-retest to compute a relation coefficient in order to establish the reliability of the research instruments. A Pearson's Product Moment Correlation Coefficient of 0.92 was obtained which indicated that this was a reliable data. Creswell (2014) asserted that in research, a reliability coefficient of 0.8 or more would imply that there was a highly reliable data.

3.9 Methods of Data Collection

The researcher obtained a research permit from the School of Graduate Studies [SGS], University of Education, Winneba. Permission from school administrative leadership for the conduct of this study was sought before students were contacted. Prior to the intervention, a pre-intervention CAT was administered to the respondents to ascertain their entry achievement in the concept of hydrocarbons. For four weeks, respondents were given instruction in chemistry on the concept of hydrocarbons using hands-on instructional strategy (molecular toolkit). After the intervention, a post-intervention CAT was given to the students. Post-intervention test scores were used as data to quantify the performance of respondents as an outcome of the intervention. Two weeks after the post-intervention test, a retention test was administered to assess the retention ability of the students in chemistry. The marks obtained on the tests were subjected to statistical analyses like descriptive and inferential analysis using the Statistical Package for Social Sciences [SPSS] version 22.

3.10 Data Analysis Techniques

Creswell (2014) explained that data analysis involves organizing what we have observed, heard and read, to make sense of the acquired knowledge. He maintained that as one does so he/she categories, synthesizes, search for patterns and interprets the data collected. Cohen Manion and Morrison (2018) defined data analysis as a systematic process involving working with data, organizing and breaking them into manageable units. It is also concerned with synthesizing data, searching patterns, discovering what is important, what is to be learned and deciding what to tell others.

Upon successful collection of data, the researcher organized the quantitative data systematically in frequency tables, the corrections where necessary were made. Thereafter the data code sheet was prepared and coded in the statistical package for social sciences [SPSS] computer software. In this study, the quantitative data was analysed using descriptive techniques (frequencies, means, modes and percentages). Data was presented in frequency tables and charts.

The t-test was used to determine whether a statistically significant difference existed between students' scores on the pre- and post-intervention tests.

3.11 Intervention Activities

An intervention was designed and carried out to address students' difficulty in understanding hydrocarbons using experiential hands-on activity. The intervention was carried out within four weeks. The details of each lesson are presented next.

3.11.1 Lesson one: Introduction to the molecular model toolkit

Lesson Duration: 60 minutes.

Lesson Objectives: by the end of the lesson, the learner will be able to use the molecular model toolkit correctly.

Teacher Learner Activities:

The teacher introduced the students to the molecular model toolkit and allowed them to interact with the various components of the toolkit. Then the teacher took the students through how to use the various components of the molecular model toolkit in a discussion.

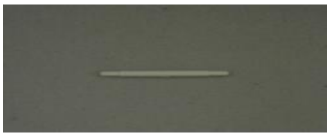
Dear learners, models of organic molecules provide a physical representation of the three-dimensional arrangement of atoms in space. Using a molecular model toolkit throughout your study of hydrocarbons will enable you to better understand both the chemical and physical properties of the molecules you encounter. The first step involves using a molecular model kit to become acquainted with the contents of your kit and what each unit represents. A model kit contains several polyhedrons and spheres that will represent the atoms you work with. The Atom Table (Table 3) specifies the number of holes on each polyhedron.

Table 2: Number of Holes on Each Atom Model

Colour	Model	Number of Holes
Black		4
Dark Blue		4
Red		4
Green		4
Dark Gray		5
Light Blue		5
Light Gray		14
Light Blue Sphere		2

Table 3 is a bond table that specifies the scaled bond length represented by each of the connectors in your kit along with a list of common bonds you will encounter throughout your study of organic chemistry and the corresponding connector that you should use (for bonds in grey, more than one connector can be used).

Table 3: Bond Table

Orange 	H-O	H-N	H-C	CΞC	C=O	CΞN	O=N	N=N	NΞN
Green 	C=C	C-O	C-N	C=N	O-N	N-N			
White 	C-C	C-N	O-O	N-N					
Yellow 	C-Cl	C-Br	C-I						
Blue 	C=C	CΞC	C=O	C=N	CΞN	O=N	N=N	NΞN	
 	Electron lone pairs can be represented using either the green or blue orbital plates in your kit.								

Now that you are familiar with what your model toolkit contains, the next step is to learn how and when to use each unit.

When building a molecular model, it will be helpful to designate which polyhedron you will use for each atom in a molecular formula. Using different polyhedrons with different colours for different atoms will make it easier for you to keep track of atoms when creating and analysing isomers. Furthermore, using the appropriate connectors to represent your bonds (single, double or triple) will enable you to better visualize which molecules can do resonance, which molecules are conjugated and/or aromatic, and which molecules have barrier(s) to rotation and are or are not planar. Keep in mind that while some bonds may be represented by more than one connector, it may be useful to pick connectors in a way that will make it easiest for you to recognize sigma and pi bonds.

Construction of Single Bonds (Alkanes)

Single bonds are constructed by connecting two polyhedrons or a polyhedron and a sphere with a single connector (not including a blue connector) that corresponds to the atoms you are bonding.

Construction of Double Bonds (Alkenes)

Double bonds (one sigma bond and one pi bond) can be constructed in two different ways. In the first instance, two polyhedrons (usually four-holed) are connected with two blue connectors. However, this method will not enable you to distinguish between the sigma and pi bond.

For the second instance, two polyhedrons (usually five-holed) are connected with a single connector (not including a blue connector) that corresponds to the atoms you are bonding. This will represent the sigma bond. One orbital plate of each colour is attached to each polyhedron with same colour orbital plates adjacent. This will represent the pi bond. This method enables you to clearly distinguish between sigma and pi bonds; however, it will make it more difficult to see the barrier(s) to rotation that exist because of the pi bond.

Construction of Triple Bonds (Alkynes)

Triple bonds (one sigma bond and two pi bonds) can be constructed in two different ways.

1) Two polyhedrons (usually five-holed) are connected with three blue connectors. This method of construction highlights the barrier(s) to rotation that exist because of the two pi bonds. However, this method will not enable you to distinguish between the sigma and pi bonds.
2) Two polyhedrons (usually fourteen-holed) are connected with a single connector (not including a blue connector) that corresponds to the atoms you are bonding. This will represent the sigma bond. Four orbital plates (two of each colour) are attached to each polyhedron with same colour orbital plates adjacent to one another and different colour orbital plates opposite one another. This will represent the two pi bonds. This method highlights the linearity of a molecule and clearly distinguishes between sigma and pi bonds. However, it will make it difficult to see the barrier(s) to rotation that exist because of the pi bonds.

Construction of Cyclic Molecules

Cyclic alkanes, alkenes, and alkynes can be constructed using the same methods previously mentioned. Example, Benzene (C_6H_6) is a common cyclic molecule (one that you will repeatedly encounter in your study of hydrocarbons) that applies many of the model building rules listed above.

Evaluation

Build a plastic model of the following hydrocarbons.

- ✓ Butane, C_4H_{10}
- ✓ Ethane, C_2H_4
- ✓ Ethyne, C_2H_2

3.11.2 Lesson two: Structure and nomenclature of alkanes

Lesson Duration: 60 minutes.

Lesson Objectives: by the end of the lesson, the learner will be able to;

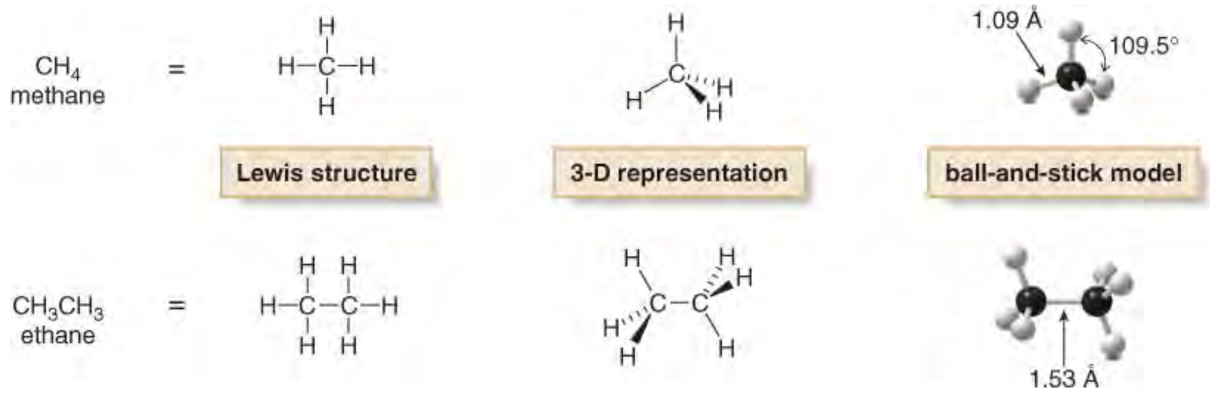
1. Draw the structural formula of some alkanes, given their molecular formula.
2. Explain isomerism in alkanes.
3. Provide correct names for all cyclic and acyclic alkanes; including the complex ones.

Core Points

Structure and Molecular Formula of Alkanes

Alkanes are aliphatic hydrocarbons having only C-H and C-C δ-bonds. They can be cyclic or acyclic.

