EFFECTS OF PREDICT-EXPLAIN-OBSERVE-EXPLAIN AND VEE HEURISTIC STRATEGIES ON STUDENTS' ACHIEVEMENT, METACOGNITIVE AWARENESS AND SELF-EFFICACY BELIEF IN ORGANIC CHEMISTRY IN EKITI STATE, NIGERIA

BY

OLUWATOSIN VICTOR AJAYI
BSU/ED/CUT/PhD/16/4257

A THESIS SUBMITTED TO POSTGRADUATE SCHOOL, BENUE STATE UNIVERSITY, MAKURDI IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (PhD) SCIENCE EDUCATION

DECEMBER, 2019

CERTIFICATION

We certify that this thesis titled “Effects of Predict-Explain-Observe-Explain and Vee Heuristic Strategies on Students’ Achievement, Metacognitive Awareness and Self-Efficacy Belief in Organic Chemistry in Ekiti State, Nigeria” has been duly presented by Oluwatosin Victor Ajayi (BSU/ED/CUT/PhD/16/4257) of the Department of Science and Mathematics Education, Faculty of Education, Benue State University, Makurdi and has been approved by the Examiners.

1st SUPERVISOR

Signature …………………………..
Professor Emmanuel Edoja Achor
Date…………………………………

HEAD OF DEPARTMENT

Signature………………………….
Professor Emmanuel Edoja Achor
Date……………………………….

2nd SUPERVISOR

Signature …………………………..
Professor Emmanuel Eriba Otor
Date…………………………………

Having met the stipulated requirements, the thesis has been accepted by postgraduate school.

……….…………………………….

Professor Toryina Ayati Varvar

Dean

Postgraduate School

……………………………………..

Date

DEDICATION

This thesis is dedicated to the Almighty God, the Alpha and the Omega who gave me the divine grace to complete the study.

ACKNOWLEDGEMENTS

To God be the glory, honour and adoration for preserving my life and more still for His special grace and strength showered on me right from the beginning to a successful end. It has been a good fortune to have the expert advice and guidance of many talented people whose knowledge and skills have enhanced this work in many ways. Their contributions are diverse. For their invaluable help, I wish to sincerely appreciate the immense contributions of my supervisors, Professor Emmanuel Edoja Achor and Professor Emmanuel Eriba Otor; whose inspiration and tireless work in spite of their tight schedules ensured the continued high quality of this work. They deserve much credit for the improvement that has resulted.

My profound gratitude goes to the Head of Department of Science and Mathematics Education, Professor Emmanuel Edoja Achor. My appreciation also goes to Professor (Mrs.) Yetunde Elizabeth Gyuse, Professor Clement Onyeke Abah, Professor Joel Obo Eriba, Professor Peter Ogbu Agogo, Professor (Mrs.) Regina Marita Onabid Samba, Professor Josiah Ogbeba, Professor Nicholas Akise Ada, Professor Chinwe Anthonia Muodumogu, Professor John Iorhemen Kyeleve, Professor Emmanuel Ijenkeli O'kwu, Professor Linus Iorember Zaria, Dr. Comfort Ojela Odoh, Dr. Titus Terver Udu, Dr. Michael Vershima Atovigba, Dr. Jerry Ebere Omenka, Dr. Benjamin Iortwam Imoko, Dr. Catherine Enayi Ochogwu, Dr.Virginia Omada Alachi, Dr. Solomon Ogebe Aligba, Dr. Maria Seraphina Kurumeh and all other lecturers in the Department of Mathematics and Science Education and Department of Art and Social Science Education respectively for preparing me for the task I have undertaken successfully. I wish to thank Professor Peter Ogbu Agogo and Dr. Solomon Ogebe Aligba who responded to this work at proposal stage. I wish to also thank Professor Nicholas Akise Ada and Professor (Mrs.) Regina Marita Onabid Samba who responded to this work at post-field stage. I acknowledge the effort of Professor Musa James Adejoh who was my external examiner.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

This research investigated the effects of Predict-Explain-Observe-Explain (PEOE) and Vee Heuristic (VH) strategies on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry in Ekiti State, Nigeria. The moderating effect of gender was also investigated. The study adopted a pretest, posttest, control group, quasi-experimental research design. The instruments used for data collection were Organic Chemistry Achievement Test (OCAT), Metacognitive Awareness Inventory (MAI) and Organic Chemistry Self-Efficacy Belief Scale (OCSEBS). Kuder-Richardson (KR-21) formula was used to test internal consistency of OCAT which yielded a reliability value of 0.94. Cronbach Alpha was used to ascertain the reliability index of MAI and OCSEBS respectively which gave reliability values of 0.84 and 0.86 respectively. The target population was 14,753 Senor Secondary II students offering chemistry in the study area. A sample of 308 students (Male=174 and female=134) drawn from 9 schools within the 9 Local Government Areas (LGA) out of 16 LGA in the Ekiti State, Nigeria was selected using multi-stage sampling techniques. Twelve research questions and twelve null hypotheses guided the study. The research questions were answered using Mean and Standard Deviation scores while the null hypotheses were tested at 0.05 level of significance using results from Analysis of Covariance (ANCOVA). The study revealed that there was significant difference in the mean achievement scores of students taught Organic Chemistry using PEOE, VH strategy and discussion method [$F_{2, 307}$=255.284, P<0.05]. It was found that there was no significant difference between the mean achievement of male and female students taught Organic Chemistry using PEOE strategy [$F_{1, 103}$ =.665, P>0.05] and VH strategy [$F_{1, 100}$ =.420, P>0.05]. The study revealed that there was significant difference in the mean metacognitive awareness scores of students taught Organic Chemistry using PEOE strategy, VH strategy and discussion method [$F_{2, 307}$=3742.616, P<0.05]. It was found that there was no significant difference between the mean metacognitive awareness of male and female students taught Organic Chemistry using PEOE strategy [$F_{1, 103}$ =.874, P>0.050] and VH strategy [$F_{1, 100}$ =.705, P>0.050]. The study revealed that there was significant difference in the mean self-efficacy belief scores of students taught Organic Chemistry using PEOE strategy, VH strategy and discussion method [$F_{2, 307}$=2953.260, P<0.05]. It was found that there was no significant difference between the mean self-efficacy belief of male and female students taught Organic Chemistry using PEOE strategy [$F_{1, 103}$ =.817, P>0.050] and VH strategy [$F_{1, 100}$ =.101, P>0.050]. It was recommended among others that since PEOE and VH strategies were found to be effective strategies for improving students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry; Chemistry teacher's trainee should be trained on the use of PEOE and VH strategies and serving teachers should use it. The curriculum developers should use PEOE and VH strategies to develop and refine the Chemistry curriculum in general and Organic Chemistry in particular.

CHAPTER ONE
INTRODUCTION

1.1 Background to the Study

Nations that are considered to be developed and largely considered as civilized have achieved that status through purposeful scientific education of their citizens. In cognizance with the importance of science and technology in Nigeria, science subject such as Chemistry is taught in secondary schools to prepare a base for meaningful scientific and technological development (Akinsola, 2011). Chemistry is an experimental science that systematically studies the composition, properties and activities of organic and inorganic substances and various elementary forms of matter (Senese, 2013). Organic Chemistry which is the main focus of this study is the Chemistry of hydrocarbon and its derivatives. It has been found very useful in different fields of science and technology. It is utilized in petrochemical industries, beverage and alcohol processing production. Chemistry is a very important subject as its knowledge is required for the successful study in many important professions. Chemistry occupies a pride of place in the senior secondary school curriculum.

The specific objectives to be achieved for Chemistry in the curriculum as stated in the report of Nigerian Educational Research and Development Council, (NERDC, 2012) includes: providing the students with basic knowledge in chemical concepts and principles through efficient selection of content sequencing; showing inter-relationships between Chemistry and other science subjects; and providing a reasonable and adequate foundation for a post-secondary school Chemistry course. It is therefore necessary that students studying Chemistry should understand the subject so that they can apply the knowledge to everyday interactions with people and the ever changing environment. Despite the importance of the knowledge of Chemistry to the society and the efforts of researchers to improve on its teaching and learning, the achievement of students in Chemistry as measured by their scores in Senior Secondary School Certificate Examinations has been very poor in Nigeria.

The poor achievement is attested to in the Chemistry result of students in Nigeria and Ekiti State in particular in the West African Senior Secondary School Certificate Examinations (WASSCE) May/June, 2009 to 2018 (Appendices B, p.166 & C, p.167) and National Examinations Council (NECO) Senior Secondary Certificate Examinations June/July, 2009 to 2018 (Appendices D, p.168 & E, p.169). However, the West African Examination Council (WAEC) Chief Examiners' report (2016/2017) on Chemistry result indicates that students are weak in Organic Chemistry concept such as hydrocarbon, isomerism, alkanes, alkenes, alkynes, benzene, alkanols, alkanoic acids, alkanoates (esters), fat and oil, and classification of nomenclature of organic compound, due to the fact that candidates do not familiarize themselves with the required syllabus; teachers do not emphasize on areas of the syllabus where candidates appear to be weak such as Organic Chemistry; and teachers do not employ effective instructional methods (Appendix F).

The poor achievement of students in Chemistry has affected the educational pursuits and aborted the ambition of many candidates who aspire to study professional courses such as Medicine, Pharmacy and Chemistry. Consequently, the effective teaching and learning of Chemistry has become an issue of concern to Chemistry educators. A good number of research efforts have been made to diagnose the problems associated with the teaching of Chemistry in order to proffer solution that could lead to higher achievement. Studies by Usman (2011), Olorunyomi (2013) and Ajayi (2016) revealed students background problems, negative attitude towards Chemistry and teacher related factors such as poor teaching methods as some of the factors that could also hinder students' achievement in Chemistry.

Chemistry teachers have used a number of teaching strategies in the past. Such methods are demonstration, lecture, expository, question and discussion methods. Studies have shown that these methods have not yielded expected results (Inomesia & Unuero, 2012; Otor, 2013). Adeyemi (2014) and Haruna (2016) investigated the causes of students' poor achievement in SSCE Organic Chemistry concepts. The findings of these authors revealed that the ineffective teaching methods such as lecture and discussion method employed by secondary school Chemistry teachers are the most recurring causes of students' poor achievement. Similarly, Adedayo (2015) noted that discussion method is popular in teaching/learning of Chemistry in secondary schools in Nigeria. Discussion teaching method is the collaborative exchange of ideas among a teacher and students or among students for the purpose of furthering students thinking, problem solving, and understanding (Wilkinson, 2016). Adedayo (2015) further added that discussion method has received a lot of criticisms from different scholars such as Archibong (2012) and Olorundare (2014).

The scholars noted that discussion method may degenerate into mere talk and may be monopolized by few individuals. This may consequently lead to a conclusion far from the truth even though such may be accepted by the group as a whole. These has led to teachers not exposing the students to meaningful learning and this at the same time has made students to perceive Chemistry as abstract and difficult concepts to understand. In the long run, learners often resort to memorizing the concepts without meaningful learning taking place. Consequently, Chemistry teaching can only be result oriented when students are willing and the teachers are favourably disposed to using appropriate strategies and considering the fast speed of change and innovation in knowledge, being socially and mentally active learners, being learners who are aware of their own cognition and develop critical thinking and metacognitive awareness seems necessary (Cihanoglu, 2012).

Awareness and understanding of the process of learning help an individual to take control of one's learning (Gassner, 2009). Becoming aware of what happens in one's mind and one's thinking process may help individuals to have more control over their cognitive process and lead it toward being more effective. This assertion calls for the need to find innovative strategies such as Predict-Explain-Observe-Explain (PEOE) and Vee Heuristic (VH) instructional strategies that have the potentials to equip learners to think about their cognition, monitor their learning activities and evaluate the results of these activities and thereby enhancing their conceptual understanding of scientific knowledge and problem solving abilities. Learning is a personal and unique experience that differs from individual to individual and it can be enhanced by collaborative learning (Cicognani, 2011). Currently, PEOE and VH instructional strategies have been integrated into collaborative learning activities to facilitate productive collaborative learning and artifacts. Collaborative knowledge building is a central issue in the field of collaborative learning. Collaborative learning is an umbrella for a variety of educational strategies involving joint efforts by both teachers and learners.

The technique of Predict-Explain-Observe-Explain (PEOE) was modified from Predict-Observe-Explain (POE) by Rickey and Stacey (2015) to emphasize that the students need to explain their predictions to make their beliefs explicit. POE is a strategy which involves learners in writing down their predictions before doing the activity and the predictions are then followed by an activity in which learners observe their predictions and acclaim on whether or not their predictions were correct or incorrect. Chris (2016) also presented a template of PEOE with a space for explanation of students' prediction. Students should know that their beliefs are important. PEOE is named to emphasize the importance of students' explanation. Rickey and Stacey (2015) explain that, PEOE is an instructional strategy where learner make predictions for an event and explain the reasons for his predictions, then conduct and observe a laboratory experiment and are required to compare his observations with his predictions in order to monitor his learning activities, thereby enhancing conceptual understanding of scientific knowledge and problem solving abilities.

A Vee heuristic diagram is a V-shaped diagram showing the relationships between conceptual or theoretical and methodological framework and the resultant knowledge or value claims of a concept. Vee Heuristic (VH) strategy is the process of creating a V-shaped diagram to represent key elements (ideas) that are contained in the structure of knowledge with two sides namely the theoretical or conceptual side (thinking side) on the left and methodological side (doing side) on the right in order to enhance conceptual understanding of scientific knowledge (Gowin, 2010). Vee Heuristic strategy is a tool that helps in seeing the interplay between what is known and what needs to be known or understood. The Vee heuristic diagram has two sides; The left hand side represents the philosophy, theories, principles and concepts that guide learners in selecting or constructing objects or event and the right hand side highlights the knowledge and value claims as well as data recording and transforming procedures and placed in the middle of the Vee heuristic diagram is the focus question and events or objects to be observed in the learning process. Metacognition awareness is often thought of as thinking about thinking (Schraw, 2012).

Metacognitive awareness refers to the knowledge and control of cognitive processes. In other words, it is the knowledge about cognition and control of cognition. Metacognitive awareness is not only thinking about thinking, but also regulating and executing cognition (Coutinho, 2014). Metacognitive awareness can be viewed as thought about one's own thoughts and cognitions. Metacognition awareness is generally further grouped into two aspects namely knowledge of cognition and the regulation of cognition (Bruning, Schraw, & Ronning, 2012). Knowledge of cognition has been defined as knowledge that has been memorized regarding the goals and strategies of individuals in their efforts to accomplish tasks (Desoete & Veenman, 2011). Knowledge of cognition can further be thought of as involving declarative, procedural, and conditional types of knowledge (Schraw & Moshman, 2012). Metacognitive regulation or regulation of cognition refers to activities that control one's thinking and learning. Regulation of cognition contains three regulatory skills such as planning, monitoring comprehension and evaluation (Çetin, 2015).

Schraw (2013) revealed that learners who are aware of their metacognition perform better than unaware learners. The author recognized high metacognitive awareness as an indicator of better performance since it allows learners to plan, sequence, and regulate their learning in a way that improve performance. Consequently, Olorundare (2015) revealed that students' low metacognitive awareness is often attributed to poor teaching methods such as lecture and discussion methods adopted by teachers. Thus, the teacher's role is to carefully plan and use innovative teaching strategies that will train students to be consciously aware about their own thinking and teach them how to regulate it to ensure that they become more responsible in developing their own learning. Developing lessons that enhance students' participation and metacognition when engaging in Organic Chemistry activities are anticipated to uplift metacognitive awareness.

According to Bandura (2012), self-efficacy belief is one's trust about one's capability to successfully accomplish a task. Self-efficacy belief is learner's belief or reliance about his/her abilities to perform better in a learning environment. Self-efficacy belief determines how people feel, think, motivate in themselves and behave. By implication, self-efficacy belief is people's judgment about their ability to organize and carry out some behaviour in order to reach predetermined goals or self-efficacy belief is related to the way students judge their academic competence. Expectations of self-efficacy belief would be effective in actual performance, emotions, behaviour and, ultimately the amount of effort spent on an activity. Individuals with low self-efficacy belief are pessimist about their abilities; hence they avoid situations deemed beyond their abilities. Conversely, people with high self-efficacy belief consider difficult tasks as challenges which they can overcome. These individuals choose challenging tasks, recover their self-efficacy faster, and keep on trying in spite of difficulties.