Acyclic alkanes have the molecular formula $C_nH_2n_{+2}$ (where n = an integer). They are also called saturated hydrocarbons because they have the maximum number of hydrogen atoms per carbon. Examples are methane and ethane.



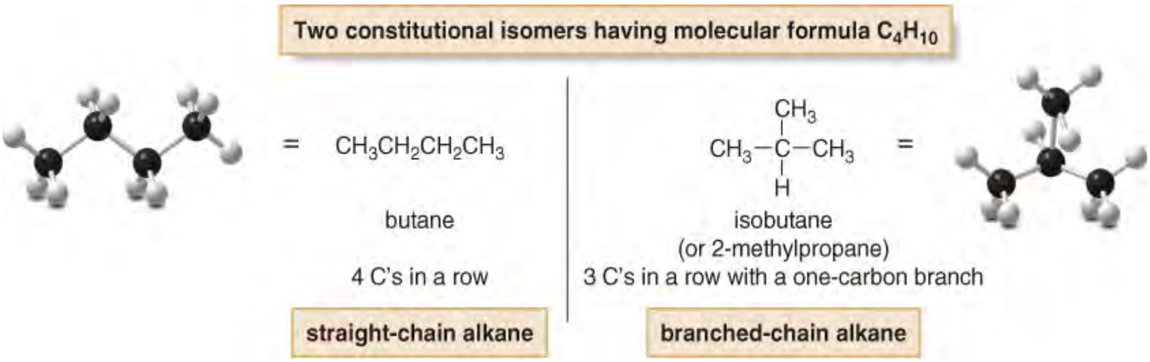
Cyclic alkanes contain carbon atoms joined into a ring. They have molecular formula C_nH_{2n}.

Unbranched Alkanes

Alkanes with unbranched carbon chains are also known as normal alkanes or *n*-alkanes. The first four *n*-alkanes: CH_4, C_2H_6, C_3H_8 and C_4H_{10}.This is an example of a family of compounds known as homologous series (each member differs from the next by the

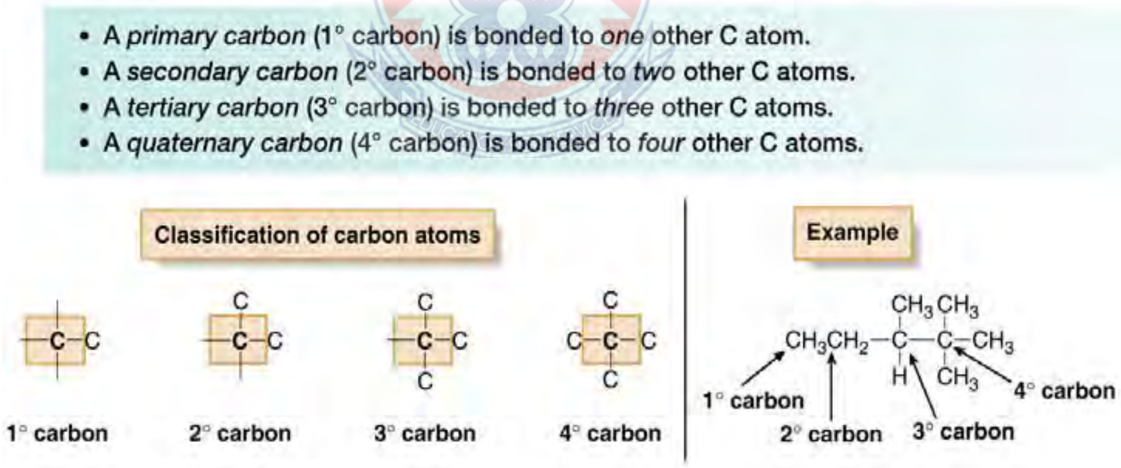
Branched Alkanes

As the number of carbons of an alkane increase beyond three, the number of possible structures increases. There are two different ways to arrange four carbons, giving two compounds with molecular formula C_4H_{10}, named butane and isobutane. Butane and isobutane are isomers—two different compounds with the same molecular formula. Specifically, they are constitutional or structural isomers. Constitutional isomers differ in the way the atoms are connected to each other.



Carbons in alkanes or other organic compounds can be classified as primary (1°), secondary (2°), tertiary (3°), and quaternary:

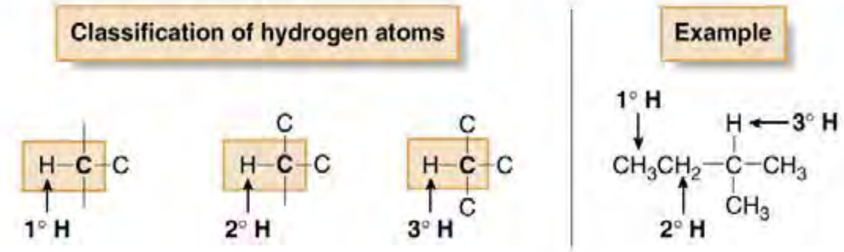
- A primary carbon is bound to one other carbon
- A secondary carbon is bound to two other carbons
- A tertiary carbon is bound to three other carbons
- A quaternary carbon is bound to four other carbons



Hydrogens can also be classified as 1°, 2°, and 3°:

- Primary H is attached to primary carbons
- Secondary H is attached to secondary carbons
- Tertiary H is attached to tertiary carbons

- A *primary hydrogen* (1° H) is on a C bonded to one other C atom.
- A *secondary hydrogen* (2° H) is on a C bonded to two other C atoms.
- A *tertiary hydrogen* (3° H) is on a C bonded to three other C atoms.



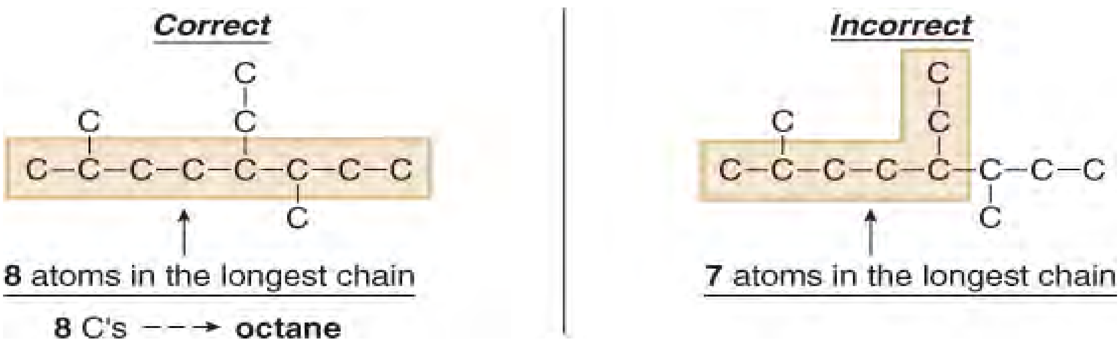
Alkyl Groups

Removing a H from an alkane gives an alkyl group or alkyl substituent.

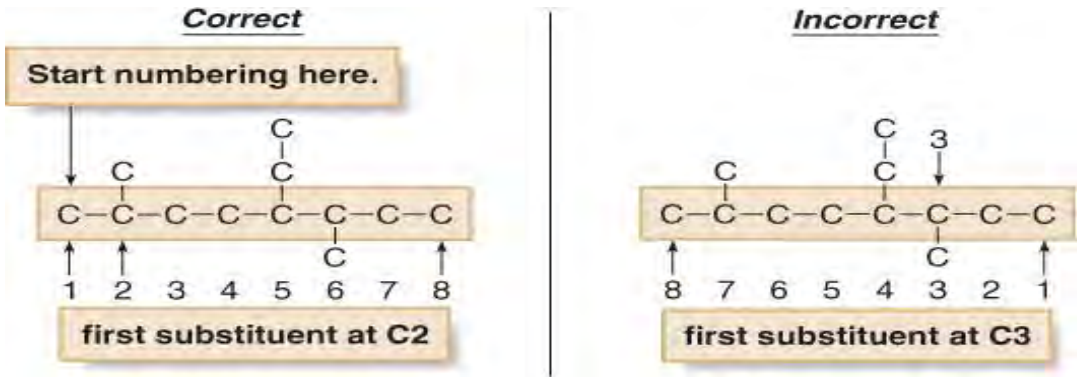
Systematic (IUPAC) Nomenclature of Alkanes

The systematic name of an alkane is obtained using the following rules:

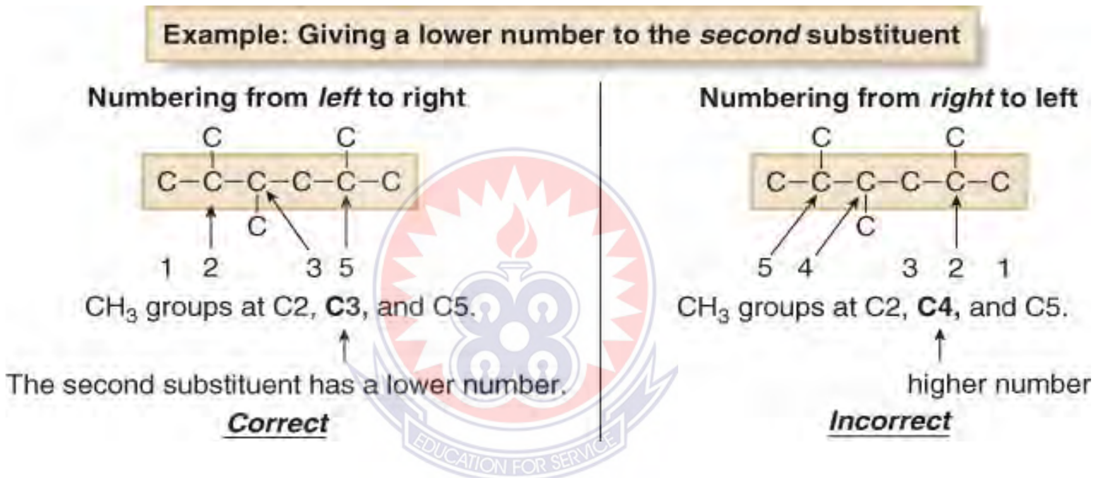
1) The unbranched alkanes are named according to the number of carbon atoms.
2) For alkanes containing branched carbon chains, find the longest continuous chain (if two or more chains within a structure have the same length, choose the one with the greatest number of branches). This is your parent chain.



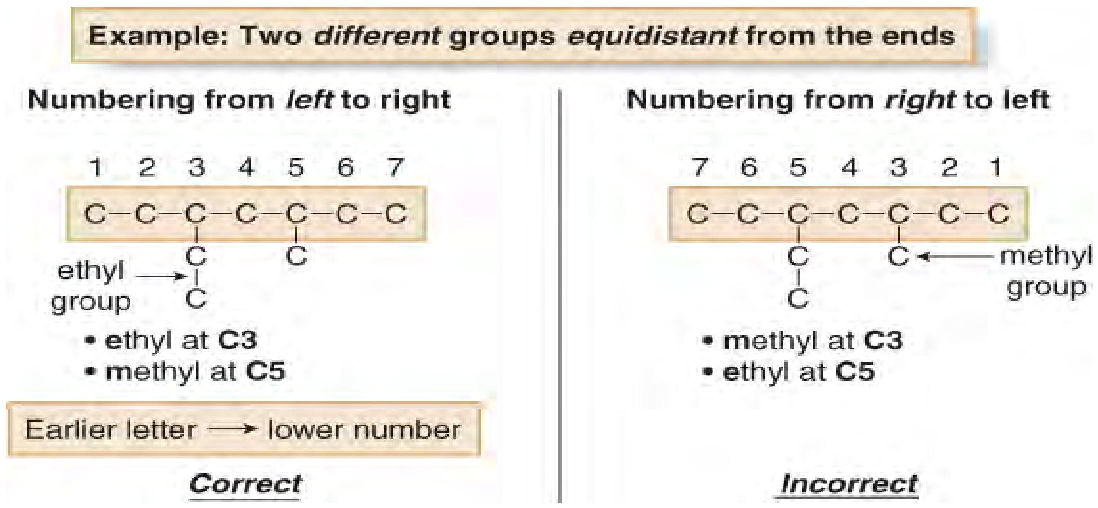
3) Number the carbons of the parent chain from one end to the other in the direction that gives the first branch the lower number.



If the first substituent is the same distance from both ends, number the chain to give the second substituent the lower number.

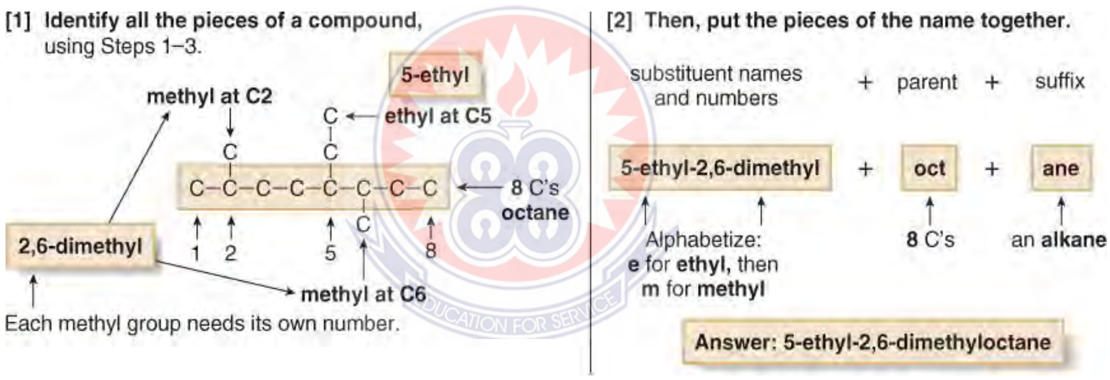


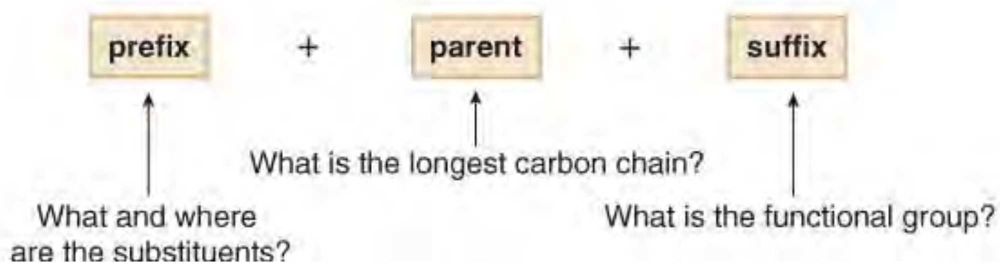
When numbering a carbon chain results in the same numbers from either end of the chain, assign the lower number alphabetically to the first substituent.



4) Name each branch (substituent) and identify the carbon number of the parent chain at which it occurs. If two substituents are on the same carbon atom, use that number twice. When two or more substituents are identical, use a prefix (di, tri, tetra, etc.) to indicate how many. Alkyl substituents are named by changing the ane ending to yl.

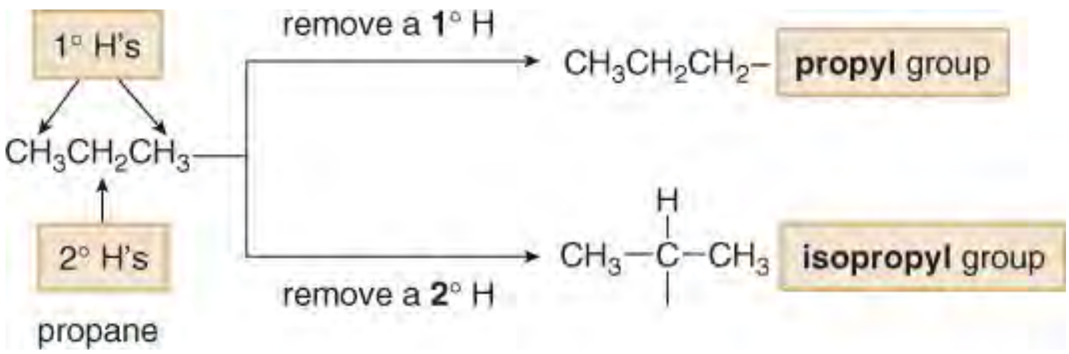
5) Construct the name by writing substituents first, followed by the name of the alkane corresponding to the parent chain. The substituent groups are listed in alphabetical order (the numerical prefixes di-, tri-, etc. as well as the prefixes tert- and sec- are ignored in alphabetizing, but the prefixes iso, neo, and cyclo are considered in alphabetizing substituent groups).





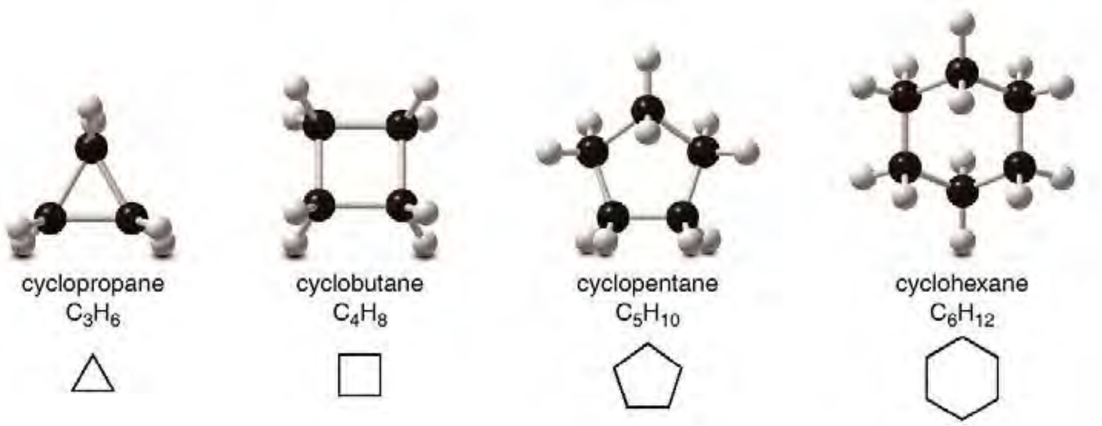
Naming Substituents

Carbon substituents bonded to a long carbon chain are called alkyl groups. An alkyl group is formed by removing one H atom from an alkane. To name an alkyl group, change the –ane ending of the parent alkane to –yl. Thus, methane (CH_4) becomes methyl (CH_3-) and ethane (CH_3CH_3) becomes ethyl (CH_3CH_2-). Naming three- or four-carbon alkyl groups is more complicated because the parent hydrocarbons have more than one type of hydrogen atom. For example, propane has both 1° and 2° H atoms, and removal of each of these H atoms forms a different alkyl group with a different name, propyl or isopropyl.