Self-efficacy belief shows how confident a student is about performing specific task (Joanne & Shui-fong, 2012). For instance, high self-efficacy belief in Mathematics does not necessary translate to high self-efficacy belief in Chemistry. According to Ahmed (2016), student's low self-efficacy belief that he or she has the ability needed to complete the cognitive-ability test or task has also been attributed to the ineffective teaching methods such as discussion method adopted by teachers. Hence, developing lessons using innovative strategies that involve students' active participation when engaging in Organic Chemistry activities are anticipated to uplift self-efficacy belief. Predict-Explain-Observe-Explain (PEOE) and Vee heuristic (VH) strategies are associated with meaningful and mastery learning. They enable students to identify the major concepts and relate them to the concepts in their existing knowledge structure (Kinchin, 2013). The learner therefore plays an active role in knowledge construction, which leads to meaningful learning. Pajares and Schunk (2012) and Gassner (2015) noted that individuals with low self-efficacy beliefs tend to avoid tasks that they think or believe they do not have the capabilities to accomplish those specific tasks.

Gender issues in the learning process have continued to engage the interest of researchers in Chemistry because of the influence it exerts on Chemistry learning. Gender inequality in Chemistry in general has remained a perennial problem of global scope. The differences between boys and girls in relation to Chemistry achievement have received a lot of attention in recent years. Some studies indicate that boys achieve better (Gipps, 2014; Kingdon, 2015), either no difference (Achor, Wude, & Duguryil, 2013; Ventura, 2013; Calsambis, 2014; Ajayi & Ogbeba, 2017) or girls outperform boys (Calsambis, 2013; Soyibo, 2014) have been demonstrated. Studies on gender differences in Chemistry achievement continued to yield inconsistent results and it has usually been attributed to unequal exposure of males and females to learning instructions relevant to Chemistry learning.

1.2 Statement of the Problem

Chemistry being a core science subject at the senior secondary school level of education is expected to serve as a base for scientific and technological knowledge that will enable the child to fit into the scientifically and technologically progressive society. A good number of students who offer science and science related courses in higher institutions are expected to pass Chemistry at credit level and above. Despite this expectation, poor achievement in Chemistry by students appears to have persisted. The high rates of failure recorded by students offering Chemistry in senior secondary schools in Nigeria have been a major concern to researchers in recent time. Consequently, the poor achievement in Chemistry in external examinations such as Senior Secondary Certificate Examination (SSCE) conducted by West Africa Examination Council (WAEC) and National Examination Council (NECO) and students' low level of metacognitive awareness and self-efficacy belief appears to have persisted which is often blamed on poor teaching methods.

Poor strategy to teaching invariably translates to students' poor achievement, low level of metacognitive awareness and self-efficacy belief. Most Nigerian Chemistry teachers use discussion method most frequently in their classrooms which has not yielded expected results. Consequently, the poor achievement of students in Chemistry could lead to poor enrolment, students' dropout and could also abort the ambition of many candidates who aspire to study professional courses in higher institutions. Therefore, the nation's quest for science and technological advancement will become a mirage, if effective modality is not put in place to incorporate innovative methods that promote meaningful learning and considering the importance of Chemistry in all round development, there is need to ensure that Chemistry is properly taught most especially the difficult concepts such as Organic Chemistry using innovative strategies in order to enhance students' academic achievement, metacognitive awareness and self-efficacy belief. In the same vein, research reports advocate the use of self-learning strategies, as a way of enhancing students' learning outcome. Therefore, this study investigated the effects of Predict-Explain-Observe-Explain (PEOE) and Vee Heuristic (VH) instructional strategies on Senior Secondary Students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry in Ekiti State, Nigeria.

1.3 Purpose of the Study

The purpose of this study was to investigate the effects of Predict-Explain-Observe-Explain (PEOE) and Vee Heuristic (VH) instructional strategies on Senior Secondary Students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry in Ekiti State, Nigeria. Specifically, the study set out to:

1. Determine the effects of PEOE strategy, VH strategy and discussion method on students' achievement in Organic Chemistry.
2. Find out if there is any difference in the effect of PEOE strategy on male and female students' mean achievement scores in Organic Chemistry.
3. Determine the difference in the effect of VH strategy on male and female students' mean achievement scores in Organic Chemistry.
4. Ascertain the interaction effect of treatments and gender on students' achievement in Organic Chemistry.
5. Determine the effects of PEOE strategy, VH strategy and discussion method on students' metacognitive awareness in Organic Chemistry.
6. Find out if there is any difference in the effect of PEOE strategy on male and female students' mean metacognitive awareness scores in Organic Chemistry.

7. Determine the difference in the effect of VH strategy on male and female students' mean metacognitive awareness scores in Organic Chemistry.
8. Ascertain the interaction effects of treatments and gender on students' metacognitive awareness in Organic Chemistry.
9. Determine the effects of PEOE strategy, VH strategy and discussion method on students' self-efficacy belief in Organic Chemistry.
10. Find out if there is any difference in the effect of PEOE strategy on male and female students' mean self-efficacy belief scores in Organic Chemistry.
11. Determine the difference in the effect of VH strategy on male and female students' mean self-efficacy belief scores in Organic Chemistry.
12. Ascertain the interaction effect of treatments and gender on students' self-efficacy belief in Organic Chemistry.

1.4 Research Questions

The following research questions guided this study:

1. What are the mean achievement scores differences among students taught Organic Chemistry using PEOE strategy, VH strategy and discussion method?
2. What is the difference in the mean achievement scores between male and female students taught Organic Chemistry using PEOE strategy?
3. What is the difference in the mean achievement scores between male and female students taught Organic Chemistry using VH strategy?
4. What is the mean interaction effect of treatments and gender on students' achievement in Organic Chemistry?
5. What are the mean metacognitive awareness scores differences among students taught Organic Chemistry using PEOE strategy, VH strategy and discussion method?

6. What is the difference in the mean metacognitive awareness scores between male and female students taught Organic Chemistry using PEOE strategy?
7. What is the difference in the mean metacognitive awareness scores between male and female students taught Organic Chemistry using VH strategy?
8. What is the mean interaction effect of treatments and gender on students' metacognitive awareness in Organic Chemistry?
9. What are the mean self-efficacy belief scores differences among students taught Organic Chemistry using PEOE strategy, VH strategy and discussion method?
10. What is the difference in the mean self-efficacy belief scores between male and female students taught Organic Chemistry using PEOE strategy?
11. What is the difference in the mean self-efficacy belief scores between male and female students taught Organic Chemistry using VH strategy?
12. What is the mean interaction effect of treatments and gender on students' self-efficacy belief in Organic Chemistry?

1.5 Hypotheses

The following null hypotheses were tested at 0.05 level of significance:

1. There is no significant difference in the mean achievement scores of students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee heuristic (VH) strategy and discussion method.
2. The difference in the mean achievement scores of male and female students taught Organic Chemistry using PEOE strategy is not statistically significant
3. There is no significant difference between the mean achievement scores of male and female students taught Organic Chemistry using VH strategy
4. There is no significant interaction effect of treatments and gender on the mean achievement scores of students in Organic Chemistry.

5. There is no significant difference in the mean metacognitive awareness scores of students taught Organic Chemistry using PEOE strategy, VH strategy and discussion method.
6. There is no significant difference between the mean metacognitive awareness scores of male and female students taught Organic Chemistry using PEOE strategy
7. The difference in the mean metacognitive awareness scores of male and female students taught Organic Chemistry using VH strategy is not statistically significant
8. There is no significant interaction effect of treatments and gender on the mean metacognitive awareness scores of students in Organic Chemistry.
9. The difference in the mean self-efficacy belief scores of students taught Organic Chemistry using PEOE strategy, VH strategy and discussion method is not statistically significant.
10. There is no significant difference between the mean self-efficacy belief scores of male and female students taught Organic Chemistry using PEOE strategy
11. The difference in the mean self-efficacy belief scores of male and female students taught Organic Chemistry using VH strategy is not statistically significant
12. There is no significant interaction effect of treatments and gender on the mean self-efficacy belief scores of students in Organic Chemistry.

1.6 Significance of the Study

It is hoped that the findings of this study could encourage the use of Predict-Explain-Observe-Explain (PEOE) and Vee Heuristic (VH) instructional strategies during teaching/learning processes to enhance students’ achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry. Specifically, students, teachers, school authorities, educational administrators, prospective researchers, curriculum developers and authors of textbooks may stand to benefit from the findings of the study.

To the students, the findings of the study might reveal the problem solving nature of Predict-Explain-Observe-Explain (PEOE) and Vee Heuristic (VH) strategies which may help students in the organization of incoming information, build mental bridges between what was already known and what would be learnt and also the knowledge needed to accomplish task and control their thinking processes and also enhance their self-efficacy belief and achievement in Chemistry and Organic Chemistry in particular, especially in external examinations such as Senior Secondary School Certificate Examinations conducted by West African Examination Council (WAEC) and National Examination Council (NECO).

The findings of this study may create confidence in the teachers that the use of PEOE and Vee heuristic strategies are capable of enhancing students' achievement, metacognitive awareness and self-efficacy belief, thereby encouraging the teachers to carefully plan and use the teaching strategies to train students to be consciously aware about their own thinking and teach them how to regulate it to ensure that they become more responsible in developing their own learning with confidence and motivation. It is also hoped that the findings of this study may also give useful insights to the teachers on ways and means of enhancing Chemistry teaching and learning and such efforts may enhance students' achievement in external examinations.

To the school authorities, the findings of this study may make them to see the need to motivate and encourage their Chemistry teachers to engage the students in activities that involve knowledge construction such as Predict-Explain-Observe-Explain (PEOE) and Vee heuristic activities during class instructions. The findings of the study could encourage them to strive hard and make it a priority to furnish their Chemistry laboratory with standard equipment/materials where students could learn by doing. In the same vein, this could provide school authorities the opportunity for self-evaluation and necessary adjustment.

To the educational administrators, it is hoped that the findings may provide information with which educational administrators could use to organize seminars, conferences and workshops for Chemistry teachers on better strategies for teaching Chemistry effectively.

To the researchers, the findings of this study may be a frame work for further studies in related studies in Chemistry or other fields of study.

To the Curriculum developer, the findings may give further evidence for or against the use of Predict-Explain-Observe-Explain (PEOE) and Vee Heuristic (VH) strategies and would therefore provide basis for future work in curriculum development. To the authors of textbooks, this may lead to the writing of books that may assist teachers have adequate information on the use of PEOE and VH instructional strategies and popularize its use in Nigerian schools.

1.7 Scope of the Study

This research work investigated the effects of Predict-Explain-Observe-Explain (PEOE) and Vee Heuristic (VH) instructional strategies on senior secondary students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry in Ekiti State, Nigeria. Specifically, the study focused on only Senior Secondary two (SS2) students offering Chemistry, because it is the only class that have Organic Chemistry in details in their scheme of work. The study covered the following variables: the effects PEOE and VH strategies on male and female students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry.

The study covered six sub-topics under Organic Chemistry which includes alkanes, alkenes, alkynes, alkanols, alkanoic acids (carboxylic acids) and alkanoates (esters) selected from the Senior Secondary two (SS2) scheme of work. The choice of the sub-topics was to help students overcome the difficulties associated with self-efficacy belief, metacognitive awareness and achievement in Organic Chemistry as one of the areas that standout as problem areas to students offering Chemistry in the report by the Chief Examiner's for West African Examination Council (2015/2016; 2016/2017). The study area was restricted to Ekiti State, Nigeria. Ekiti State is made up of sixteen Local Government Areas and it is divided into three Zones; Ekiti North, Ekiti Central and Ekiti South with many institutions at all levels. The choice of Ekiti State for the study was premised on the fact that there was a scarcity of such studies on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) and Vee heuristic (VH) instructional strategies in Ekiti State, Nigeria.

1.8 Operational Definition of Terms

The terms used in this research are operationally defined as follows:

Predict-Explain-Observe-Explain (PEOE) Strategy: Is an instructional strategy where four or more Senior Secondary two (SS2) students in a small group setting make predictions for an event and explain the reasons for their predictions, then conduct and observe a laboratory experiment and are required to compare their observations with their predictions, thereby enhancing conceptual understanding of scientific knowledge in Organic Chemistry.

Vee Heuristic (VH) Strategy: Is an instructional strategy where four or more SS2 students in a small group setting are engaged in coordinated and sustained efforts in the creation of a V-shaped diagram to represent key elements (ideas) that are contained in the structure of knowledge with two sides namely the theoretical (thinking side) on the left and methodological (doing side) on the right in order to monitor their learning activities and evaluate the results of these activities, thereby enhancing conceptual understanding of scientific knowledge in Organic Chemistry.

Achievement: This is the learning outcome or attainment of SS2 students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) and Vee heuristic (VH) strategies as expressed in scores in this study.

Metacognitive Awareness: Is SS2 students' knowledge about their capability to accomplish Organic Chemistry task and control their thinking processes using Predict-Explain-Observe-Explain (PEOE) and Vee Heuristic (VH) strategies as expressed in scores in this study.

Self-Efficacy Belief: Is SS2 students' confidence or trust about their ability to solve Organic Chemistry related problems using Predict-Explain-Observe-Explain (PEOE) and Vee Heuristic (VH) strategies as expressed in scores in this study.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Introduction

Relevant literatures are reviewed here under four major sub-headings: theoretical and conceptual frameworks as well as empirical studies and summary. This section provides theories that anchor for the strategies employed in this work. Similarly, concepts related to this study are reviewed in relation to the topic.

2.2 Theoretical Framework

This section discusses the relevant theories that anchor this research. The theories discussed include: Ausubel's (1962) Assimilation Learning Theory, Piaget's (1965) Cognitive Development Theory, and Vygotsky's (1978) Social Development Theory.

2.2.1 Ausubel's (1962) Assimilation Learning theory

David Paul Ausubel is an American psychologist who's most significant contribution is in the fields of educational psychology, cognitive science, and science education. Ausubel developed his assimilation theory of learning in 1962. Ausubel believed that understanding concepts, principles, and ideas are achieved through deductive reasoning. The theory emphasizes that learning occurs through the assimilation of new concepts into existing concept frameworks held by the learner. Learning, according to Ausubel's theory, occurs through development of new cognitive structures that will hold newly acquired information.

Ausubel stressed that learning of new knowledge relies on what the learner has already known. That is, construction of knowledge begins with our observation and recognition of events and objects through concepts learners already have. Learners learn by constructing a network of concepts and adding to them. Similarly, he believed in the idea of meaningful learning as opposed to rote memorization. The theory stressed that, meaningful learning helps the learner to understanding the relationships between the objects in hierarchical manner because meaningful learning involves recognition of the links between concepts; it has the privilege of being transferred to long-term memory. The most crucial element in meaningful learning is how the new information is integrated into the old knowledge structure. Accordingly, Ausubel believes that knowledge is hierarchically organized; that new information is meaningful to the extent that it can be related (attached, anchored) to what is already known.

The theory is relevant to this present study, as it emphasizes that meaningful learning is essential for the development of cognitive structure. By implication, for information to be learnt it must be presented in a meaningful way. Teachers should implement events which facilitate meaningful learning. Thus, the instructional strategies used in this study represent the most recent application of Ausubel's meaningful learning strategy. In this context, the Predict-Explain-Observe-Explain (PEOE) strategy used in this study would help learners in the development of cognitive structure by organizing knowledge in a meaningful manner. For instance, each Organic Chemistry PEOE task is composed of different parts. Preliminary questions are presented to the students in which they make their own prediction. The task acknowledges the prior knowledge of the students by writing their explanation to the prediction. Then, they perform the experimentation and write their observation. Finally, they compare their prediction with the data they have gathered. In the same vein, they are allowed to share their ideas with other groups with the supervision of the teacher. This is to reconcile contradiction between what they predicted and what they observed, thereby facilitating meaningful learning.