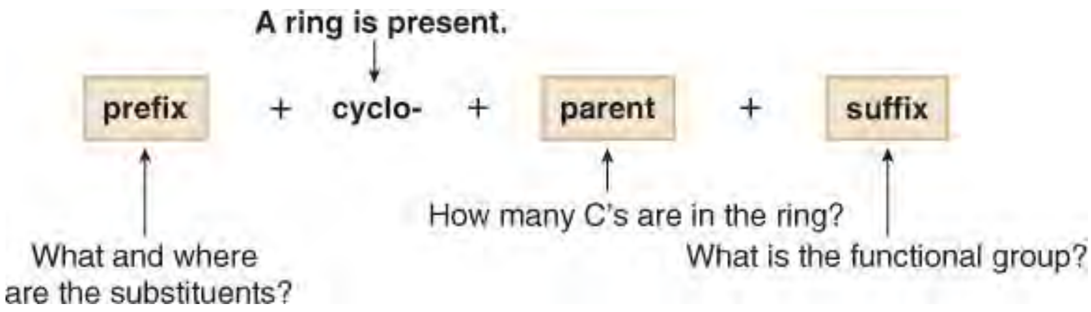
Cycloalkanes

Cycloalkanes have molecular formula CnH2n and contain carbon atoms arranged in a ring. Simple cycloalkanes are named by adding the prefix cyclo- to the name of the acyclic alkane having the same number of carbons.

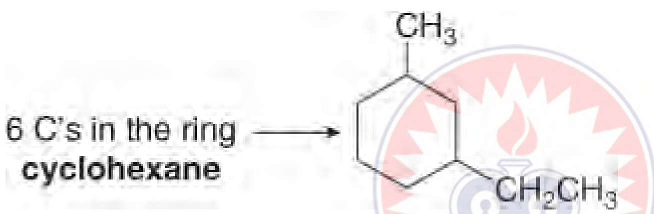


Naming Cycloalkanes

Cycloalkanes are named by using similar rules, but the prefix cyclo immediately precedes the name of the parent.

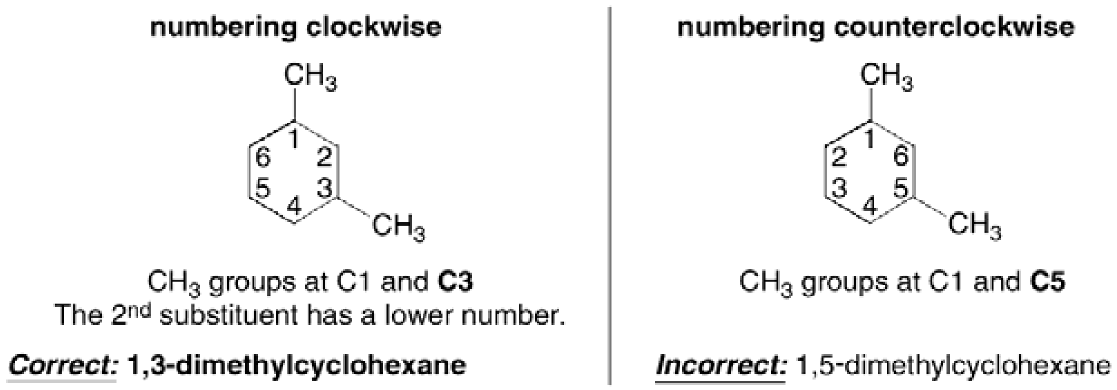


1. Find the parent cycloalkane.

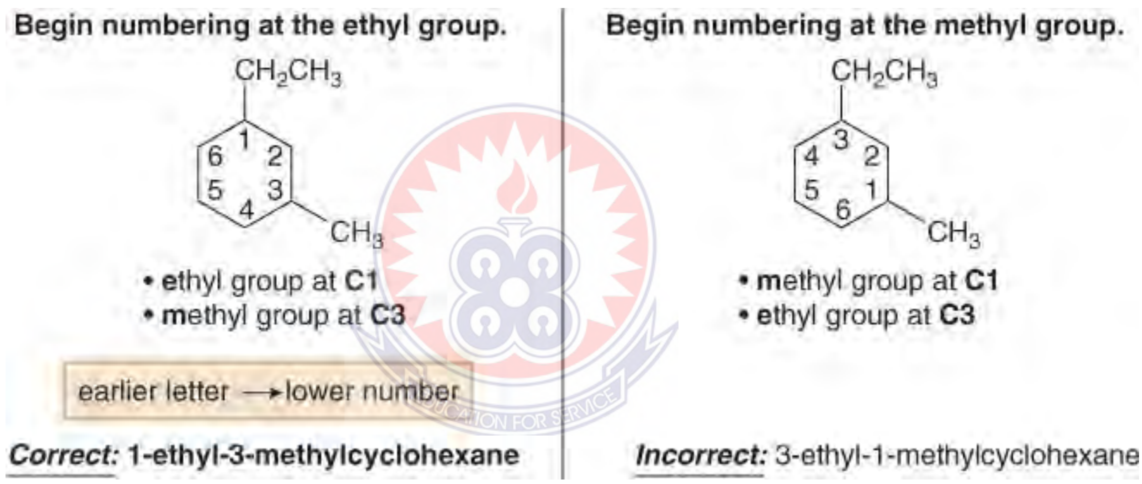


2. Name and number the substituents. No number is needed to indicate the location of a single substituent.

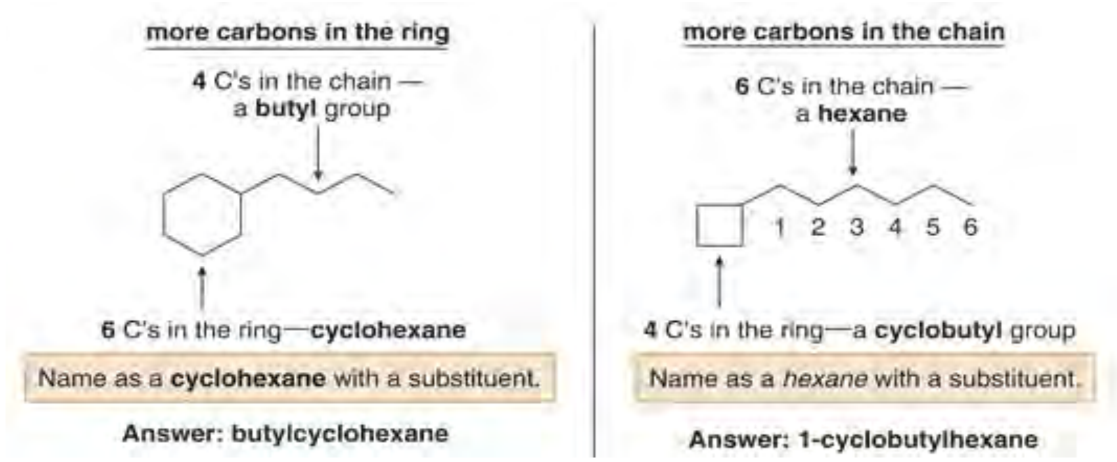
For rings with more than one substituent, begin numbering at one substituent and proceed around the ring to give the second substituent the lowest number.



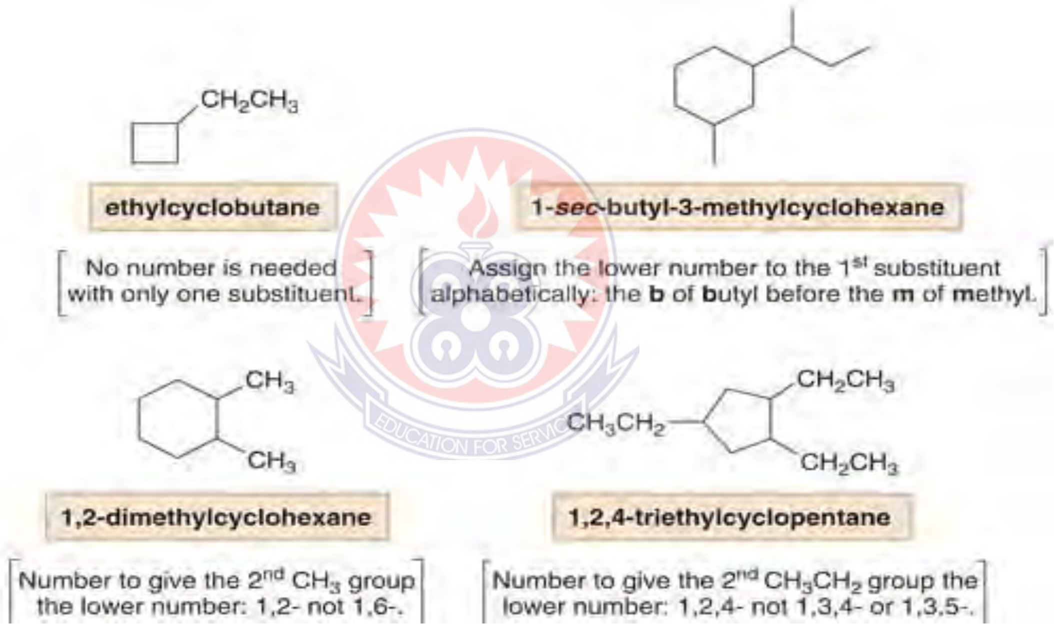
With two different substituents, number the ring to assign the lower number to the substituents alphabetically.



Note the special case of an alkane composed of both a ring and a long chain. If the number of carbons in the ring is greater than or equal to the number of carbons in the longest chain, the compound is named as a cycloalkane.



Examples of cycloalkane nomenclature



Evaluation

1. Provide the structural formula for the following alkanes; C_3H_8, C_5H_{12}, CH_4.

2. Construct the plastic model of the following alkane; cyclo-butane, cycloheptane.

3. Determine by drawing the structural isomers of the following alkanes; C_6H_{14}, C_5H_{12}.

4. Provide the systematic names for the following alkanes; CH_3-CH_2-CH_2-CH_2-CH_3, CH_3-$CHCH_3$-CH_2-CH_3.

3.11.3 Lesson three: Structure and nomenclature of alkenes

Lesson Duration: 60 minutes.

Lesson Objectives: by the end of the lesson, a student will be able to;

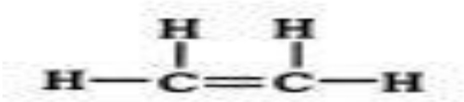
1. Draw the structural formula of alkenes, given their molecular formula.
2. Explain isomerism in alkenes.
3. Name alkenes systematically.

Core Points

Structure and Molecular Formula of Alkenes

Alkenes are molecules containing a C=C double bond. They are also sometimes referred to as olefins or as unsaturated compounds. They are called unsaturated because the C atoms in a C=C double bond don't have as many hydrogens bonded to them as an alkane does. Molecules with one double bond are called monounsaturated. Molecules with multiple double bonds are called polyunsaturated. In contrast, alkane molecules with no double bonds are saturated. The alkenes comprise a series of compounds that are composed of carbon and hydrogen atoms with at least one double bond in the carbon chain. This group of compounds comprises a homologous series with a general molecular formula of C_nH_{2n}, where *n* equals any integer greater than one.

The simplest alkene, ethene, has two carbon atoms and a molecular formula of C_2H_4. The structural formula for ethene is

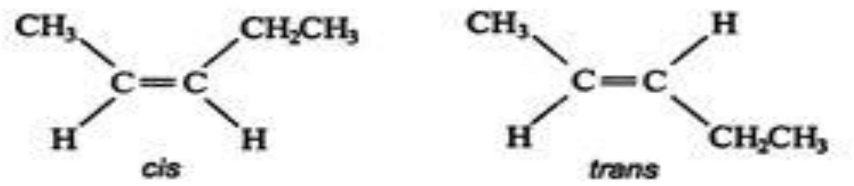


In longer alkene chains, the additional carbon atoms are attached to each other by single covalent bonds. Each carbon atom is also attached to sufficient hydrogen atoms to produce a total of four single covalent bonds about itself. In chains with four or more carbon atoms, the double bond can be located in different positions, leading to the formation of structural isomers**.** For example, the alkene of molecular formula C_4H_8 has two isomers.

$$CH_3-CH_2-CH=CH_2 \quad \text{and} \quad CH_3-CH=CH-CH_3$$

Isomerism in Alkenes

In addition to structural isomers, alkenes also form stereoisomers**.** Because rotation around a multiple bond is restricted, groups attached to the double-bonded carbon atoms always remain in the same relative positions. These "locked" positions allow chemists to identify various isomers from the substituents' locations. For example, one structural isomer of C_5H_{10} has the following stereoisomers.



The isomer on the left, in which the two substituents (the methyl and ethyl groups) are on the same side of the double bond, is called the cis isomer, while the isomer on the right, with two non-hydrogen substituents on opposite sides of the double bond, is called the trans isomer**.**

Nomenclature of Alkenes

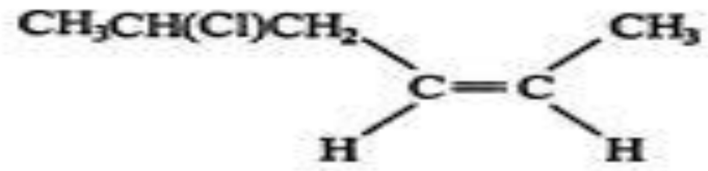
Alkenes are normally named using the IUPAC system. The rules for alkenes are similar to those used for alkanes. The following rules summarize alkene nomenclature.

1) Identify the longest continuous chain of carbon atoms that contains the carbon-carbon double bond. The parent name of the alkene comes from the IUPAC name for the alkane with the same number of carbon atoms, except the -ane ending is changed to -ene to signify the presence of a double bond. For example, if the longest continuous chain of carbon atoms containing a double bond has five carbon atoms, the compound is a pentene.
2) Number the carbon atoms of the longest continuous chain, starting at the end closest to the double bond. Thus, is numbered from right to left, placing the double bond between the second and third carbon atoms of the chain. (Numbering the chain from left to right incorrectly places the double bond between the third and fourth carbons of the chain.)

$$CH_3-CH_2-CH=CH-CH_3$$

3) The position of the double bond is indicated by placing the lower of the pair of numbers assigned to the double-bonded carbon atoms in front of the name of the alkene. Thus, the compound shown in rule 2 is 2-pentene.
4) The location and name of any substituent molecule or group is indicated. For example, is 5-chloro-2-hexene.

5. Finally, if the correct three-dimensional relationship is known about the groups attached to the double-bonded carbons, the cis or trans conformation label may be assigned. Thus, the complete name of the compound in rule 4 (shown differently here) is cis-5-chloro-2-hexene.



Evaluation

Provide the systematic names of the following alkenes.

- ✓ H_3C CH CH CH_2 CH_2 CH_3
- ✓ H_3C CH_2 CH CH CH CH CH_3CH_3

3.11.4 Lesson four: Structure and nomenclature of alkynes

Lesson Duration: 60 minutes.

Lesson Objectives: by the end of the lesson, a student will be able to;

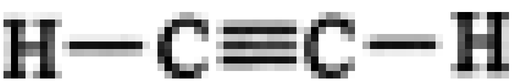
1. Draw the structural formula of alkynes, given their molecular formula.
2. Name alkynes systematically.

Core Points

Molecular and Structural Formulas

The alkynes comprise a series of carbon- and hydrogen-based compounds that contain at least one triple bond. This group of compounds is a homologous series with the general molecular formula of C_n H_{2n--2}, where *n* equals any integer greater than one.

The simplest alkyne, **ethyne** (also known as acetylene), has two carbon atoms and the molecular formula of C_2H_2. The structural formula for ethyne is



In longer alkyne chains, the additional carbon atoms are attached to each other by single covalent bonds. Each carbon atom is also attached to sufficient hydrogen atoms to produce a total of four single covalent bonds about itself. In alkynes of four or more carbon atoms, the triple bond can be located in different positions along the chain, leading to the formation of structural isomers. For example, the alkyne of molecular formula C_4H_6 has two isomers,

$$HC\equiv C-CH_2CH_3 \quad \text{and} \quad CH_3-C\equiv C-CH_3$$

Although alkynes possess restricted rotation due to the triple bond, they do not have stereoisomers like the alkenes because the bonding in a carbon-carbon triple bond is *sp* hybridized. In *sp* hybridization, the maximum separation between the hybridized orbitals is 180°, so the molecule is linear. Thus, the substituents on triple-bonded carbons are positioned in a straight line, and stereoisomers are impossible.

Like alkenes, alkynes are unsaturated because they are capable of reacting with hydrogen in the presence of a catalyst to form a corresponding fully saturated alkane.

Nomenclature

Although some common alkyne names, such as acetylene, are still found in many textbooks, the International Union of Pure and Applied Chemistry (IUPAC) nomenclature is required. The rules for alkynes in this system are identical with those for alkenes, except for the ending. The following rules summarize alkyne nomenclature.

1. Identify the longest continuous chain of carbon atoms that contains the carbon-carbon triple bond. The parent name of the alkyne comes from the IUPAC name for the alkane of the same number of carbon atoms, except the -ane ending is changed to - yne to signify the presence of a triple bond. Thus, if

the longest continuous chain of carbon atoms containing a triple bond has five atoms, the compound is pentyne.

2. Number the carbon atoms of the longest continuous chain, starting at the end closest to the triple bond. Thus, is numbered from right to left, placing the triple bond between the second and third carbon atoms of the chain. (Numbering the chain from left to right incorrectly places the triple bond between the third and fourth carbons of the chain.)

$$CH_3-CH_2-C\equiv C-CH_3$$

3. The position of the triple bond is indicated by placing the lower of the pair of numbers assigned to the triple-bonded carbon atoms in front of the name of the alkyne. Thus, the compound shown in rule 2 is 2-pentyne.
4. The location and name of any substituent atom or group is indicated. For example, the compound is

5-chloro-2-hexyne.

Evaluation

Name the following alkyne.

3.12 Ethical Considerations

Gray (2019) insists on the need of the researcher to observe the principle of ethics when conducting educational research.