The concept of Vee heuristic (VH) instructional strategy is also founded on the principles of Ausubel's meaningful learning strategy as such it is relevant to this study. VH instructional strategy used in this study also helps students to understand the structure and process of knowledge construction by linking conceptual framework to the methodological framework of a concept thereby resulting to meaningful learning. For instance, each Organic Chemistry VH task is composed of thinking and doing frameworks. On the thinking side of the Vee diagram, students write down what they already know about a focus question under investigation and on the doing side of the Vee diagram, students write down what they observe after experimentation. Then, reconcile any contradiction between what they think and what they observed, thereby facilitating meaningful learning.

2.2.3 Piaget's (1965) Cognitive Development Theory

Cognitive development theory was propounded by Jean Piaget in 1965. Piaget produced a comprehensive theory of cognitive development which has impacted educational practice till date. Piaget was particularly concerned with the study of growth of knowledge within the individual. Initially, Piaget studied the intellectual growth of infants from the first day of life. He later investigated the importance of language and logic in cognitive development, as well as, the development of abstract and scientific reasoning. This enabled Piaget to advance the following stages of intellectual development: Sensory motor stage 0-2 years, pre-operations stage from 2-7 years, concrete operation stage from 7-11 years, and formal operation stage from 11-16 years. The entire stages of intellectual development will be not discussed, rather the area of concern that are relevant to this study which are concrete operational stage and formal operational stage are discussed.

(i) Concrete Operational Stage (7-11 years)

During this stage, logical reasoning capabilities emerge but are limited to concrete objects and events. In other words, children demonstrate logical, concrete reasoning. Children's mental representations remain concretely linked to things they have seen and touched throughout the middle childhood period because their representations are limited to the tangible, touchable and concrete, their appreciation of the consequences of events is similarly limited, local and concrete scope. In this Piagetian theory, it is not until children enter adolescence that they become capable of more abstract "formal" operations involving representations of things that are intangible and abstract. Piaget described multiple operations that children begin to matter in middle childhood, including conservation, decentration, reversibility, hierarchical classification, seriation and spatial reasoning. Concrete operational stage is relevant to this study because research reports reveal that many children will be at concrete operational stage even at adolescent age.

(ii) Formal Operational Stage (11-16 years)

This stage is relevant to the senior secondary school children, who are already in their adolescent/adult stage. This stage is the concern of the present study hence discussed fully here. The formal operational child is advanced in his thinking and is capable of engaging in abstract thought. He is able to think logically with abstractions or feelings. He engages in prepositional thinking and manipulation of idea without necessarily manipulating objects. He retains his previous attainment of concrete operational level and is able to reason not simply with concrete preposition but with verbal preposition.

The prepositional thinking helps the development of hypothetical procedures which are vital for the understanding of science, Chemistry inclusive. Formal operation thought, helps the child to go beyond the actual and deal with the possible. He can transfer reasoning patterns from one content to another, and engage in deductive reasoning from general to specific. He thinks about the past, present and is able to project into future events. The child becomes more introspective and self critical and analyses values and behaviour. Social interaction is well established in this stage. This therefore informed the choice of relating the formal operational stage to senior secondary level in this study.

According to Piaget, cognitive growth is relative, functional, dialectical and intrinsic. It is said to be relative because new information must be related to existing knowledge. That is, new information or concepts are always interpreted in terms of pre-existing knowledge in the schemata of the learner. Cognitive growth is functional in that the relevant and usable information that is needed for successful living in the environment is usually incorporated into the schema. It is dialectical because it results from opposing processes of assimilation and accommodation. Assimilation refers to the process of changing new knowledge or information to enable it fit into existing knowledge structure or schema of the learner. Accommodation has to do with changing of existing knowledge in order to incorporate incoming information. Cognitive growth is also intrinsic in that the child seeks the most useful information for his cognitive growth. Piaget plans that what happens in any teaching/learning situation is as follows:

(i) Any given information that is at variance with existing knowledge in the learner's schema or knowledge structure is not assimilated because it will not result in any cognitive growth.

(ii) If the information is similar to what the learner already knows, it will be taken in but will not result in cognitive growth.

(iii) Cognitive growth occurs only when incoming information is slightly more complex than the existing knowledge in the learner's schema. In such a case the learner assimilates and accommodates information through the process of equilibration. This result in the formation of a new cognitive structure which is capable of assimilating slightly more complex information than the previous schema.

The implication of this theory for science teaching is that teachers should be conscious of the developmental levels of their students and accordingly adopt instructions that will suit their capabilities. Although, most students in the senior secondary school (SSS) are expected to be in formal operational stage but concrete operational stage of intellectual development is also relevant to at stage because research reports reveal that many children will be at concrete operational stage even at adolescent age. In other words, children's mental representations remain concretely linked to things they see and touch even at adolescent age. Therefore, teachers should adopt instructions that will challenge students reasoning ability or thought processes, to enhance cognitive growth, as well as advance his thinking ability. In this regard, the instructions should be child-centered and activity oriented to engage students in appropriate manipulative skills, because according to Piaget, children learn more by doing. Cognitive growth at any point in time therefore depends on activity. Therefore, engaging students in activities such as predict-explain-observe-explain and Vee heuristic activities especially in collaborative settings provide the opportunity for social interaction and cognitive learning which are characteristic of formal operational stage.

The theory is relevant to this present study, as it emphasizes that learning by doing is essential for the development of cognitive structure. In this context, the Predict-Explain-Observe-Explain (PEOE) strategy used in this study would help learners in the development of cognitive structure through abstract thinking and concrete activities. For instance, each Organic Chemistry PEOE task exposed learners to abstract thinking through predict-explain and to concrete activities through observe-explain, thereby facilitating the development of cognitive structure. VH instructional strategy used in this study also help students to understand the structure and process of knowledge construction by linking conceptual framework (thinking) to the methodological framework (doing) of Organic Chemistry concepts thereby resulting to the development of cognitive structure.

2.2.4 Vygotsky's (1978) Social Development Theory

Vygotsky's social development theory is one of the foundations of social constructivism which argues that social interaction precedes educational development. Social development theory was propounded by Lev Vygotsky in 1978. Vygotsky propounded that children learn through interactions with their surroundings. Vygotsky's theory asserts three major themes:

(i) Social Interaction: Social interaction plays a fundamental role in the process of cognitive development. The theorist argues that the learner is much more actively involved in a joint enterprise with the teacher in creating or constructing new meaning if the learner is allowed to interact with his environment. Vygotsky argues that every function in the child's educational development appears twice: first, on the social level (inter-psychological), and later, on the individual level (intra-psychological). It emphasizes how meanings and understanding grow out of social encounters.

(ii) The More Knowledgeable Other (MKO): The MKO refers to anyone who has a better understanding or a higher ability level than the learner, with respect to a particular task, process, or concept. The MKO is normally thought of as being a teacher, coach, or older adult, but the MKO could also be peers, a younger person, or even computers.

(iii) The Zone of Proximal Development (ZPD): The ZPD is the distance between a student's ability to perform a task under adult guidance and/or with peer collaboration and the student's ability in solving the problem independently. According to Vygotsky, learning occurred in this zone.

Vygotsky focused on the connections between people and the socio-cultural context in which they act and interact in shared experiences. Vygotsky's theory promotes learning contexts in which students play an active role in learning. Role of the teacher and student are shifted, as a teacher collaborate with his or her students in order to help facilitate meaningful construction of knowledge by students. Learning therefore becomes a reciprocal experience for the students and teacher.

The theory is relevant to this present study, because Predict-Explain-Observe-Explain and Vee heuristic instructional strategies in collaborative setting has its base also in Vygotsky theory of social development. The theory emphasizes that for Chemistry instruction to be effective, teacher must plan activities that encompass not only what children are capable of doing on their own but what they can learn with the help of others (collaboratively). In this study, this is what PEOE and Vee heuristic instructional strategies implemented in a Chemistry classroom.

Predict-Explain-Observe-Explain (PEOE) instructional strategy makes use of Vygotsky's theory of social development theme of social interaction. Since, learning experiences are organized in PEOE instructional package such that interaction and collaboration is permitted. For instances, students are divides into groups to interact and collaboratively brainstorm to come out with group ideas. The theme of More Knowledgeable Other (MKO) is also employed either through the knowledgeable facilitator (teacher) or the students that form the groups. In the same vein, Vygotsky's concept of the zone of proximal development is also employed because learning experiences are organized in PEOE instructional package such that each member of the group is expected to independently answer questions and they are to compare individual answers and collectively brainstorm to come out with group answers.

Vee Heuristic (VH) instructional strategy also makes use of Vygotsky's theory of social development theme of social interaction. In this study, VH instructional package is integrated into collaborative learning. The themes of More Knowledgeable Other (MKO) and Zone of Proximal Development (ZPD) are also relevant. This theory is important to this study as teacher's knowledge about both MKO and ZPD of Vygotsky's themes are important in organizing classroom activities for individual or group of students in VH strategy.

2.3 Conceptual Framework

The conceptual framework is discussed under the following: Predict-Explain-Observe-Explain (PEOE) instructional strategy, Vee Heuristic (VH) instructional strategy, discussion method, collaborative learning, facilitating collaborative learning using PEOE and Vee heuristic instructional strategies, PEOE, Vee heuristic Instructional Strategies and Information Communication and Technology (ICT), Organic Chemistry, students' achievement in Chemistry, students' metacognitive awareness in Chemistry, students' self-efficacy belief in Chemistry, gender issues in Chemistry and interaction effect.

2.3.1 Predict-Explain-Observe-Explain (PEOE) Instructional Strategy

Predict-Explain-Observe-Explain **(**PEOE) strategy is used as an instructional strategy where learners are engaged in making predictions for an event and explain the reasons for their predictions, then observe a demonstration or conduct a laboratory experiment and are required to compare their observations with their predictions in order to monitor their learning activities and evaluate the results of these activities and thereby enhancing conceptual understanding of scientific knowledge. This strategy focuses on linking students to existing ideas and beliefs relevant to a situation and exploring the appropriateness of these ideas and beliefs (Rickey & Stacey, 2015).

The technique of Predict-Explain-Observe-Explain (PEOE) was modified from Predict-Observe-Explain (POE) by Rickey and Stacey (2015) to emphasize that the students need to explain their predictions to make their beliefs explicit. Meanwhile, Predict-Observe-Explain (POE) was originally modified from Demonstrate-Observe-Explain (DOE) by White and Gunstone (1992). Champagne, Klopfer and Anderson (1979) were the first to design this strategy as DOE to assess the understanding of first year physics students at the University of Pittsburg in 1979. DOE is about real-world situations or real-world experiences. The strategy involves formulating a question for prediction of the results of situation and then observing the effect of the change and explaining results. The advantage of DOE strategies includes a reduction in the quantity of verbal description and a reliance on open-ended questions which provide data to make inferences about students' conceptualizations (Champagne, Klopfer & Anderson, 1979).

White and Gunstone (1992) redesigned the Demonstrate-Observe-Explain (DOE) strategy and developed the first Predict-Observe-Explain (POE) strategy. The scholars used POE strategy to probe children's understanding of science concepts in elementary science. The scholars opine that in POE, the students must first predict the outcome of an event, describe their observation and then reconcile contradictions between what they predicted and what they observed. This was supported by Liew and Treagust (2010), Costu, Ayas and Niaz (2012), Mosca (2014) and Phanphech and Tanitteerapan (2017) who were able to note that POE is a strategy that lets the students explore concepts and generate investigation. Furthermore, the students are given the chance to express their schema and experience the science ideas behind the activity to satisfy their curiosity. The difference between Predict-Explain-Observe-Explain (PEOE) and POE is that students have to explain both after their prediction and again after their observation. The PEOE emphasizes on students' explanation.

Burçin (2013) opined that Predict-Observe-Explain (POE) is a strategy which involves learners in writing down their predictions before doing the activity and the predictions are then followed by an activity in which learners observe their predictions and acclaim on whether or not their predictions were correct or incorrect. POE is one of the learning strategies that explores the initial knowledge of the students and provides an opportunity for each student to play an active role in the learning process. In addition, the POE strategy refers to a constructivist strategy, in which the student will build knowledge in his own mind based on the direct experience encountered during the learning process (Kearney & young, 2011; Burçin, 2013). According to Hilario (2015), POE is one of the efficient strategies to create student discussions about the concept of science. This learning strategy involves students in predicting phenomena, performing observations through demonstrations, and finally explaining the results of their previous demonstrations and forecasts.

Hilario (2015, p.8), emphasized that Predict-Observe-Explain (POE) provides a step by step procedure to be followed during its application. Basically there are three phases which involves:

Phase 1: Predict

After presenting students with all the relevant background information, students predict what they think will happen next. It is important that they actually commit this to paper, so that they can't "wiggle out" of their prediction at a later stage if they find out they were wrong.

Phase 2: Observe

After prediction has been recorded, students observe what happens next. In a scientific experiment this may involve closely watching what happens and recording any key information such as measurements.

Phase 3: Explain

Explanation comes after observation, and it is here that students who have predicted wrongly need to wrestle with their internal assumptions that led them astray (these may be unconscious, and hence need drawing out first). For those who predicted correctly, they may still have had incorrect assumptions, so this is important to keep in mind (watch out for students with correct answers but low confidence).

According to Dalziel (2010, p.12), the role of the teacher when applying Predict-Observe-Explain (POE) in classroom includes:

Phase 1: The teacher needs to provide all the important background information about the experiment/situation so that students have the building blocks for a reasonable prediction. It is not fair to leave out critical details if these are central to making a prediction. Where you or your students are running a live experiment, you may need to provide safety advice and information about the equipment required.

Phase 2: It is important that students participate in the observation phase attentively. It can be a shame to ruin an otherwise great teaching moment through insufficient student attention at a critical moment, leading to them missing the whole point. If the experiment is very brief or the key event is easy to miss, you can draw students' attention to the essential aspect to observe, but this should only be done after their predictions are completed.

Phase 3: After observation, teacher facilitate a discussion where students attempt to understand their incorrect starting assumptions or theories, and try to construct new theories that better match the reality they have observed. Depending on the topic and any addition materials that the teacher provides at this stage, there may be little for the teacher to do other than guide the general discussion of students as they develop their new understanding; in other cases, you may need to help students articulate their initial misconceptions, and then help them piece together a new theory by drawing their attention to key observations.

Liew (2011) outlines some benefits of the Predict-Observe-Explain (POE) strategy as follows; it can be used to explore students' initial ideas; generating good discussions between students with students and students with teachers; provide motivation to students to investigate concepts that have not been understood; and awakening the students' curiosity to a litter.

Despite the benefits of Predict-Observe-Explain (POE), Rickey and Stacey (2015) emphasize that there is need for students' explanation for their prediction. The scholars opine that, this step (explanation for prediction) engages the metacognitive skill of assessing the students' certainty about an idea; and in cases where students make false predictions of which they were very confident, it teaches the important realisation that you can be wrong even when you are quite certain you are right. Predict-Explain-Observe-Explain (PEOE) is named to emphasize the importance of students' explanation. Chris (2016) presented a template of PEOE with a space for explanation of students' prediction. Students should know that their beliefs are important. PEOE is a teaching strategy that probes understanding by requiring students to carry out four tasks. Firstly, the students must predict the outcome of some event; and secondly, must explain their prediction; thirdly, they must observe an experiment and finally, they must explain their observation and also reconcile any conflict between prediction and observation.

Predict-Explain-Observe-Explain (PEOE) strategy is used as an instructional strategy where learners are engaged in making predictions for an event and explain the reasons for their predictions, then observe a demonstration or conduct a laboratory experiment and are required to compare their observations with their predictions in order to monitor their learning activities and evaluate the results of these activities and thereby enhancing conceptual understanding of scientific knowledge. This strategy focuses on linking students existing ideas and beliefs relevant to a situation and exploring the appropriateness of these ideas and beliefs (Rickey and Stacey, 2015).