While this research will contribute to knowledge on the effect of hands-on instructional strategy on academic performance among senior high school chemistry students, it maintained utmost confidentiality about respondents. The researcher explained to the respondents the importance of data to be collected. They were informed that all data sought for would be treated with confidentiality. Where necessary, clarification was made on the items of the questionnaire. The respondents were not required to indicate their names on the questionnaire and the researcher ensured that all respondents were given free will to participate and contribute voluntarily to the study. Besides, the researcher ensured that relevant authorities were consulted and permission granted. Due explanations were given to the respondents before commencement of data collection.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

This chapter presents the analyses of the data collected from the study's respondents and the interpretation of the same. The chapter includes the questionnaire return rate and the respondents' demographic information. The results were presented based on the research questions posed in chapter one. The results were discussed alongside the presentation.

4.1 Demographic Data of the Respondents

Completion rate is the proportion of the sample that participated as intended in all the research procedures. In this research, all 34 respondents (students) participated in the research to completion. All questionnaires administered to the students to collect data on their pre- and post-attitudes toward the teaching and learning of chemistry were returned, giving 100% as the return rate. The demographic data of students was based on sex and age. The data collected showed that 19 of the respondents representing 56% of the respondents were males while 15 (44 %) were females. Further to this, the data revealed that nine (26 %) about a quarter, of the respondents were either 16 or 17 years old while 25 (73.5 %) about three-quarters, were either 18 or 19 years old.

4.2 Research Question One

What is the attitude of students toward chemistry before and after the use of hands-on activity?

From Table 4, it is shown that the respondents exhibited poor attitudes toward the teaching and learning of chemistry before the intervention. Twenty-four (70.6 %) respondents disagreed that they liked studying chemistry very much. Six (17.6 %)

were indecisive. Furthermore, twenty-five (73.5 %) respondents disagreed with the statement "I like chemistry because of positive guidance from my chemistry teacher (Table 4)." Again, six (17.6 %) were undecided. Only 11.5 % of the students accepted that they enjoyed chemistry because their teacher used hands-on methods to teach the subject; 88.5% either disagreed or were undecided. Nine (26.2 %) of the respondents wished to take chemistry at higher levels of education. Twenty (58.8 %) were undecided whiles the remaining 5 (15 %) disagreed. Also, close to two-thirds of the respondents (64.7 %) thought chemistry concepts were difficult to comprehend.

Table 4: Students' Pre-Intervention Attitudes toward Chemistry

Statement	Response Type		
	Agree F (%)	**Undecided F(%)**	**Disagree F(%)**
1. I like chemistry very much.	4(11.8)	6(17.6)	24(70.6)
2. I like Chemistry because of the positive guidance from my chemistry teacher.	3(8.9)	6(17.6)	25(73.5)
3. Concepts in chemistry are difficult to understand.	22(64.7)	8(23.5)	4(11.8)
4. I enjoy doing chemistry because my teacher uses an interesting and hands-on methodology to teach the subject.	4(11.5)	5(15)	25(73.5)
5. I do chemistry only to prepare for my future career.	9 (26.2)	20(58.8)	5(15)
6. I would like to take a chemistry-related career at a higher level of education.	9 (26.2)	20(58.8)	5(15)

The data imply that the majority of respondents expressed poor attitudes toward the teaching and learning of chemistry before the intervention. Poor attitude of students towards a subject invariably leads to low levels of motivation, and subsequently, poor performance in the subject (Practical Educational Network, 2016). The literature sufficiently established that students with a positive attitude towards chemistry performed better in the subject than those students who showed poor attitudes towards the subject (Supriyatman & Sukarno, 2014; Saputri, 2021). The poor attitudes exhibited by the respondents before the intervention could be credited to the absence of hands-on instructional methods needed to facilitate meaningful teaching and learning of chemistry, ultimately resulting in a loss of interest in the subject by the respondents. This could result in poor performance in chemistry. There could be other underlying reasons or factors, such as assessment methods which influenced the respondents' attitudes that were not looked into in this study. According to Zimmerman (2018), students with a positive attitude towards chemistry are motivated to work hard and this is reflected in their assessment scores. On the other hand, students who show poor attitudes are not motivated, therefore, lacked the self-drive to work hard. As a result, they ended up scoring poor grades hence performing poorly in chemistry.

It was also revealed that there was a high improvement in students' attitudes towards chemistry after the intervention. Twenty-seven (79.4 %) respondents reported that they enjoyed chemistry because their teacher used hands-on methods to teach the subject, three (8.8%) thought otherwise while the remainder four (11.8 %) were indecisive. Additionally, twenty-six (76.4 %) respondents indicated that they liked chemistry because of positive guidance from the teacher. Again, four (11.8 %) were undecided. Only two (6 %) respondents accepted that chemistry concepts are difficult to comprehend; 94 % of them either disagreed or were undecided (Table 5). Further to that, some three-fifths of the respondents reported that they would like to take chemistry-related careers at a higher level of education compared to nine respondents before the intervention.

Table 5: Students' Post-Intervention Attitudes toward Chemistry

Statement	Response Type		
	Agree F (%)	Undecided F (%)	Disagree F (%)
1. I like Chemistry because of the positive guidance from my chemistry teacher.	26(76.4)	4 (11.8)	4 (11.8)
2. Concepts in chemistry are difficult to understand.	2(6)	4(11.8)	28(82.2)
3. I enjoy doing chemistry because my teacher uses an interesting and hands-on methodology to teach the subject.	27(79.4)	4(11.8)	3 (8.8)
4. I do chemistry only to prepare for my future career.	9(26.2)	5(15)	20(58.8)
5. I would like to take a chemistry-related career at a higher level of education.	21(61.6)	8 (23.4)	5(15)

The findings revealed that students' attitudes towards the teaching and learning of chemistry improved tremendously after the intervention. The improvement in attitude towards the teaching and learning of chemistry could be credited to the use of a hands-on instructional approach. Abrahams and Millar (2018) argued that students who were taught chemistry with a hands-on activity approach showed a positive attitude towards the subject and also recorded higher academic performances. On the contrary, students taught with conventional approaches exhibit poor attitudes toward the subject. Gormally et al. (2019) explained that students with a positive attitude towards chemistry are self-driven to actively participate in learning the subject since self-drive is influenced by perception and attitude. Gormally et al. further stated that poor attitude was always associated with low performance in chemistry. The findings presented above are in tandem with the literature. For instance, Abdi (2014) and Gormally et al. (2019) investigated the effects of hands-on instructional strategies on the attitude, assessment scores and acquisition of process skills in chemistry among 208 high school students. Their findings did show hands-on approaches to enhance students' attitudes, improve assessment scores, and increase scientific process skills acquisition in chemistry. Additionally, Ergul et al. (2011) reported from their study conducted among 480 middle school students to assess the impacts of hands-on approaches on attitude and motivation that hands-on approaches potentially encouraged more students to pursue chemistry-related careers. Bando *et al*. (2019) conducted an empirical study across four West African countries, assessing the efficacy of the hands-on activity approach in teaching chemistry among a total of seventeen-thousand students. Their results showed an improved attitude towards the learning of chemistry and a 0.16 standard deviation increase in chemistry test scores after seven months of hands-on chemistry learning.

More than half of the respondents consistently displayed poor attitudes toward chemistry before the intervention (Table 4), except statement 5 where most students agreed they studied chemistry to prepare for the future. Over half of the students surveyed did not enjoy learning chemistry before the intervention. Few students demonstrated total confidence in their attitudes as can be noted by the percentage of students selecting agree. When the intervention period concluded, the measurement survey was administered again and evaluated using the same method. The results from the post-intervention survey showed that the attitudes of the students improved substantially over the course of the intervention period. Confidence in their abilities to comprehend chemistry concepts also improved. In comparison, students reported more positive attitudes on the post-survey measurement than they did on the pre-survey measurement. This is attributed to the hands-on approach used during the intervention period.

4.3 Research Question Two

What is the effect of hands-on activity on the levels of skill performance among students in chemistry?

The mean performance of the students on the pre-intervention test was 10, with a standard deviation of 4.5. The pre-intervention test was scored out of 40 with 15 set as the pass mark. A mean score of 10 suggests that most of the students scored below the pass mark on the pre-intervention test. Also, a low standard deviation (4.5) implies that the majority of the scores obtained by the students on the pre-intervention test were centred around the mean (10).

The mean and standard deviation scores on the post-test are 20.4 and 6 respectively. The mean gain score for the post-test was 10.4. The gain was recorded in favour of the post-intervention test. These results indicated that the intervention improved the performance of the students in chemistry.

Testing null hypothesis H_{o1}: There is no statistically significant difference between the performance of students on the pre- and post-intervention tests.

The first null hypothesis was tested at a 0.05 level of significance. The results from the paired sample t-test (Table 6) indicated that the difference between the mean scores of the pre-test and the post-test is statistically significant ($p<0.05$). Also, a large effect size ($\Theta = 1.78$) indicates it can be inferred from the data that the impact of the intervention is significant in real-world scenarios. Further to this, a positive Pearson's Correlation Coefficient value ($r = 0.36$) implies a direct relationship between hands-on activity and the level of process skills acquisition among students in chemistry. Based on the results from the statistical analysis (Table 6), null hypothesis one was rejected. This suggests that there is a statistically significant difference between the pre-and post-test performances of the students. Judging from the mean performances of the students (Table 6), it is clear that the difference was in favour of the post-intervention test. This may be credited to the intervention activity. This suggests that the use of a hands-on activity to teach process skills in chemistry is effective.