Chris (2016, p.54) outlines some conditions that make Predict-Explain-Observe-Explain (PEOE) an effective instructional strategy as follows:

1. Asking students to predict first will make them to observe carefully.
2. Asking students to write down explanations for their prediction motivates them to want to know the answer.
3. Asking students to explain the reasons for their predictions gives the teacher indications of their theory or prior experience. This can be useful for uncovering misconceptions or developing understanding they have. It can provide information for making decisions about the subsequent learning

4. Explaining and evaluating their predictions and listening to others' predictions help students to begin evaluating their own learning and constructing new meanings.
5. Asking students to explain their predictions and observations and listening to others' predictions and observations help students to begin to reconcile any conflict between their predictions and observations and thereby enhancing their learning outcome.

Bajar-Sales, Avilla and Camacho (2015, p.9), opine that the Predict-Explain-Observe-Explain (PEOE) is done by requiring students to carry out four tasks as follows:

Predict (P):

In the Predict (P) step, information about an experiment or event is given to students and the students are supposed to predict the outcome of this event or situation. The prediction stage provides students an opportunity to focus on observation and it promotes motivation.

Explain (E):

They are expected to give explanation or reason for their prediction. In this step, the students' understanding and alternative conceptions are identified while they are discussing on their task.

Observe (O):

The students describe what they see in the Observe (O) step. This may be an experiment, an event or a video related to the learning issue. These activities should be easy for observation and they should constitute a conflict.

Explain (E):

In the Explain (E) step, the students inquire differences between their prediction and observation in order to reconcile any conflict between their prediction and observation. The students discuss and share their explanations. In this way, they do not repeat the knowledge in books; they can explain the phenomenon with their own sentences.

Learning is a personal and unique experience that differs from individual to individual and it can be enhanced by collaborative learning (Cicognani, 2011). Consequently, in this study, Predict-Explain-Observe-Explain (PEOE) is used as an instructional strategy where four or more learners in a small group setting are engaged in making predictions for an event and explain the reasons for their predictions, then conduct and observe a laboratory experiment and are required to compare their observations with their predictions in order to monitor their learning activities and evaluate the results of these activities and thereby enhancing conceptual understanding of scientific knowledge.

The researcher proposed a seven-step format for Predict-Explain-Observe-Explain (PEOE) instructional package in a collaborative setting as follows;

Step One: Introduction

Teacher Activity; Teacher to

- Arouse students' interest by making clear to the students the objectives of the day's study and making clear to them the importance of the subject matter and it relevance to daily life.
- Give the students a resume of what is to be taught, after asking them a few questions to probe into their prior knowledge, teacher then explains what the concept/ topic to be taught is all about.

Students' Activity; students

- Answer the questions orally.
- Students jot down some points as the teacher speaks. They are also allowed to ask questions

Step Two: Grouping/Elicitation of Students' Ideas

Teacher Activity; Teacher to

- Share students out into groups of four to seven depending on the class size

- Ask students to assume different roles
- A few minutes of full-class discussion will provide the students with the opportunity to reflect on their past experiences and understanding.

Students' Activity; Students to

- Move to their respective groups and assume their different roles viz: captain, recorder, timekeeper and so on
- Give responses to the questions based on prior knowledge.
- Jot down some points as the teacher speaks. They are also allowed to ask questions

Step Three: Introducing the Experiment

Teacher Activity; Teacher to

- Introduces the experiment. Linking it to the previous discussion will help make it meaningful.

Students' Activity; Students to

- Listen to the teacher and also jot down some points as the teacher speaks. They are also allowed to ask questions for clarification.

Step Four: Predict (P)

Teacher Activity;

- Before doing the experiment, ask a challenging question(s) that can be addressed through the experiment that follows.
- Ask each member of the group to write down their prediction to the question(s) asked on a piece of paper.
- Ask the students to write down their prediction(s) on the PEOE worksheet as agreed upon by the group.
- Goes round various groups to supervise the activities.

Students’ Activity;

- Each member of the group is expected to write out their prediction on a piece of paper.
- All members spread out their papers on a flat surface (desk), where it can easily be read. Have a look at each other’s predictions, and make quick comments.
- Then, the recorder for the group or whoever is assigned, write down their prediction(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet

Step Five: Explaining the Predictions (E)

Teacher Activity; Teacher

- Ask each member of the group to write down the explanation for their prediction to the question(s) asked on a piece of paper.
- Ask the students to write down the explanation for their prediction on the PEOE worksheet as agreed upon by the group. (This exercise is valuable for both the students and the teacher. Making their reasons explicit helps the students become more aware of their own thinking. It also provides the teacher with useful insights and an opportunity to plan ahead).
- While students are writing, you might stroll around so as to prepare yourself for the discussion that will follow.
- Then, ask each group to present their PEOE worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the PEOE worksheet only contains highlight of the predictions and explanations for each group). (This needs to be handled with sensitivity on account of some students’ feeling anxious about seeming “wrong”).
- After this has been done, you might invite the class to discuss which predictions and reasons or explanations they now think are best. (When students reconsider their reasons, some may begin to change their minds and reconstruct their thinking. Immediately prior to the experiment, it’s often fun and illuminating to have a straw vote about the outcome).

Students’ Activity; Students

- Each member of the group is expected to write out the explanation for their prediction on a piece of paper.
- All members spread out their papers on a flat surface (desk), where it can easily be read. Have a look at each other’s explanation for their predictions, and make quick comments.
- Then, the recorder for the group or whoever is assigned, write down the explanation for their prediction(s) as agreed upon by the group on the PEOE worksheet
- Team leaders or selected group representatives makes their respective presentations in full class discussion
- Students to share their PEOE worksheet containing both their predictions and the explanation for their predictions in full-class discussion

Step Six: Observe (O)

Teacher Activity; Teacher

- Ask the students to watch a demonstration or carryout a laboratory activities related to the questions asked in step three.
- Ask each member of the group to write down their observation from the experiment
- Ask the students to write down their observations on the PEOE worksheet as agreed upon by the group.
- Goes round various groups to supervise the activities.

Students’ Activity; Students

- Each member of the group is expected to write out their observation on a piece of paper.
- All members spread out their papers on a flat surface (desk), where it can easily be read. Have a look at each other’s observations, and make quick comments.
- Then, the recorder for the group or whoever is assigned, write down their observation(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet.

Step Seven: Explaining the Observations (E)

Teacher Activity; Teacher

- Ask each member of the group to write down the explanation for their observation(s) on a piece of paper.
- Ask the students to write down the explanation for their observation(s) on the PEOE worksheet as agreed upon by the group. (This exercise is valuable for both the students and the teacher. Making their reasons explicit will helps the students to reconcile any conflict between their predictions and observations).
- While students are writing, you might stroll around so as to prepare yourself for the discussion that will follow.
- Then, ask each group to present their PEOE worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the PEOE worksheet contains highlight of the predictions, explanations for their predictions, observation, and explanations for their observation for each group)
- After this has been done, you might invite the class to discuss which observation and reasons or explanations they now think are best. (When students correlate their prediction with their observation, they reconstruct their thinking).
- Engage the students in full class discussion in order to reconcile any conflict between their predictions and observations.
- To disengage from their groupings

Students' Activity; Students

- Each member of the group is expected to write out the explanation for their observation on a piece of paper.
- All members spread out their papers on a flat surface (desk), where it can easily be read. Have a look at each other's explanation for their observations, and make quick comments.

- Then, the recorder for the group, write down the explanation for their observation(s) as agreed upon by the group on the PEOE worksheet
- Team leaders or selected group representatives makes their respective presentations in full class discussion
- At this stage, students are expected to compare their prediction and observation in order to reconcile any conflict between their predictions and observations in a brief full class discussion
- They are allowed to ask questions for clarification.
- Students move to their respective sits.

Predict-Explain-Observe-Explain (PEOE) in collaborative setting can facilitate the exchange of information in a group; can make the viewpoints of individual collaborators more clear; and can encourage participation in the collaborative process (Gao, 2012). Thus, the seven-step format for PEOE instructional package in a collaborative setting proposed by Chris (2016) was employed in this study.

Chris (2016, p.67) outlined some advantages of Predict-Explain-Observe-Explain (PEOE) as follows:

1. PEOE strategy enhances students understanding of concepts. It is a powerful instructional strategy that fosters students inquiry and challenge preconceptions that students bring to the classroom;
2. PEOE strategy also benefits preservice teachers who need to develop strong pedagogy as they attempt to engage students in science learning and understanding or teachers who are unexpectedly tasked with teaching science;
3. PEOE can give more insight into the misconceptions students bring with them into a science class;
4. It can be used for finding out students initial ideas;

5. PEOE provide teachers with information about students thinking; and
6. PEOE helps in motivating students to want to explore the concept and generate investigation.

Bajar-Sales, Avilla and Camacho (2015, p.8) outlined the advantages of Predict-Explain-Observe-Explain (PEOE) as follows:

1. PEOE is a strategy that lets the students explore concepts and generate investigation. Furthermore, the students are given the opportunity to express their schema and experience the science ideas behind the activity to satisfy their curiosity;
2. PEOE is an efficient strategy for encouraging students to discuss about their ideas;
3. PEOE strategy focuses on linking students existing ideas and beliefs relevant to a situation and exploring the appropriateness of these ideas and beliefs;
4. PEOE strategy is a powerful instructional approach that guides and motivates learners to express their own ideas about a certain topic based on their experiences and background knowledge;
5. PEOE strategy is a learner-centred and activity-based strategy with a view of nurturing learners' personal growth; and
6. PEOE is important as it is used to find out learners' prior knowledge and thought processes.

Despite the advantages of Predict-Explain-Observe-Explain (PEOE) as outlined by various scholars. Rickey and Stacey (2015, p.11) outlines some limitations of PEOE as follows:

1. Younger primary school students may have difficulty explaining their reasoning.
2. It is not suitable for all topics. For example, topics that are not "hands-on" or in which it is difficult to get immediate results.

3. If the PEOE strategy is used often, some demonstrations should be chosen to not give surprising results, otherwise students start looking for the trick. This may affect the explanations they give.

2.3.2 Vee Heuristic (VH) Instructional Strategy

Vee Heuristic (VH) instructional strategy is the process of creating of a V-shaped diagram to represent key elements (ideas) that are contained in the structure of knowledge with two sides namely the theoretical or conceptual side (thinking side) on the left and methodological side (doing side) on the right in order to enhance conceptual understanding of scientific knowledge. VH instructional strategy is a tool that helps in seeing the interplay between what is known and what needs to be known or understood. A Vee heuristic diagram is a V-shaped diagram showing the relationships between conceptual or theoretical and methodological framework and the resultant knowledge or value claims of a concept (Gowin, 1995).

Vee Heuristic (VH) instructional strategy was first introduced in 1995 by Gowin Vee. Based on the assimilation theory of Ausubel, Gowin (1995) developed the epistemological "V" to help students understand the structure and process of knowledge construction. The scholar argued that the major motive behind the VH strategy is a willingness to improve and develop experiments and activities that enhance understanding of scientific concepts. Gurley cited in Qilada (2012), considered VH strategy as a tool that identifies the ways in which knowledge is formed as a result of persistent inquiry. In order to understand the structure of knowledge as well as to investigate the process of knowledge construction, Gowin's 5-question Vee diagramming is used; the questions are

(1) What are the telling questions (focus questions)?

(2) What are the key concepts?

(3) What methods of inquiry are used?

(4) What are the major knowledge claims?

(5) What is the value claims?

Gowin (1995) argued that the Vee Heuristic (VH) strategy achieves substantial advancement in the teaching/learning process, as the cognitive theory stresses integration between the concepts, principles, and theories used to observe events and the demands of cognitive structures. The cognitive theory provides the learner with a conceptual framework for what has already been learned and works as a cognitive bridge for new knowledge, thus helping the learner to understand the nature and development of knowledge. Khataibeh (2011) and Zaitoun (2012) indicated that a student's use of the VH strategy in his or her learning makes him or her conscious of what he or she does by linking the theoretically based content of concepts, principles, and theorems with practical activities that support more abstract concepts. This creates an effective interaction between the intellectual (left) and the practical (right) aspects of the Vee diagram.

Gowin's Vee heuristic diagram enables the learner to understand the nature of scientific knowledge as being both theoretical and practical. The theoretical side includes; associated words, philosophy, theory, principles, constructs and concepts. While, the methodological side includes; records, transformations, knowledge claims and value claims. At the tip of the Gowin's Vee diagram are events or objects to be studies which interact with both sides in order to achieve the answer to the focus question (Gowin, 1995). Figure 2 shows Gowin's Vee heuristic diagram with a description of all the twelve epistemological elements which are involved in the construction or description of new knowledge. All elements interact with one another in the process of constructing new knowledge or value claims, or in seeking understanding of these for any set events and questions.

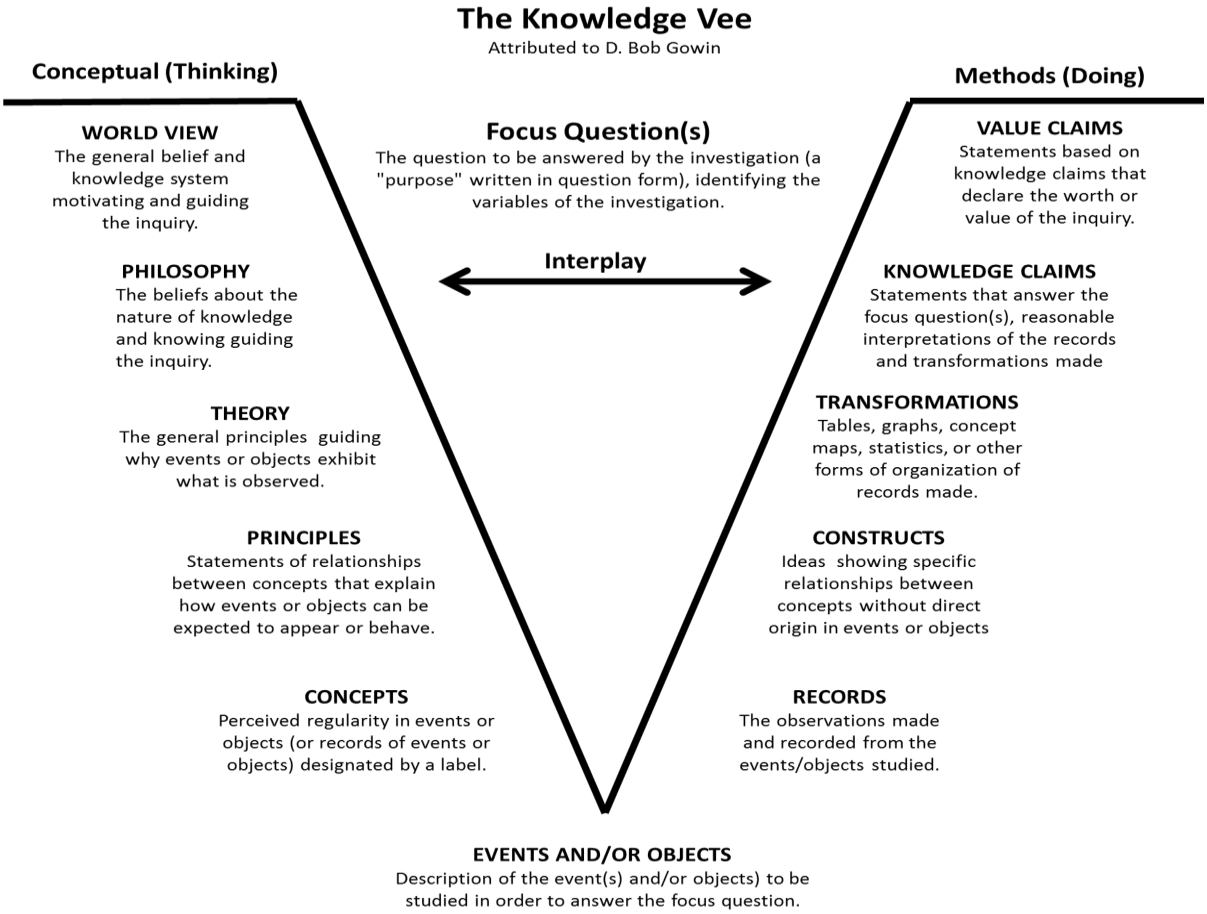


Fig 1: Vee Diagram Epistemological Components (Gowin, 1995).

When using Vee heuristic strategy in the teaching and learning process, it is important that the learner starts by filling in the focus question under investigation at the centre of the V-shaped diagram. Then write down any of the activities, procedures, descriptions, apparatus objects and events needed in order to answer the focus question. In the conceptual side the learner indicates the theories, principles, constructs and concepts used in the study (Afamasaga, 2013). Under record section, in the methodological side, the learner fills in data in tables form. In the transformation section the learner analyzes the data using graph or charts. The answer to the focus question is written under the knowledge claims section. Finally, the relevance and importance of the knowledge attained is written under the value claims. After filing in all the sections of the Vee heuristic diagram, the learner relates or reconciles any contradiction between both sides which lead to conceptual understanding of the scientific knowledge (Afamasaga, 2013).

Ausubel's assimilation theory explains that for information to be learnt, it must be presented in a meaningful way. Meaningful learning will result when new concepts are integrated with those already possessed. In this study, the Vee heuristic instructional strategy will be used as an instructional instrument representing the most recent application of Ausubel's meaningful learning strategy. In this context, meaningful learning takes place by linking practical and theoretical or cognitive aspects together, in addition to dealing with events and phenomena. The practical aspect will become meaningful when associated with a learner's prior cognitive constructs thus allowing the instructional content to be treated in a way that renders it educationally useful.

Learning is a personal and unique experience that differs from individual to individual and it can be enhanced by collaborative learning, which is regarded as a powerful pedagogical process that fosters social creativity (Cicognani, 2006). Collaborative connote sharing ideas. According to Samba (2012), collaborative learning idea is borne out of the fact that individual could sometimes be boring and frustrating particularly when one is not getting it right. However, the scholar added that, when more than one brainstorms together, each one is encouraged or stimulated to think and bring out more ideas which when shared, will go a long way to upgrade individual conceptual framework. This will not only promote meaningful learning, but will go further to help develop critical thinking and other social skills which are fundamental in functional and impactful living. Moreover, such interactions make learning more exciting, arouse self-efficacy and keep the students focused.

Vee heuristic (VH) instructional strategy may benefits from the interactions with others by allowing learners to blend their thoughts and experiences while trying to achieve understanding of a common concept. It is thus believed that if this strategy is put into use, learning may be enhanced. Therefore, in this study, Vee heuristic instructional package in collaborative setting was employed. Thus, VH instructional strategy becomes collaborative when instead of an individual creating the Vee diagram, a group of students come together to brainstorm, share ideas, generate a pool of concepts/facts, which when put together, they eventually come out with a Vee diagram that represents the thought of the group. In this regard, VH strategy was used in this study as an instructional strategy where four or more learners are engaged in coordinated and sustained efforts in the creation of a V-shaped diagram to represent key elements (ideas) that are contained in the structure of knowledge with two sides namely the theoretical (thinking side) on the left and methodological (doing side) on the right in order to enhance conceptual understanding of scientific knowledge.

The researcher proposed a 7-step format for Vee heuristic instructional package in a collaborative setting as follows;

Step I: Set Induction

Teacher activity;

- Makes known to the students the teaching technique and its demand on them. The teacher explains that Vee heuristic is a learning strategy that involves making of a V-shaped diagram representation with two sides namely the theoretical (thinking side) on the left and methodological (doing side) on the right.
- The teacher rehearses each of the elements in the Vee heuristic process. The elements in the thinking side includes; theory, principles, constructs and relevant concepts that constitute the prior knowledge of the learner (what the learner knows) on the left hand side of the V-shaped diagram and the elements in the doing side includes; value claims, knowledge claims (facts), transformations and records on the right hand side that shows how to carry out a learning task for example an experiment in order to answer the focus

question. At the tops and tips of the V-diagram are focus question and events or objects respectively.

- Teacher then probes into students' prior knowledge through questioning. He coordinates the students' responses and then introduces the topic to the whole class

Students' activity;

- Students jot down some points as the teacher speaks.
- Students answer the questions asked by the teacher. They are also allowed to ask questions

Step II: Formation of Groups/Pooling of Ideas

Teacher Activity; Teacher to

- Share students out into groups of five to seven depending on the class size.
- Ask students to assume different roles
- A few minutes of full-class discussion will provide the students with the opportunity to reflect on their past experiences and understanding.

Students' Activity; Students to

- Move to their respective groups and assume their different roles viz: captain, recorder, timekeeper and so on
- Students listen to the teacher explanation and they are asked to increase their list of ideas, fact, and concepts on topic as the lesson progresses as well as write out responses to the questions asked by the teacher.
- They are also allowed to ask questions.

Step III: Group Brainstorming (Thinking)

Teacher activity;

- Asks students to write out all facts, ideas or thought that they feel based on their prior experience on the conceptual or theoretical side (Thinking side) of V-shaped diagram under the following Vee heuristic conceptual epistemological elements; associated words, theory, principles, constructs and relevant concepts in relation to the focus question(s).

- Each member of the group is expected to write down their ideas/thoughts on pieces of papers.
- Ask the students to write down their ideas/thoughts on the Vee worksheet (cardboard provided) as agreed upon by the group.
- Teacher goes round various groups to supervise the activities.

Students' activity;

- Each students write out their ideas/thought on pieces of paper in relation to the focus question(s).
- All members spread out their papers on a flat surface, where it can easily be read. Have a look at each other's thoughts and make quick comments.
- Then, the recorder for the group or whoever is assigned, write down their thought as agreed upon by the group and directed by the group captain on the Vee worksheet for the group

Step IV: Group Carrying out Learning Task (Doing)

Teacher activity;

- At this stage, teacher asks students to carry out a learning task. For example, an experiment in order to answer the focus question(s).
- Asks students to write down or record the findings of such learning task on the methodological side (doing side) of V-shaped diagram under the following Vee heuristic methodological epistemological elements; value claims, knowledge claims (facts), transformations and records.
- Each member of the group is expected to write out their experimental findings on pieces of papers.

- All members spread out their papers on a flat surface, where it can easily be read. Have a look at each other's thoughts and make quick comments.
- Ask the students to write down their experimental findings on the Vee worksheet (cardboard provided) as agreed upon by the group.
- Teacher serves as facilitator guiding the students in various groups to do the right thing.

Students' activity;

- Students engage in the learning task as directed by the teacher.
- Each students write out their findings on pieces of paper
- All members spread out their papers on a flat surface, where it can easily be read. Have a look at each other's experimental findings and make quick comments.
- Then, the recorder for the group or whoever is assigned, write down their findings as agreed upon by the group and directed by the group captain on the Vee diagram for the group

Step V: Presentation of Group Vee Diagram

Teacher Activity; Teacher

- Ask each group to present their Vee worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the Vee worksheet contains highlight of the thinking and the experimental findings for each group)
- Asks the team leaders or appointed group representatives to come out and make their presentations.

Students' Activity; Students

- Team leaders or selected group representatives makes their respective presentations in full class discussion while member watch, listen, discuss and make contributions at the end of each presentation.

Step VI: Summary and Final Class Vee Diagram

Teacher Activity; Teacher

- After group presentations of Vee diagram has been done, you might invite the class to discuss which thinking and experimental finding they now think are best. (This exercise is valuable for both the students and the teacher. Having full-class discussion will helps the students to reconcile any conflict between their thinking and experimental findings) (When students correlate their thinking with their experimental findings, they reconstruct their thinking).
- At this stage, the class teacher or anyone he or she may choose, harmonizes the ideas from the respective Vee diagrams posted on the board into one class Vee diagram
- Eventually a Vee diagram that depicts the understanding of the entire class is drawn.
- Ask the students to disengage from their groupings

Students' Activity; Students

- Reconcile any conflict between their thinking and experimental findings.
- Students move to their respective sits.

Step VII: Evaluation

Teacher activity;

- Teacher encourages students to copy the final class Vee diagram and compare it with their respective group diagrams
- To submit a neatly drawn and beautifully arranged individual Vee diagrams the next class.

Students' Activity; Students

- Students will perform all the tasks as detailed above and they are allowed to ask questions.

As the Vee diagram is constructed, students working in groups talk with one another to develop each area of the diagram. They agree on selected words and events and decide how to analyze data. In this setting, students can socially construct their knowledge with peers. The teacher can then move among the groups and effectively assist each group in developing their knowledge. Thus, it is very likely that Organic Chemistry could be simplified and made easier to understand as students go through Vee heuristic teaching/learning steps or phases collaboratively. Therefore, the study adopted the seven-step format for Vee heuristic instructional package in a collaborative setting as proposed by Keraro (2014).

Passmore (2014, p.16) outlined some importance of Vee Heuristic (VH) instructional strategy as follows:

1. VH strategy is one of the most effective tools that provide meaningful learning and developing metacognitive awareness;
2. It is a metacognitive thinking tool that helps people understands the nature of knowledge and construction processes of knowledge;
3. VH strategy is a tool which can be used in educational environment to foster students' thinking skills and force them to use these thinking skills as well as constructing positive attitudes for deeper thinking;
4. VH strategy is essentially a pedagogical technique whereby learning occurs via student-directed, constructivist, and inquiry-based discoveries;
5. It is ideal for enabling students to understand how events, processes, or objects are meaningfully related because its overall purpose is then interplay between what is familiar and what they has yet to be known or understood in scientific or mathematical investigations;

6. VH strategy enables students to understand the structure of knowledge (e.g., relational networks, hierarchies, and combinations) and to understand the process of knowledge construction;
7. VH strategy is used to facilitate reflective thinking and learning, as students plan and conduct their own investigation; and
8. It aids students in this linking process by acting as a metacognitive tool that require students to make explicit connections between prior and newly acquired information.

Ozsoy (2015, p.33) also discusses some benefits of Vee heuristic (VH) instructional strategy as follows:

1. VH strategy can be used as a tool to guide students' systematic analysis of the relevant domain or problem statement and critical identification of multiple methods of solution;
2. VH strategy can be used in place of any laboratory report.
3. VH strategy is a tool that guides students learning during lecture and laboratory experiences.
4. VH strategy provides a format for students to construct their knowledge about a concept. Students can see how scientific knowledge is developed through the process of reflecting on what they know and the investigation they undertake. This occurs as students reflect on the left and right sides of the Vee diagram as they try to answer their focus question.
5. VH strategy also reveals the process by which a student constructs knowledge. Teachers can identify the prior knowledge of a student through the word list. The data analysis area can show teachers how students support their claims or hypotheses, while the conclusion section demonstrates the level of students' understanding. As a student progresses through each of these areas, the teacher can modify instruction and

curriculum to meet each student's need. Traditional laboratory reports typically do not provide this much information.

6. Vee heuristic ensures forming relationships between theoretical knowledge and laboratory work for students and it makes laboratory reports more understandable and useful.
7. Vee heuristic strategy also helps students penetrate the structure of knowledge they seek to understand.
8. VH strategy did not only help in constructing link between theoretical knowledge and practical knowledge but also provide an opportunity for the students to use the knowledge they already have.
9. VH strategy helps students to better organize their thinking, investigate more efficiently, and create guidelines for learning

According Keraro (2014, p.7) some advantages of Vee heuristic instructional strategy are as follows:

1. Vee heuristic strategy makes students feel better about learning because the students are in control of the learning situation and therefore know what they are doing.
2. Vee heuristic instructional strategy will help students to understand the nature and purpose of laboratory activities and how new knowledge is attained in an experimental situation.
3. Vee heuristic strategy begins by focusing students' attention on what they know before the inquiry, students then generate research questions, design and conduct experiments, and interpret the data. Through interpretation, they arrive at new knowledge that must be integrated with their prior knowledge.

Despite the advantages of Vee heuristic (VH) strategy as outlined by various scholars, Olarewaju (2013, p.21) outlined some limitations of VH strategy as follows include:

1. Vee heuristic strategy may offer limited benefits if instructors introduce a stage of the learning at the wrong times; and
2. Vee heuristic strategy is more suitable for branches of experimental sciences and less useful for subjects of social sciences.

2.3.3 Discussion method

Discussion method is a teaching method that involves collaborative exchange of ideas among a teacher and students or among students for the purpose of furthering students thinking, learning, problem solving and understanding (Wilkinson, 2016). The author further added that participants present multiple points of view, respond to the ideas of others, and reflect on their own ideas in an effort to build their knowledge, understanding, or interpretation of the matter at hand. Discussions may occur among members of a small group, or whole class and be teacher-led or student-led. Gall and Gillett (2012) opined that, discussion method is a "thinking together" process or type of co-operation in learning. It can also be described as a learning process, which requires teamwork among the learners and teacher. The method is organized on the ground that the knowledge or ideas of several people pooled together, have greater merit than those of a single person.

Gall and Gillett (2012) opined that every student has background information that provides him with view point as it would be ridiculous for the teacher to ask students to discuss a subject which they know nothing about. Most times, a teacher will give an idea to his class on what is to be discussed. When a proper discussion takes place, students are free to express their viewpoint(s) and they are motivated by teachers' questions which make them to reason, rather than recall and the teacher does not dictate or influence the viewpoint of the students as he moderates the discussion. Mehan (2009) also has a similar opinion on discussion method. According to the author, knowledge and ideas of several people are more likely to find solutions or answers to specified problems, issues or topics. This understanding is illustrated by the saying that “two heads are better than one”. He goes on to say that, in discussion method, the leader who may be the teacher of the class is responsible for regulating the activities of the discussion group.

Mehan (2009, p.14) outlined some advantages of discussion method as follows:

1. The classroom employment of discussion method provides students with a receptive area for suggestion, by helping them to clarify ideas, and promote the spirit of team work among them.
2. Discussion method provides the students with a sense of confidence through frequent exchange of ideas between students and teachers.
3. It helps to increase the student’s sense of respect for and tolerance of the opinion of others even in disagreement.
4. It stimulates thought as it calls on every member of the group to do some clear thinking.
5. The listeners learn to be attentive since they have to ask questions after the discussion
6. The ideas of several people pooled together will help the individual student correct some wrong impression and view the hitherto had.
7. It serves as an exercise in oral examination.
8. It is very important for the treatment of controversial and current issues. It is a means of raising challenging problems to the students.

The discussion method also has some disadvantages as outlined by the same author that discuss the advantages:

1. Students lack the authority that the teacher has.
2. The problem may not be clear to all members of the group.

3. The problem chosen may not interest all the students in the class and the discussion may degenerate into mere talk and may be monopolized by few individuals. This may consequently lead to a conclusion far from the truth even though such may be accepted by the group as a whole.
4. Finally, it is usually time consuming to employ discussion method.

2.3.4 Collaborative Learning

Collaborative learning is an umbrella for a variety of educational strategies involving joint efforts by both teachers and learners. Collaborative connote sharing ideas. Collaborative learning engages learners in active learning where they work and learn together in small groups to accomplish shared goals. This strategy is characterized by group discussions which allow learners' expression and revision of their beliefs in the context of discourse (Sharan, 2011). In collaborative learning students explore their ideas, clarify them for themselves and to one another, expand and modify them and finally make them their own. Collaborative learning has positive effects on students' discussions in which they elaborate on the subject, challenge and amend one another's ideas, and thus remember these ideas more easily. In small group students can share strengths, develop their weaker skills, interpersonal skills and also learn to deal with conflict. When guided by clear objectives, students engage in numerous activities that improve their understanding of a subject (Sharan, 2011).

Collaborative learning is based on the view that knowledge is a social construct. Collaborative learning involves groups of learners working together to solve a problem, complete a task, or create a project. Collaborative learning is based on the idea that learning is a natural social act in which the participants talk among themselves. It is through the talk that learning occurs. Students learn best when they are actively involved in the process. Research reports like Johnson and Johnson (2008), and Suther (2009) contend that, regardless of the subject matter, students working in small groups tend to learn more of what is taught and retain it longer than when the same content is presented in other instructional formats. Students who work in collaborative groups also appear more satisfied with their classes. Collaborative learning activities can include collaborative writing, group projects, joint problem solving, debates, study terms, and other activities. The strategy is closely related to cooperative learning.