Table 6: T-Test: Paired Two Sample for Means

Test Statistic	Pre-Intervention Test	Post-Intervention Test
Mean	9.71	20.41
Pearson Correlation	0.36	
ϴ	1.78	
P	0.00	
Sign. at $p<0.05$	**	

***** = significant; ϴ = effect size***

The results from the data analysis align with the findings of previous studies. Supriyatman and Sukarno (2014) and Çelik (2022), for example, observed that students' proper utilisation of instructional materials during hands-on activities significantly influenced students' academic performance in chemistry. This may be because science students who utilised instructional materials involving hands-on activities made the lesson real and so they were able to assimilate and internalise the concept meaningfully and effectively. Supriyatman and Sukarno (2014) studied the role of hands-on activity in skills performance and knowledge retention among 288 senior high school students. Their findings indicated that students improved in observation, prediction, communication and in making conclusions. Retention ability was also greatly enhanced. Çelik (2022) explored the role of hands-on activity in improving science process skills in chemistry, the findings indicated that although hands-on activity improves science process skills and content retention, the effect on high achievers was relatively low compared to low achievers. Furthermore, Stieff (2011) examined the effect of hands-on activity in enhancing students' basic SPS in learning the states of matter at microscopic, macroscopic, and symbolic levels among students in senior high schools. It was found that hands-on activity improved students' performances on post-intervention tests with large effect sizes reported.

4.4 Research Question Three

What is the impact of the hands-on activity on the retention ability of students in chemistry?

Table 7: Mean and Standard Deviation Scores of Students' Retention test Performance

Instructional Approach	**Retention Test**			
Hands-on Activity	N	$\overline{X}$	SD	Mean Gain from Pre-test
	34	20.7	5.7	0.3

****N=Number of respondents; $\overline{X}$=Mean Score; SD=Standard Deviation***

A comparison between the mean scores on the pre-test, post-test and retention test revealed a trendline with a positive slope (Fig. 3). This implies that the students performed equally well in the retention test as they did in the post-test. This may be attributed to the use of a hands-on activity to teach chemistry.

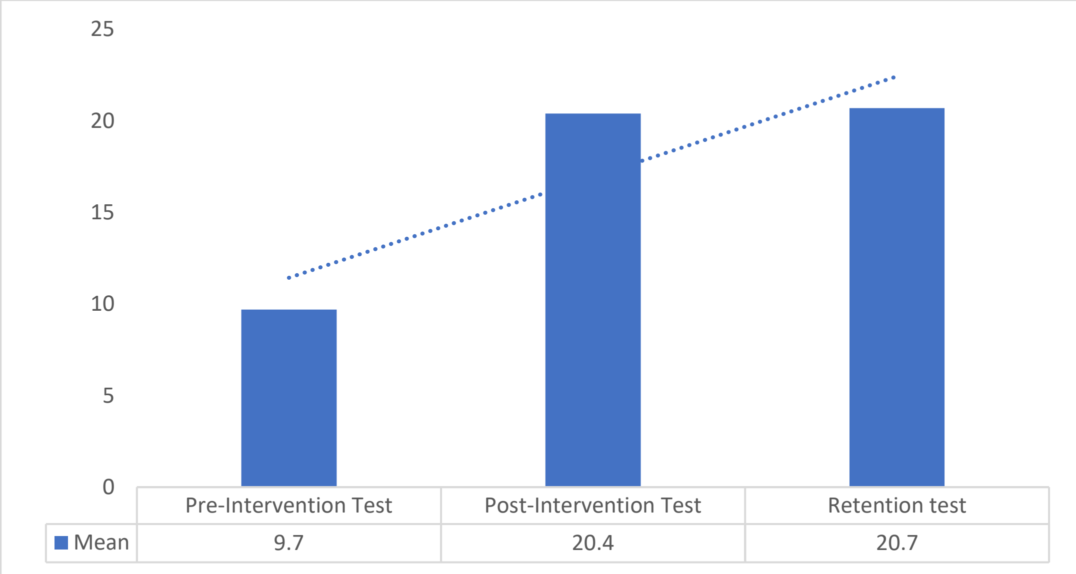


Figure 3: Comparison of Mean Scores between Tests

Testing null hypothesis H_{o2}: There is no statistically significant difference between the mean scores of students on the pre-intervention test, the post-intervention test and the retention test.

The results from the ANOVA test (Table 8) showed that there was a statistically-significant difference between the mean performances of the students on the tests between the groups F (2, 114) = 3.076; p = 0.000). This suggests that at least one of the means is significantly different from the others. Based on this, null hypothesis two was rejected.

Table 8: ANOVA Table

Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	3045.453	2	1522.726	51.449	0.000	3.076
Within Groups	3374	114	29.596			
Total	6419.453	116				

To determine which of the mean scores is significantly different from the others, a Tukey honest significant difference [HSD] post-hoc test was conducted to reveal the significant pairwise differences between the mean scores. The post-hoc test (Table 9) revealed significant differences between the pre-intervention test scores (A) and the post-intervention test scores (B) (10.7 > 3.31), with an average difference of 10.7% and between the pre-intervention test scores and the retention test scores (C) (11.0 > 3.31), with an average difference of 11.0%. The Tukey HSD test revealed no significant difference between the mean score obtained on the post-intervention test and that obtained on the retention test (0.3 < 3.31). this implies that students retained concepts taught to them during the intervention period since their performance on the retention test did not differ significantly from that on the post-intervention test. Hence, it can be said that the hands-on activity teaching approach had a significant positive impact on the retention ability of students in chemistry.

Table 9: Tukey HSD Test

Pair	$\bar{x}_1 - \bar{x}_2$	**Critical Value**	**Significant at 0.05**
A & B	10.7	3.31	Yes
A & C	11.0	3.31	Yes
B & C	0.3	3.31	No

A = Pre-Intervention Test; B = Post-Intervention Test; C= Retention Test; $\bar{x}$= Mean

This result is similar to the findings of Saat (2004) in which hands-on activities enabled students to conduct experiments in chemistry weeks after the intervention was carried out. Again, the finding supports that of Siahaan *et al*. (2017), who found that hands-on activity enhanced the retention ability of second-grade students enrolled in chemistry courses. Siahaan *et al*. (2017) studied the impact of the hands-on activity on the retention ability of 308 second-grade students enrolled in chemistry courses.

The respondents were administered two retention tests four weeks after a post-test. The results proved positive. Additionally, Ardac and Sezen (2002) explored the effectiveness of hands-on activity on retention ability and process skills for controlling variables among students in secondary schools. The findings indicated that students learning with hands-on activity reported improved retention abilities after an intervention. They also exhibited the acquisition of SPS by developing the ability to control different variables. Based on the findings from this study and the literature, it is inferred that hands-on activity is a potent instructional approach to enhance the retention of concepts in chemistry.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Overview

This chapter presents the summary of the main findings and conclusions drawn from the study. The chapter also presents recommendations for various stakeholders and suggestions for further research.

5.1 Summary of the Study

This study aimed to examine the effect of hands-on activity on senior high school students' skill performance and attitudes toward chemistry. This entailed comparing the outcomes of a pre-intervention test to that of a post-intervention test. To realise the research purpose, the study was guided by the following specific objectives: To examine the attitude of students toward chemistry before and after the use of hands-on activity; to determine the effect of hands-on activity on the levels of skill performance among students in chemistry; and to assess the impact of hands-on activity on the retention ability of students in chemistry. Three research questions were answered: What is the attitude of students toward chemistry before and after the use of hands-on activity? What is the effect of hands-on activity on the levels of skill performance among students in chemistry? What is the impact of hands-on activity on the retention ability of students in chemistry? Further, two null hypotheses: **H_{o1}:** There is no statistically significant difference between the performance of students on the pre-and post-intervention tests, and **H_{o2}:** The mean scores of students on the pre-intervention test, the post-intervention test and the retention test are equal, were tested at 0.05 level of significance. The study adopted an action research design and involved an intact form two chemistry class, conveniently selected for the study. Data were collected using tests and questionnaires. The t-test, ANOVA and Tukey HSD test were used to test the significant differences between the mean scores obtained on the tests.

5.2 Summary of Main Findings

5.2.1 Students' attitudes toward chemistry before and after the intervention

Data were collected from the respondents of the study using questionnaires. Respondents were asked to respond to statements that could indicate their attitudes toward the teaching and learning of chemistry. Before the intervention, twenty-four (70.6 %) respondents disagreed that they liked studying chemistry very much. Six (17.6 %) were indecisive. Furthermore, twenty-five (73.5 %) respondents disagreed with the statement "I like chemistry because of positive guidance from my chemistry teacher." Again, six (17.6 %) were undecided. Only 11.5 % of the students accepted that they enjoyed chemistry because their teacher used hands-on methods to teach the subject; 88.5 % either disagreed or were undecided. Nine (26.2 %) of the respondents wished to take chemistry at higher levels of education. Twenty (58.8 %) were undecided whiles the remaining five (15 %) disagreed. Also, close to two-thirds of the respondents (64.7 %) thought chemistry concepts were difficult to comprehend. However, when the same questionnaire was administered after the intervention was concluded, twenty-seven (79.4 %) respondents reported that they enjoyed chemistry because their teacher used hands-on methods to teach the subject, three (8.8 %) thought otherwise while the remaining 4 (11.8 %) were indecisive. Additionally, twenty-six (76.4 %) respondents indicated that they liked chemistry because of positive guidance from the teacher. Again, four (11.8 %) were undecided. Only two (6 %) respondents accepted that chemistry concepts are difficult to comprehend; 94 % of them either disagreed or were undecided. Further to that, some three-fifths of the respondents reported that they would like to take chemistry-related careers at a higher level of education compared to nine before the intervention.