The terms collaborative and cooperative learning have become murky in popular usage, and often, distinctions are not made between the two. According to Brown and Lara (2011), collaborative learning is the umbrella term encompassing many forms of collaborative learning from small group projects to the more specific form of group work called cooperative learning. Cooperative learning as pointed out by authors is a type of collaborative learning developed by Johnson and Johnson in the 1960's and is still widely used today. Panitz (2008) describes the differences between cooperative and collaborative leaning by acknowledging the parallels they both have in that they both use groups both assign specific tasks and both have the groups share and compare their procedures and conclusions in the plenary class sessions. They major difference lies in the fact that cooperative deals exclusively with traditional (canonical) knowledge while collaborative ties into the social constructivist movement, the authority for testing and determining the appropriateness of the group product rest with, first, the small group, second, the plenary group (the whole class) and finally the requisite knowledge community that is, the disciplines such as Geography, History, Biology, Physic and Chemistry.

The terms overlap in that both indicated that students were working in groups. It can get confusing because the term collaborative learning will sometimes be used in higher education circles to designate the same practices that at the elementary and secondary level would be called cooperative learning. According to Johnson and Johnson (2008), cooperative or collaborative learning is now an accepted and often the preferred instructional procedure at all levels of education. Collaborative learning is presently used in schools and universities in every age student. It is difficult to find a text on instructional methods, a teachers' journal, or instructional material that does not discuss cooperative or collaborative learning. Materials on cooperative learning have been translated into dozens of languages. Collaborative learning is now an accepted and highly recommended instructional procedure (Johnson & Johnson, 2008). Collaborative learning is instruction that involves students working in teams to accomplish a common goal, under conditions that include the following elements, as outlined by Johnson, Johnson, and Smith (2009):

1. Positive interdependence: Team members are obliged to rely on one another to achieve the goal. If any team members fail to do their part, everyone suffers consequences.
2. Individual accountability: All students in a group are held accountable for doing their share of the work and fro mastery of all of the material to be learned.
3. Face-to-face pro motive interaction: Although some of the group work may be parceled out and done individually, some must be done interactively, with group members providing one another with feedback, challenging one another's conclusions and reasoning, and perhaps most importantly, teaching and encouraging one another.
4. Appropriate use of collaborative skills: Students are encouraged and helped to develop and practice trust-building, leadership, decision-making, communication, and conflict management skills.
5. Group processing: Team members set group goals, periodically assess what they are doing well as a team, and identify changes they will make to function more effectively in the future.

Collaborative learning is not simply a synonym for students working in groups. A learning exercise only qualifies as collaborative learning to the extent that the above listed elements are present, according to Johnson, Johnson, and Smith, (2009) as shall be reflected in this study. According to Johnson, Johnson, and Holubec (2014) cited in Kyado (2018), the various forms of collaborative learning are identified as follows:

(a) Formal Collaborative Learning: Formal collaborative learning consists of students working together, for one class period as several weeks, to achieve shared learning goals and complete jointly specific tasks and assignments. In formal collaborative learning groups the teachers' role includes:

1. Making pre-instructional decisions: Teacher formulate both academic and social skills objectives; decide on the size of group; choose a method for assigning students to groups; decide which roles to assign group members; arrange the room; and arrange the materials students need to complete the assignment. In these pre instructional decisions, the social skills objectives specify to interpersonal and small group skills students are to learn. By assigning students roles, role interdependence is established. The way in which materials are distributed can create resource interdependence. The arrangement of the room can create environmental interdependence and provide the teacher with easy access to observe each group, which increases individual accountability and provides data for group processing.

2. Explaining the instructional task and collaborative structure: Teachers explain the academic assignment to students; explain the criteria for success; structure positive interdependence; structure individual accountability; explain the behaviours (that is, social skills) students are expected to use; and emphasize intergroup collaboration (this eliminates the possibility of competition among students and extends positive goal interdependence to the class as a whole). Teachers may also teach the concepts and strategies required to complete the assignment by explaining the social skills emphasized in the lesson, teachers operationalize the social skill objectives of the lesson; and the interaction patterns (such as oral rehearsal and jointly building conceptual frameworks) teachers wish to create.

3. Monitoring students' learning and intervening to provide assistance in completing the task successfully; or using the targeted interpersonal and group skills effectively: During lesson, teachers monitor each learning group and intervene when needed to improve task work and teamwork. Monitoring the learning groups creates individual accountability; whenever a teacher observes a group, members tend to feel accountable to be constructive members. In addition, teachers collect specific data on promoting interaction, the use of target social skills, and the engagement in the desired interaction patterns. This data is used to intervene in groups and to guide group processing.

4. Assessing students' learning and helping students process how well their group: Teachers bring closure to the lesson; assess and evaluate the quality and quantity of students' achievement; ensure that students carefully discuss how effectively they worked together (that is, process the effectiveness of their learning groups); have students make a plan for improvement; and have students celebrate the hard work of group members. The assessment of students' achievement highlights individual and group accountability (that is, how well each students performed) and indicates whether the group achieved its goals (that is, focusing on positive goal interdependence). The group celebration is a form of reward interdependence. The feedback received during group processing is aimed at improving the use of social skills and is a form of individual accountability. Discussing the processes the group used to function, furthermore, emphasizes the continuous improvement of promoting interaction and the patterns of interaction needed to maximize students learning and retention.

(b) Informal Collaborative Learning: Informal collaborative learning consists of having students work together to achieve a joint learning goal learning in temporary, ad-hoc groups that last from a few minutes to one class period. During a lesson, informal collaborative learning can be used to focus students' attention on the material to be learned, set a mood conducive to learning, help set expectations as to what will be covered in a class session, ensure that students cognitively process and rehearse the material being taught, summarize what was learned and pre cue the next session, and provide closure to an instructional session. The teacher's role for using informal cooperative learning to keep students more actively engaged intellectually entails having focused discussions before and after the lesson (that is, bookends) and interspersing pair discussion throughout the lesson. Two important aspects of using informal collaborative learning groups are making the task explicitly precise and requiring the groups to produce a specific product (such as a PEOE worksheet and Vee diagram, as in the case of his study). The procedure is as follows:

1. Introductory focused discussion: The teacher assign students to pair or triads and explain the task of answering the question in a four to five minutes time period; and the positive goal independence of reaching consensus. The discussion task is aimed at promoting advance organizing of what the students know about the topic to be presented and establishing expectations about what the lesson will cover. Individual accountability is ensured by the small size of the group. A basic interaction pattern of eliciting oral rehearsal, higher level reasoning, and consensus building is required.

2. Intermitted focused discussions: Teacher divide the lesson into 10 to 15 minute segments. This is about the length of time a motivated adult can concentrate on information being presented. After each segment, students are asked to turn to the person next to them and work collaboratively in answering a question (specific enough so that students can answer it about three minutes) that requires students to cognitively process the material just presented. The procedure is:

a. Each student formulate his or her answer;

b. Students share their answer with their partners;

c. Students listen carefully to their partner's answer; and

d. The pairs create a new answer that is superior to each member's initial formulation by integrating the two answers, building on each other's thoughts, and synthesizing.

The question may require students to:

a. Summarize the material just presented;

b. Give a reaction to the theory, concepts, or information presented;

c. Predict what is going to be presented next; hypothesize;

d. Relate material to past learning and integrate it into conceptual frameworks; and

e. Resolve conceptual conflict created by presentation.

The teacher should ensure that students are seeking to reach an agreement on the answers to the questions (ensure positive goal interdependence is established), not just share their ideas with each other. Randomly choose two or three students to give 1-3 minute summaries of their discussions. Such individual accountability ensures that the pairs take the tasks seriously and check each other to ensure that both are prepared to answer. Periodically, the teacher should structure a discussion of how effectively the pairs are working together (that is, group processing). Group celebrations add reward interdependence to the pairs.

3. Closure focused discussion: Teacher give students an ending discussion task lasting four to five minutes. The task requires students to summarize what they have learned from the lecture and integrate it into existing conceptual frameworks. The task may also point students toward what the homework will cover or what will be presented in the next class session. This provides closure to the lecture. Informal collaborative learning ensures students are actively involved in understanding what is being presented. It also provides time for teacher to move around the class listening to what students are saying. Listening to students' discussions can give instructor direction and insight into how well students understand the concepts and materials as well as increase the individual accountability of participating in the discussions.

(c) Collaborative Base Groups

Collaborative base group are long-term, heterogeneous collaborative learning group with stable membership. Members' primary responsibilities are to ensure all members are making good academic progress (that is, positive goal interdependence); hold each other accountable for striving to learn (that is, individual accountability); and provide each other with support, encouragement, and assistance in completing assignments (that is, promotive interaction). In order to ensure the base groups function effectively, periodically teacher should teach needed social skills and have the groups' process how effectively they are functioning. Typically, collaborative base groups are heterogeneous in membership (especially in terms of achievement, motivation and task orientation), meet regularly (for example, daily or biweekly), and last for the duration of the class (a semester or year) or preferably for several years. The agenda of the base group can include academic support tasks (such as ensuring all members have completed their homework and understand it or editing each other's essays), routine tasks (such as taking attendance), and assessment tasks (such as checking each other's understanding of the answers to test questions when the test is first taken individually and then retaken in the base group). The teacher's role in using collaborative base groups is to:

a. Form heterogeneous group of three or four;
b. Schedule a time when they will regularly meet (such as beginning and end of each class session or the beginning and end of each week);
c. Create specific agendas with concrete tasks that provide a routine for base groups to follow when they meet;
d. Ensure the five basic elements of effective collaborative groups are implemented; and
e. Have students periodically process the effectiveness of their base groups.

The longer a collaborative group exists, the more caring their relationships will tend to be, the greater the social support they will provide for each other, the more committed they will be to each other's success, and the more influence members will have over each other. Permanent collaborative base groups provide the arena in which caring and committed relationships can be created that provide the social support needed to improve attendance, personalize the educational experience, increase achievement, and improve the quality of school life.

According to Johnson, Johnson and Holubec (2008), the above three types of collaborative learning may be used together. A typical class session may begin with a base group meeting, which is followed by a short lecture in which informal collaborative learning is used. The lecture is followed by the formal collaborative learning lesson. Near the end of the class session another short lecture may be delivered with the use of informal collaborative learning. Some of the steps outlined in the collaborative learning classroom situation are relevant for this study and were closely utilized.

2.3.5 Facilitating Collaborative Learning using Predict-Explain-Observe-Explain (PEOE) and Vee Heuristic (VH) Instructional Strategies

Collaborative learning is broadly defined as a leaning situation in which two or more people learn or attempt to learn something together, and more specifically as joint problem solving (Dillenbourg, 2011). Roschelle and Teasley (2013) define collaboration learning as a mutual engagement of participants in a coordinated effort to solve a problem together. Boxtel, Linden, and Kanselaar (2016) opine that, collaborative learning activities allow students to provide explanations of their understanding, which can help students, elaborate and reorganize their knowledge. Social interaction stimulates elaboration of conceptual knowledge as group mates attempt to make themselves understood, and research demonstrates that providing elaborated explanations improves student comprehension of concepts.

Educators are now seeking new methods or technologies to respond to the demand for personalized education and knowledge creation. Predict-Explain-Observe-Explain (PEOE) and Vee Heuristic (VH) instructional strategies are powerful techniques that can facilitate knowledge creation in the 21st century (Scardamalia, 2015; Hilario, 2016). Collaborative knowledge building is a central issue in the field of collaborative learning. Knowledge building can result in the creation or modification of public knowledge, which leads to personal learning (Scardamalia, 2015). Currently PEOE and VH instructional strategies have been integrated into collaborative learning activities to facilitate productive collaborative learning and artifacts. Thus, PEOE and VH instructional strategies have been interesting strategies that responds to educational demands. The effectiveness of PEOE strategy in collaborative knowledge building has been examined in previous studies (Bajar-Sales, Avilla & Camacho, 2015; Teerasong, Chantore, Ruenwongsa & Nacapricha, 2016) and also the effectiveness of VH strategy in collaborative learning has also been investigated in previous studies (Mutai, Changeiywo & Okere, 2014; Fred, 2015; Haruna, 2016; Njue & Magana, 2016; Njue, Kamau & Mwania, 2018).

Chris (2016), believed the combined use of a Predict-Explain-Observe-Explain (PEOE) and collaborative learning may synergistically amplify the benefits by facilitating knowledge building. This was supported by Karamustafaoğlu and Naaman (2015) and Stoyanova and Kommers (2016) who were able to note that using PEOE strategy collaboratively facilitate knowledge building easily. Engelmann and Hesse (2010) conducted an empirical study giving 20 triads access to create Vee diagrams and 20 triads no access to Vee diagrams creation to compare their group performance in problem solving tasks. They found that the triads that involves in Vee diagrams creation acquired more knowledge and solved problem faster and more correctly than triads with no access to Vee diagrams creation. Collaborative learning with Vee diagrams was more effective than other activities with non-diagram creation materials.

Thus, Predict-Explain-Observe-Explain (PEOE) and Vee Heuristic (VH) instructional strategies were integrated into collaborative learning in this study. Since, studies have shown that collaborative learning can facilitate the exchange of information in a group; can make the viewpoints of individual collaborators more clear; and can encourage participation in the collaborative process (Gao, 2012).

2.3.6 Predict-Explain-Observe-Explain (PEOE), Vee Heuristic (VH) Instructional Strategies and Information Communication and Technology (ICT)

Technology is the organization of knowledge for practical purposes. Abayomi (2015) describe technology as the cumulative understanding of science and, applied in the exploration of environmental resources through processes of instrumentation, manipulation and production. Information Communication and Technology (ICT) is the organization of knowledge for the achievement of practical purposes of disseminating such knowledge to the society. According to MacKinnon and Aylward (2014), Information Communication and Technology (ICT) provide promising chances to create new teaching and learning frameworks that enrich the educational context in which students and teachers are enrolled. Specifically, ICT have an important role in the field of science education, since they can open access to information and knowledge about sustainability.

Consequently, the design of instructional strategies with informatics tools help teachers to use ICT in the classroom effectively, improves teaching communicative abilities, encourages educational innovation and increases educators' motivation (Pontes, 2014). Banky and Wong (2014) described advantages of use of simulation software in terms of the capacity to let users observe outcomes without harm and without the inconvenience of equipment failure. Kearney (2016) summarized the advantages of assigning PEOE tasks for completion in a computer-based environment. These include opportunities for small group work, computer scaffolding, student pacing and autonomy, opportunities for discussion and reflection. In addition, Kearney noted that computer-based demonstrations can reveal interesting science phenomena that go beyond our temporal, perceptual or experiential limits. The usefulness of PEOE strategies in the classroom is providing students with opportunities to observe scientific phenomenon in a way that is real, authentic and, most importantly, safe.

Kate (2016) used multimedia with PEOE to provide students with opportunities to observe “difficult, expensive, time consuming or dangerous demonstrations of real, observable events”. Developments of multimedia within a PEOE framework have also been reported (Tao, 2016). Tao (2016) developed a set of computer simulation programs carrying out PEOE tasks. The tasks provided cognitive conflicts that fostered students’ conceptual change. Students worked in pairs on the topic of force and motion. Although the finding showed that students probably achieved conceptual change without any peer conflict, collaborative work helped students get through the tasks and develop shared understanding. Acar-Sesen (2017) investigated that the preservice science teachers’ understanding of surface tension, cohesion and adhesion forces by using computer-mediated predict-explain-observe-explain tasks. The study revealed that computer-mediated predict-explain-observe-explain task was an effective method to diagnose students’ understanding.

Kothari (2013) used video of real-life events to support Vee Heuristic (VH) strategy to engage meaningful learning. In this exercise, students worked collaboratively on computers. Vee heuristic tasks motivated students’ thinking and conversation, since the program was designed to not allow students to watch a video until they completed the conceptual side of the Vee diagram through thinking. The study showed the successful contribution of technology media-based Vee heuristic strategy for teaching and learning in science classroom. Hussain (2016) used virtual simulations with Vee heuristic strategy in a basic electric circuits course. The authors explained that the topic is abstract therefore simulations can help students visualize these abstractions. Wright (2016) also used a computer program with VH instructional strategy to help science teachers build and photographic, sound or video-based (digital) demonstrations.

There is a lot of software that enables creating a Vee diagram or creating PEOE worksheet collaboratively. For example, thinkature (http://www.thinkature.com), CmapTools (http://cmap.ihmc.us) and conceptshare (http://www.conceptshare.com) are web-based visual workspace for collaborative learning environment with annotation tools which enable the creation of PEOE or Vee diagram (Canas, Hill, Carff & Suri, 2015). These computer workspaces are tools that can support synchronous and asynchronous collaboration involving two or more learners in co-construct Vee diagrams or create PEOE worksheet. User can browse and edit the diagram produced by other learners, at the same time they can discuss online, enabling them to revise PEOE worksheet or Vee diagrams.

In spite of the value of using technology for this purpose, there are few examples of use of technology with Predict-Explain-Observe-Explain (PEOE) and Vee heuristic (VH) strategies particularly at the secondary school level. However, in educational settings, collaborative creation of PEOE worksheet or Vee diagram may take many forms. Session may be conducted face-to-face (Basque and Lavoie, 2016), or at a distance and may be synchronous such as all participants working concurrently, or asynchronous for instance one collaborator complete edits and then the another collaborator edits (Jonassen, Lee, Young, & Laffey, 2009). Collaborations in the creation of PEOE worksheet or Vee diagram in any of the contexts described in this study can be performed locally or at a distance and synchronously or asynchronously.

Chiu and Hsiao (2016) identified three forms of PEOE worksheet and Vee diagram creation in a collaborative learning situation as follows: Face-to-face computer-mediated PEOE creation or Vee Diagramming (VD), synchronous networked PEOE or VD, and asynchronous networked PEOE or VD. Mostly, face-to-face PEOE or VD research is usually conducted in laboratory settings. Specifically, participants were brought into the laboratory, assigned into small groups, and required to create a PEOE worksheet or construct a Vee diagram collaboratively only by communicating through networked computer limited time. Thus, most of the laboratory research findings reported in the literature on how PEOE worksheet or Vee diagrams are constructed collaboratively is not easily generalized into real world learning situations (Young, 2015).

From the foregoing, use of face to face table-top paper-pencil-collaborative predict-explain-observe-explain and Vee heuristic strategies even in the absence of computers, as the case, in some of the schools in the study area is a better option. Furthermore, no internet connection is required; internet connection is not available everywhere and even where it is available it can be subject to heavy controls and limitations. Since there is little empirical research on computer-mediated predict-explain-observe-explain and Vee diagram creation and the nature of task is similar to face-to-face as long as findings would be empirically-based and participants would be required to create predict-explain-observe-explain worksheet and Vee diagrams collaboratively. Therefore, in this study, face to face table-top paper-pencil predict-explain-observe-explain and face to face-table-top paper-pencil Vee heuristic instructional strategies were employed in this study.

2.3.7 Organic Chemistry

Chemistry is one of the three main branches of pure science, others being Biology and Physics. Chemistry has been defined differently by various authors. Ababio (2009) defined Chemistry as the branch of science that deals with the composition, properties and uses of matter. It probes into the principles governing the changes that matter undergoes. Omwirhiren (2015), Chemistry is a branch of science concerned with the properties, composition, and structure of substances and the changes they undergo when they combine or react under specified conditions. Furthermore, Chemistry can be characterized and studied under its varying branches; organic, inorganic, physical, analytical, industrial and nuclear.

Organic Chemistry which is the main focus of this study, in its simplest term is the Chemistry of carbon compounds, excluding carbon oxides, metal carbonyls, metallic carbonates and other related compounds (Inikori, 2013). Organic Chemistry is the Chemistry of hydrocarbon and its derivatives. Organic compounds are any of a large class of chemical compounds in which one or more atoms of carbon are covalently linked to atoms of other elements, most commonly hydrogen, oxygen, or nitrogen (Britannica, 2015). Organic Chemistry is an aspect of Chemistry involving the scientific study of structure, properties, and reactions of organic compounds and organic materials that is matter in its various forms that contain carbon atoms. The study of carbon compounds is considered as Organic Chemistry. It deals with carbon compounds ranging from solids like graphite, solvents and even gases.

Organic Chemistry is the study of carbon-based chemical compounds. Carbon is the sixth element in the periodic table and one of the most vital building blocks for life on earth. Living things are made up of molecules made mainly of carbon. This means that Organic Chemistry includes the Chemistry that goes on inside your body every day. It also includes the Chemistry that occurs inside animals, plants, and natural ecosystems (Leonard, 2012). Organic Chemistry is the study of the structure, properties, composition, reactions, and preparation of carbon-containing compounds, which include not only hydrocarbons but also compounds with any number of other elements, including hydrogen (most compounds contain at least one carbon-hydrogen bond), nitrogen, oxygen, halogens, phosphorus, silicon, and sulfur. This branch of Chemistry was originally limited to compounds produced by living organisms but has been broadened to include human-made substances such as plastics. The range of application of organic compounds is enormous and also includes, but is not limited to, pharmaceuticals, petrochemicals, food, explosives, paints, and cosmetics.

Aliu cited in Adewale (2014, p.43), outline some importance of Organic Chemistry as follows:

1. Medicine: Medicine is the prime store of organic compounds. Though not all but many medicines are made of organic substances such as antibiotics, anticancer drugs, painkillers, anti-depressant, and anesthetics.
2. Food: Food materials are solely made of carbon compounds via carbohydrate (CHO), proteins (NH_2-CH-COOH), and fats (CH-COO-CH). Even vitamins are organic in nature. Study of the requirement of body for various purposes like pregnancy, disease condition, and body fitness. Experts advice use of vitamins (Folic acid in pregnancy), fat (minimize in heart diseases) and (protein rich diet for body building).
3. Cleansing agents: In industries and laboratories, organic solvents are widely used to clear of impurities. For example in drug extraction from plants, the fatty matter from the pulp is removed using petroleum ether. Thus, Organic Chemistry through its knowledge of polarity, solubility, partition factors uses solvents to separate components for better use.
4. Sterilizing agents: Most of the sterilizing agents and disinfectants such as phenol, and formaldehyde are carbon compounds. Due to their properties such as solubility and pH they can kill microbes and even human body cells. These kill the bacteria and other microbes due to either dissolving the microbe cell wall or damaging the protein layer. Their efficiency is enhanced by making small tweaks in the chemistry. Besides

solvents there are gases such as ethylene oxide which are used for sterilization of drugs and manufactured substances.

5. Analytic substance: Most substance we use such as drugs, insecticides and pesticides are analyzed qualitatively and quantitatively using different types of titrations, chromatography techniques, and spectrophotometry. Here the reagent uses such as acids or bases or oxidative reductive species is organic in nature. Further the end point indicator in titration is developed by Organic Chemistry.
6. Valuable: Diamonds, graphite, petroleum. The carbon compounds such as diamonds, graphite and petroleum are found to be highly valuable, durable and hardest in the world. Diamond and graphite are both pure carbon alone compound without any other elements inside. They are both highly used and expensive. Their properties are studies in Organic Chemistry. Petroleum is the other most valued resources on the earth for fuels needs in the world. These petroleum products are further diversified for various uses. Petroleum is one of the factors which influence the world economy.

According to Leonard (2012, p.4), Organic Chemistry finds its application to a large extent in the field of medicine, petroleum, and textile as follows:

1. For analysis: Not all organic substance is soluble in water so they can be analyses by non-aqueous titration. For this they use organic solvents like pyridine, methanol, and acetone. Other methods such as chromatography, spectroscopy (infra red spectroscopy) also employ organic solvents for analysis. This analysis helps to test the given compound for its purity and quantity.
2. For synthesis: Organic Chemistry helps us synthesis many compounds which are needed on a large scale. For example, we find a drug molecule in nature by chance or as bi-product of some reaction. Then, such drug molecule can be synthesized by knowledge of Organic Chemistry for large scale use.

2.3.8 Students' Achievement in Chemistry

Achievement refers to the students' present performance level or academic skills in studying or reading Chemistry (Usman, 2011). The Longman Dictionary of Contemporary English (2009) defines achievement as something important that you succeed in doing by your own efforts. According to Central New Mexico (CNM) (2009), academic achievement is all about what students do when they have finished a course of study. Elliot and Zahn (2012) define achievement motive as a dispositional motivational tendency to energize competence-relevant behaviour and orient individuals towards success or failure possibilities. Those theorist have identified two primary achievement motives; the need for achievement which represents a desire to strategy success, and fear of failure, which represents a desire to avoid failure.

Elliot and Zahn (2012) further added that achievement value is the degree to which competence is considered important or valued by the individual. Elliot and Zahn (2012) viewed achievement value in terms of effectively based incentives for success or failure. The authors have retained the motion that value is grounded in effect, but have emphasized a general effective commitment to competence valuation rather than anticipations of a specific affect upon success. Achievement oriented behaviour may occur in any human endeavor that involves level of competence. Achievement situations typically contain cues pertaining to standard of excellence, which will indicate degree of competence or incompetence (Usman, 2011).

The issue of poor academic achievement in Chemistry at the secondary level of education in Nigeria has been widely documented. For instance, Daudu (2017) study on this issue revealed that all the secondary school candidates that registered for the West African School Certificate Examination in 2014 only 40.28% passed Chemistry at credit level and in the subsequent years the percentage passes at credit level dropped to 38.68% in 2015 and only 39.75% in 2016. This is an indication that the major problem facing the educational system in Nigeria is the abysmal failure of students in public examinations, particularly at the secondary level of education. Abe (2017) also revealed that of all secondary school candidates in Ekiti State that took the West African School Certificate Examination in 2015, only 39.94% passed Chemistry and in the subsequent years, 40.76% passed Chemistry in 2016; 38.32% passed Chemistry in 2017. Therefore, it appears right to claim, that there is a general trend of poor academic achievement in Chemistry both at the national and Ekiti State secondary education levels. The implication of the persistent poor achievement in Chemistry is that the much needed technological development of this nation will remain a wishful thinking until the inherent problems are identified and remedied.

Akorede (2017) observes that there is perennial poor Chemistry achievement in Nigerian secondary schools which has generated an overwhelming need for a review of current teaching and learning methods. The WAEC (2016) annual report specifically pointed out that that candidate’s Chemistry achievement were generally poor as the model marks for most centers, fell between 0 and 18%. The report further stated that about 82% of the candidates scored between 0 and 25% in Chemistry (essay) part II. Olorundare (2016) trace the problem of poor achievement in Chemistry among Nigerian secondary schools to quality of Chemistry teacher and the quality of his teaching, which stand out as the most contributory factors to the students’ poor achievement in Chemistry. This can verify the reason for which (43.70-40.18%) of students had achieved grade (A1-C6) in Chemistry between 2009 and 2018 (WAEC, 2018).

This shameful mass failure of students in Nigeria and Ekiti State in particular regretfully is a reflection of the precipice on which the nation has found itself. Thus, poor students’ achievement in Chemistry has in the recent time being traced to the poor teaching methods adopted by Chemistry teachers. To this effect, Olorundare (2016) suggested teaching and learning of Chemistry must also be improved in order to enhance students' achievement in the subject. Thus, would Predict-Explain-Observe-Explain (PEOE) and Vee heuristic strategies make teaching of Organic Chemistry in particular brighter, clearer and understandable to the students? Would it make much meaningful and wide demand on students' Chemistry achievement? Would PEOE and Vee heuristic strategies help the Chemistry teachers improve the quality of their teaching?

2.3.9 Students' Metacognitive Awareness in Chemistry

The term metacognitive awareness literally means cognition about cognition, or more informally, thinking about thinking. The concept of metacognitive awareness is most often associated with John Flavell (1979). He defined metacognitive awareness as knowledge about cognition and control of cognition. Metacognitive awareness as a concept originally indicates the individual's knowledge and regulation of one's cognitive activities in learning processes. Metacognitive awareness is the knowledge about one's capability to accomplish the task and control his/her thinking processes. Metacognitive awareness is a thinking activity that is closely related to constructivism because in order to build an understanding of a stimulus, one has to think and monitor his own thinking (Curwen, White-Smith, & Calfee, 2013).

Metacognitive awareness refers to an awareness of cognitive processes. Metacognitive awareness is not only thinking about thinking, but also regulating and executing cognition. In other words, the term metacognition refers to awareness and monitoring of one's thoughts and task performance or thinking about your thinking (Flavell, 1979 cited in Coutinho, 2014). It indicates high cognitive processes such as making plans for learning, using proper skills and strategies to resolve a problem, making approximation of performance and adjust the extent of learning (Coutinho, 2014). Metacognition awareness consists of two major components: metacognitive knowledge and metacognitive regulation. Metacognitive knowledge refers to knowledge of cognition such as knowledge of skills and strategies that work best for the learner and how and when to use such skills and strategies (Schraw & Dennison, 2011).

In other words, knowledge of cognition is defined as the knowledge about an individual's cognition as a learner and how, when and why to apply certain strategy to improve performance (Schraw & Dennison, 2011). Knowledge of cognition involves declarative knowledge, procedural knowledge and conditional knowledge. Declarative knowledge is recognition of self-skills, intellectual capacity and abilities. Students can gain this knowledge through presentations, demonstrations and discussions. Procedural knowledge is the knowledge of how to perform a specific task. In other word, it is the knowledge about the execution of procedural skills (Schraw & Moshman, 2012). Students can get this knowledge through discovery, collaborative learning and problem solving. Conditional knowledge is knowledge about when and why to use skills or Conditional knowledge is knowing when and why to apply various cognitive actions. Students can acquire this knowledge through simulations. Metacognitive regulation or regulation of cognition refers to activities that control one's thinking and learning. Regulation of cognition contains three regulatory skills such as planning, monitoring comprehension and evaluation (Çetin, 2015). Planning includes separating resources and selection of appropriate strategies. Monitoring is assessment of one's learning or strategy use. In other words, monitoring indicates individual's awareness of comprehension and task performance. Evaluation includes an individuals' evaluation of learning process or evaluating indicates the evaluation and judgment of outcomes and effectiveness of the regulation process if it matched the task goals (Çetin, 2015). Metacognitive awareness is vital to successful learning because it lets individuals to better regulate their cognitive skills and to determine weaknesses that can be corrected by constructing new cognitive skills (Schraw, 2013). The components of metacognitive awareness are shown in Figure 3.