5.2.2 Effect of hands-on activity on the levels of skill performance among students in chemistry

The descriptive statistics of pre-test scores revealed that students obtained lower mean scores before the application of hands-on activity. The mean score on the post-intervention test, when taught with hands-on activity (M=20.4, SD=6), was substantially greater than the mean obtained on the pre-intervention test (M=10, SD=4.5). The t-test analysis revealed that there was a statistically significant difference between the pre-test mean score and the post-test mean score ($p = 0.00$) thus the null hypothesis stating that there is no statistically significant difference between the performance of students on the pre-and post-intervention tests was rejected. Additionally, a large effect size ($\Theta = 1.78$) was reported, suggesting that the use of a hands-on activity to teach process skills in chemistry is practically effective.

5.2.3 Impact of the hands-on activity on the retention ability of students in chemistry

This study's findings showed a significant difference between the means of the retention test scores and the pre-test scores, but not the post-test scores ($F = 51.449$, $p = 0.000$). However, the retention test mean score ($M = 20.7$) was slightly higher than that for the post-test ($M = 20.4$). This implied that the use of a hands-on activity to teach chemistry significantly impacted students' knowledge retention. Thus, $\mathbf{H_{o2}}$ stating that the mean scores of students on the pre-intervention test, the post-intervention test and the retention test are equal was rejected.

Table 10: Summary of Hypotheses Testing

Hypothesis	Test Statistic	P-value	Alpha Level	Decision
H_{o1}: There is no statistically significant difference between the performance of students on the pre- and post-intervention tests	t = -10.92	0.00	0.05	Rejected
H_{o2}: The mean scores of students on the pre-intervention test, the post-intervention test and the retention test are equal	F = 51.449	0.00	0.05	Rejected

See Appendices B&C for full tables

5.3 Conclusions

Based on the findings of this study, the following main conclusions were drawn:

From the pre-testing findings, it was evident that the administration of pre-tests to the students did not interact significantly with the intervention. Therefore, greater scores in chemistry and process skills by the students on the post-test were not a result of the effect of pre-tests but a result of the effect of the intervention (hands-on activity).

Firstly, the findings showed that students, after being exposed to the hands-on activity method achieved higher test scores than they did before the intervention. Therefore, the study concludes that the use of hands-on activity instruction improves students' achievement in Chemistry as it stimulates memory for better coding and understanding of concepts. Thus, hands-on activity is a very crucial tool needed for the successful teaching and learning of chemistry.

Secondly, the findings of the study showed that the mean scores of the students on the retention test were significantly greater than that of the pre-intervention test and slightly higher than the mean score obtained on the post-intervention test when they were taught with hands-on activity instructional methods. The study, therefore, concludes that the use of hands-on activity in chemistry enhances students' knowledge retention ability. Hands-on activity seemed to capitalize on students' active participation in the course material or concepts learned. It also follows that hands-on activity produced a dual outcome of improving both academic achievement and attitudes toward chemistry. This is a particularly impressive instructional strategy, and worth adopting by chemistry teachers.

Regarding the attitudes of students toward chemistry, the findings revealed that hands-on activity caused the respondents of this study to show more positive attitudes toward the teaching and learning of chemistry. This study hence concludes that the hands-on activity instructional method is a potent instructional method that can be espoused by chemistry teachers to enhance the attitudes of their students toward the teaching and learning of chemistry.

5.4 Recommendations

Based on the findings and conclusions of this study, some classroom-based recommendations, policy recommendations for various stakeholders and recommendations for further research have been suggested hereunder. These are provided in the subsequent sections 5.4.1, 5.4.2 and 5.4.3.

5.4.1 Classroom-based recommendations

Chemistry teachers should be encouraged to use hands-on activity instructional methods in their teaching to improve students' performance, attitudes and process skills and knowledge retention in chemistry which has remained low for decades. Chemistry teachers should ensure that they expose their students to more activities to help improve their mastery of process skills in chemistry and thus, improve their performance in the subject.

5.4.2 Recommendations for policymakers

i. The Ministry of Education, through the District Education Directorates, should allocate more time for in-service training of chemistry teachers on the integration of hands-on activity to empower them, thus, enabling its application in the classroom. Currently, teachers are given in-service training only occasionally which may not be sufficient for them to acquire the essential skills. Additional time should be created for training during each school semester.

ii. Teacher training institutions such as colleges and universities should emphasise hands-on activity instructional methods as part of their chemistry training curriculum. Chemistry teacher trainees should be subjected to external assessment on the use of hands-on activity instructional methods during their teaching internship programme (TIP).

iii. The Government of Ghana, through the District Education Directorates should provide adequate instructional materials and infrastructure, including computer hardware and software in all schools.

iv. School administrators should endeavour to provide an enabling environment for the use of hands-on activity. This they can do by either providing or expanding existing resources or facilities in schools to help foster enhanced activity-based learning. They should also provide incentives to motivate chemistry teachers to empower them to better use hands-on activities in their teaching and learning events.

5.4.3 Recommendations for further research

i. This study established that the hands-on activity instructional approach proved potent in enhancing academic performance, attitudes and knowledge retention in chemistry. Future research should consider the differential effect of the hands-on activity instructional approach on the academic performance and knowledge retention of male and female students in chemistry.

ii. Longitudinal research is recommended that might be useful to investigate the effect of hands-on activity instruction on students' achievement, self-efficacy and collaborative skills for an extended period.

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APPENDIX A

QUESTIONNAIRE FOR STUDENTS

The purpose of this questionnaire is to collect data to answer a research question on your attitude towards the teaching and learning of chemistry. The researcher assures you that the information gathered will be treated with utmost confidentiality and for academic purposes only. Do not write your name anywhere in this questionnaire. Please tick (√) where appropriate or fill in the required information as guided.

Section I: Background Data

1. Please indicate your gender
   Male [ ]
   Female [ ]

2. Indicate your age group
   11 – 15 [ ]
   16 – 20 [ ]
   20 and Over [ ]

3. Your level
   Form one [ ]
   Form two [ ]
   Form three [ ]

4. Your residential status
   Day [ ]
   Boarder [ ]

Indicate by ticking (√) the extent to which you agree with the following statements.

Statement	Agree	Undecided	Disagree
I like chemistry very much.			
I like Chemistry because of positive guidance from my chemistry teacher.			
Concepts in chemistry are difficult to understand.			
I enjoy doing chemistry because my teacher uses interesting and hands-on methodology to teach the subject.			
I do chemistry only to prepare for my future career.			
I would like to take chemistry related career at higher level of education.			

APPENDIX B

T-TEST RESULTS

	Pre-Intervention Test	Post-Intervention Test
Mean	9.717948718	20.41025641
Variance	20.57624831	36.14304993
Observations	34	34
Pearson Correlation	0.355609627	
Hypothesized Mean Difference	0	
Df	33	
t Stat	-10.92975232	
P(T<=t) one-tail	1.36278E-13	
t Critical one-tail	1.68595446	
P(T<=t) two-tail	2.72555E-13	
t Critical two-tail	2.024394164	

APPENDIX C

ANOVA TABLE

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3045.452991	2	1522.726496	51.4495615	1.19366E-16	3.075853
Within Groups	3374	114	29.59649123			
Total	**6419.452991**	**116**				

APPENDIX D

DESCRIPTIVE STATISTICS

	Pre-Intervention Test	Post-Intervention Test	Retention test
Mean	9.717948718	20.41025641	20.66666667
Standard Error	0.726358115	0.96267589	0.906814309
Median	10	19	19
Mode	11	15	19
Standard Deviation	4.536104972	6.011909009	5.663053544
Sample Variance	20.57624831	36.14304993	32.07017544
Kurtosis	-0.000393957	-1.110335596	-1.151503323
Skewness	0.459296945	0.130582694	0.361225858
Range	19	20	18
Minimum	3	10	12
Maximum	22	30	30
Sum	379	796	806
Count	34	34	34
Confidence Level(95.0%)	1.470435128	1.948835454	1.835749595
effect size =	1.778521211		

APPENDIX E

TEST RESULTS

Pre-Intervention Test	Post-Intervention Test	Retention Test
6	20	29
5	13	26
5	24	17
12	27	25
9	24	18
9	25	17
9	28	20
10	26	19
11	15	24
11	17	21
11	17	27
11	17	26
12	26	26
12	18	28
13	19	29
14	19	30
16	19	29
18	19	30
22	21	30
11	23	25
10	23	20
6	23	22
7	25	19
7	25	19
8	25	19
10	26	26
10	26	21
11	29	27
11	29	23
12	29	25
14	29	15
14	30	26
16	30	30
16	30	28