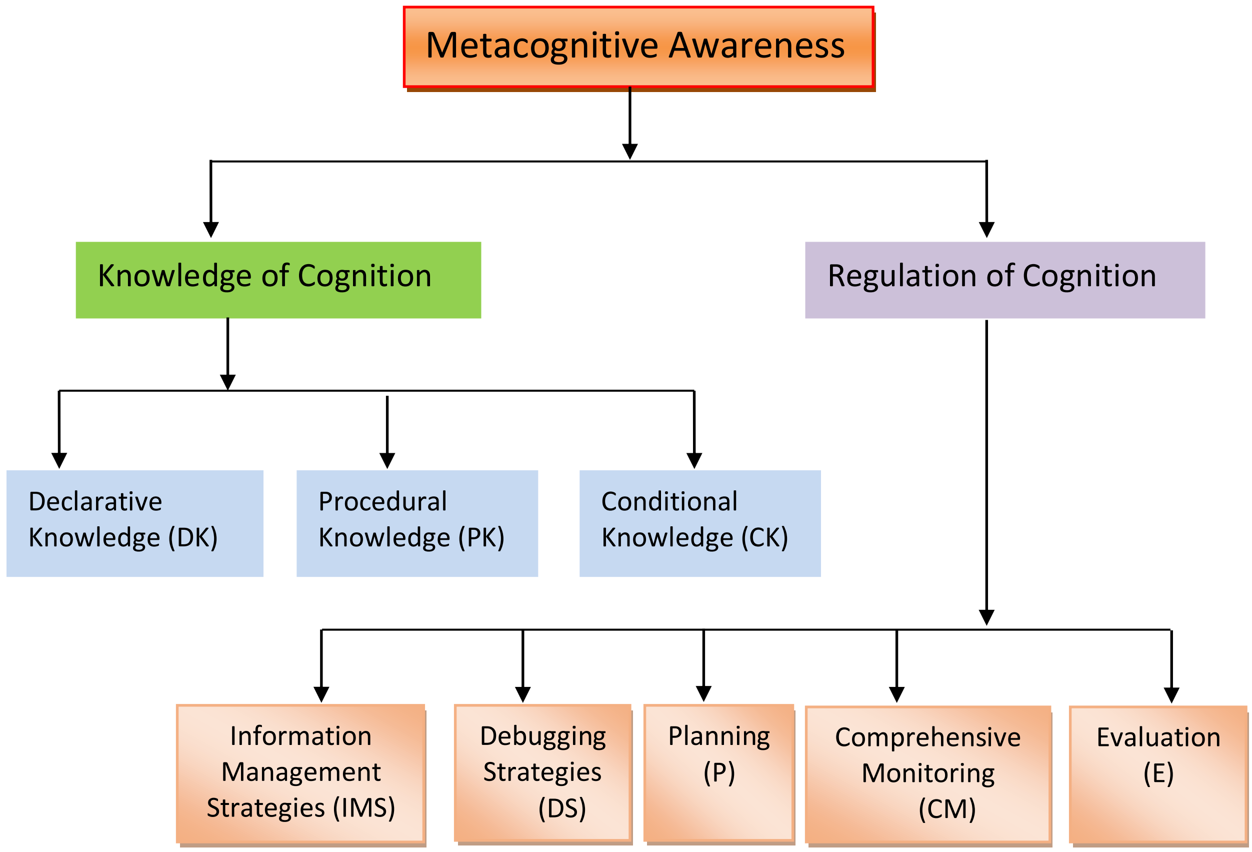


Fig 2: Metacognitive Awareness Components (Schraw, 2013).

According to Chatzipanteli, Grammatikopoulus and Gregoriadis (2014), metacognitive awareness is a teachable skill. Individuals, who are aware of their metacognitive skills, behave more strategically and productively, make plans, organize and monitor their learning better than individuals who are unaware about their metacognitive skills. According to Alexander and Jetton (2015), metacognitive processing is expressed through effective metacognitive instructional strategies which are procedural, purposeful, effortful, willful, essential and facilitative in nature. Metacognitive strategies are regarded as high order executive skills that make use of knowledge of cognitive processes and involve thinking about the learning process, planning for learning, monitoring the learning task, and evaluating how well one has learned (Chamot & Kupper, 2011; Wenden, 2013).

Olorunyomi (2016) stressed that learners are not aware of their metacognition in the study of Chemistry at all levels of education in Nigeria. This is often blamed on factors such as lack of Chemistry facilities, teachers' use of inappropriate teaching strategies and lack of qualified teachers' among other factors. Therefore, if learners' level of metacognitive awareness is concomitant with factor such as teachers' use of inappropriate teaching strategies, therefore, the study investigated if the use of predict-explain-observe-explain and Vee heuristic instructional strategies could enhance students' metacognitive awareness in Organic Chemistry.

2.3.10 Students' Self-Efficacy Belief in Chemistry

In the context of education, self-efficacy belief refers to a student's confidence in his or her ability to achieve specific academic tasks. Self-efficacy belief is the belief that one is capable of performing in a certain manner or attaining certain goals. Self-efficacy is the belief (whether or not accurate) that one has the power to produce an effect (Pajare & Urdan, 2014). For example, a person with high self-efficacy may engage in a more health related activity than when an illness occurs, whereas a person with low self-efficacy would habour feelings of hopelessness (Ormrod, 2011).

The definition of self-efficacy was further simplified by Bandura (2002). Self-efficacy was defined as a person's belief about their capability to produce designated levels of performance that exercises influence over events that affect their lives. Self-efficacy determines how people feel, think, motivate themselves and behave (Pajare & Urdan, 2014). A strong sense of efficacy enhances human accomplishment and personal well being in many ways. People with high assurance in their capabilities approach difficult task as challenges to be mastered rather than as a threat to be avoided. Such an efficacious outlook fosters intrinsic interest, and deep engrossment in activities (Bandura, 2002). It helps students set themselves challenging goals and maintain strong commitment to them. Students also heighten and sustain their efforts in the face of failure and quickly recover their sense of efficacy after failure or setback. Such students also attribute failure to insufficient effort or deficient knowledge and skills which are acquirable. Students also approach threatening situations with assurance that they can exercise control over them. Such an efficacy outlook produces personal accomplishments; reduces stress and vulnerability to depression (Zimmerman, 2012).

Individual's belief in their ability to exert control over their feelings of competence constitute self-efficacy (Elliot, Kratochwill, Littlefield and Travers, 2012). Furthermore, Joanne and Shui-fong (2012) are of the views that self efficacy is the judgment of personal capacity to perform a specific and prospective task. It affects an individual's level of motivation, affective states and action (Bandura, 2002). In general, individuals with high efficacy not only out-perform those with low efficacy but they also invest greater effort and persistence when facing setbacks (Bandura as cited in Joanne and Shui-fong, 2012). The concept of self-efficacy which is rooted in the socio-cognitive theory was proposed for the first time by Bandura (2002), "Self-efficacy is people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances".

Bandura (2002) postulated four principal sources of self-efficacy belief: Mastery experience, modeling or vicarious learning, verbal social persuasions and physiological factors.

i. **Mastery Experience:** Mastery experience is the most important factor deciding a persons' self-efficacy, simply put success raises self-efficacy, failure lower it.

ii. **Modeling/Vicarious Experience:** "If they can do it, I can do it as well". This is a process of comparison between a person and someone else. When people see someone succeeding at something, their self-efficacy will increase; and where they see people failing, their self-efficacy will decrease. This process is more effectual where the person sees himself as similarly to his /her model. If a peer who is perceived as having similar ability succeeds, this will likely increase an observers' self-efficacy. Although not as influential as past experience, modeling is a powerful influence when a person is particularly not sure of him/herself.

iii. **Social Persuasions:** Social persuasions relate to encouragement/discouragements. These can have a strong influence. Most people remember times where something said to them significantly altered their confidence. Where positive persuasions increase self-efficacy, negative persuasions decrease it. It is generally easier to decrease someone's self-efficacy belief than it is to increase it.

iv. **Physiological Factors:** In unusual, stressful situation, a person commonly exhibits signs of distress; shakes aches and pains, fatigue, fear and nausea. A person's perceptions of these responses can markedly alter a person's self efficacy. A person with high self-efficacy is likely to interpret such physiological signs as normal and unrelated to his/her actual ability, which will continue to be seen as a disregard for trembling hands. Thus, it is the person's belief on the implications of the physiological response that alters their self-efficacy, rather than the sheer power of the response.

Thus, school is a principal place where children develop the cognitive competencies and acquire the knowledge and problem solving skills essential for participating effectively in the larger society. Here are knowledge and thinking skills that are continually tested, evaluated and socially compared. As children master their cognitive skills; they develop a growing sense of their intellectual efficacy (Bandura, 2002). Students' belief in their capabilities to master academic activities affects their aspiration, their level of interest in academic activities, and their academic accomplishment (Schunk, 2009). Bandura (2002) maintained that an ideal school offers an excellent opportunity for the development of self-efficacy. Consequently, educational practice should reflect their reality. That is, materials and method should be evaluated not only for academic skills and knowledge, but also for what they can accomplish in enhancing students perception of themselves and social relationship.

According to Margolis and McCabe (2016), students with a strong self-efficacy are more likely to challenge themselves with difficult tasks and be intrinsically motivated. Self-efficacious students will exert a high amount of effort in order to meet their commitments, and attribute failure to factors which are in their control, rather than to external factors. These students recover quickly from setbacks, and ultimately are likely to achieve their personal objectives. Yet, students with low self-efficacy believe they cannot be successful and thus are less likely to make a concerted, extended effort and may consider challenging tasks as threats that are to be avoided. A number of studies have indicated that instructional strategies employed by teachers have a significant correlation with learner's level self-efficacy belief (Chou, 2011; Coutinho & Neuman, 2012; Mills, Pajares, & Herron, 2015). Gahungu (2016) showed that students who have high self-efficacy were more likely to use metacognitive instructional strategies when working on a task than those with low self-efficacy.

Bouffard-Bouchard, Parent, and Larivee (2014) concluded that students with high self-efficacy used more metacognitive instructional strategies than students with low self-efficacy. Pajares (2015) also points out that regardless of prior achievement; higher self efficacy is related to greater use of cognitive and metacognitive instructional strategies. It is on this note that, this study investigated if Predict-Explain-Observe-Explain and Vee heuristic instructional strategies have any effects on students' self-efficacy belief in Organic Chemistry in Ekiti State, Nigeria.

2.3.11 Gender Issues in Chemistry

Gender has been variously defined by different scholars. Ogunkunle (2014) opined that gender is dynamic and culturally determined whereby responsibilities are assigned to male and female children. The author further refers to gender as the characters, behaviours and roles which societies ascribed to male and females. Conceptually, gender has to do with socially constructed differences which lead to forms of inequality such that the male is regarded as superior and all-knowing and the female as inferior and incompetent. It is a term used to highlight social distinctions between male and female in terms of the position they occupy, the role they play and the social status they have. In African society, female are expected to be gentle, submissive, dependent, passive, emotional, seen but not heard, and their activities restricted to procreation and home keeping. For male they are expected to be aggressive, independent, rational, assertive and authoritative. Gender is seen in this sense as socially defined status, roles and action which differentiate men from women (Edo, 2016). Fink (2013) defines gender as a cultural construct which distinguishes the roles, behaviours, mental and emotional characteristics between male and female.

In a similar vein, Osagi (2012) see gender as the social attributes and opportunities associated with being male and female and the relationships between men and women, and boy and girls. Those attributes, opportunities and relationships are socially constructed and are learned through socialization process. One of the National objectives of Education as spelt out in the National Policy on Education (FGN, 2013) is to develop a Nigeria with bright opportunities for all citizens. The expectation of this policy is for equal opportunities to be made available for both male and female students to attain their maximum potentials in education. Instructional materials and teaching methods are expected to have gender equity if this policy is adhered to. Gender issues have attracted the attention of many psychologists, science educators and other researchers as a result of which a lot of literature exists on different aspects of the concept. For instance, numerous studies have been carried out on gender and social role; gender and work role; gender, science and technology and gender and achievement.

Gender inequality is still very prevalent. That sex roles are somewhat rigid in Africa, particularly in Nigeria, where gender differences are emphasized. To this certain vocations and professions have traditionally been regarded as men's (medicine, engineering, architecture), and others are women's (nursing, catering, typing, arts). Typically parents call on boys to wash cars, cut grass, fix bulbs or climb ladders to fix or remove things. On the other hand, chores such as washing dishes, cooking, cleaning and so on, are reserved for the girls (Arigbabu & Ariyo, 2009). The authors further added that what are regarded as complex and difficult tasks such as Chemistry are allocated to boys, where as girls are expected to handle the relatively easier tasks.

In science education generally, there is concern that girls are not achieving as boys (Ericson & Ericson, 2010; Welch, 2012; Jegede & Inyang, 2014). The difference seems to be more pronounced in the physical science. Fernema and Shema (2011) in Okoroafo (2014) noted that fewer girls take advanced sciences and mathematics courses and elect careers in sciences. Adebola (2015) noted that boys were superior to girls in school achievement especially in the sciences. Some researchers have advanced some reasons for the difference in male and female achievement in science subjects. Tracy (2016) postulates that, sex related differences might be related to social (that is, sex role model and orientation), educational and personal ability.

There are indications at all levels of education in Nigeria that females are grossly under-represented in terms of enrolment, participation and achievement in science, technology and mathematics (Okeke, 2009; Maduabum, 2011; Anaekwu & Nnaka, 2012). Becker and Hall (2014) attributed the difference to teacher characteristics. The authors opined that the teachers were friendlier with boys, which created a better rapport for better understanding for the boys. Meanwhile, some studies indicate that boys achieve better (Gipps, 2014; Kingdon, 2015), either no difference (Achor, Wude & Duguryil, 2013; Ventura, 2013; Calsambis, 2014; Ajayi & Ogbeba, 2017) or girls outperform boys (Calsambis, 2013; Soyibo, 2014) have been demonstrated. Though these researchers did not emphasize Predict-Explain-Observe-Explain (PEOE) and Vee heuristic instructional strategies, the researchers referred to instructional strategies of teaching Chemistry as such could be applied. More so, PEOE and Vee heuristic instructional strategies may be the instructional strategies that could close the gap among gender in Organic Chemistry. Therefore, the study investigated if the relationship changes in sex of students could predict their achievement, metacognitive awareness and self-efficacy in Organic Chemistry using predict-explain-observe-explain and Vee heuristic instructional strategies as instructions.

2.3.12 Interaction Effect

An interaction effect is the simultaneous effect of two or more independent variables on at least one dependent variable in which their joint effect is significantly greater (or significantly less) than the sum of the parts (Lavrakas, 2008). The presence of interaction effects in any kind of survey research is important because it tells researchers how two or more independent variables work together to impact the dependent variable. Including an interaction term effect in an analytic model provides the researcher with a better representation and understanding of the relationship between the dependent and independent variables. According to Lavrakas (2008), interaction effect helps explain more of the variability in the dependent variable. Cox (2014) describes interaction effect as the differing effect of one or more independent variable on the dependent variable, depending on the particular level of another independent variable. Statistical interaction means the effect of one independent variable on the dependent variable depends on the value of another independent variable.

In statistics, an interaction may arise when considering the relationship among three or more variables, and describes a situation in which the effect of one causal variable on an outcome depends on the state of a second causal variable (that is, when effects of the two causes are not additive) (Dodge, 2013). According to Denga (2017) an effect of interaction occurs when a relation between (at least) two variables is modified by (at least one) other variable. In other words, the strength or the sign (direction) of a relation between (at least) two variables is different depending on the value (level) of some other variable(s). The term "modified" in this context does not imply causality but represents a simple fact that depending on what subset of observations (regarding the "modifier" variable(s)) you are looking at, the relation between the other variables will be different.

Two independent variables interact if the effect of one of the variables differs depending on the level of the other variable. Treatment interaction according to Abonyi (2014) generally implies that different learners with different characteristics may profit more from one type of instructional method than from another and that therefore it may be possible to find the best match of learners' characteristic and instructional method in other to maximize learning outcomes. In this regard, the study investigated if the simultaneous effect of two independent variables (Predict-Explain-Observe-Explain and Vee heuristic strategy) on one dependent variable (gender) is significantly greater (or significantly less) than the sum of the parts.

2.4 Empirical Studies

In this section some research works relevant to this work have been reviewed. Teerasong, Chantore, Ruenwongsa and Nacapricha (2016) conducted a research on the effect of Predict-Explain-Observe-Explain (PEOE) and lecture teaching strategies on achievement of Elementary Basic Science students in Thailand. The study involved 103 participants in four elementary grade II classes of Mahidol University Staff School, Central Thailand. All the four classes were exposed to a 12 weeks teaching period. Two research questions and two hypotheses guided the study. The study used pre-test, post-test quasi experimental design. Three classes were designated to the PEOE group while the fourth was designated to the lecture group. A validated 40-item Elementary Basic Science Achievement Test (EBSAT) was the instrument used to collect data. Mean (M) and Standard Deviation (SD) scores were used to answer the research questions while t-test was used to test the hypotheses at 0.05 levels of significance. The result revealed, among others that, students' in PEOE group who were allowed to predict, explain, observe, and explain in order to construct knowledge themselves performed better than those in lecture group who were passive listeners.

This reviewed study has a basis or implication for the present study though the study was on achievement in Elementary Basic Science, and it was carried out in Central Thailand. Though the reviewed study was carried out in Central Thailand, the study is similar to the present study in terms of teaching strategy. Meanwhile, the reviewed study did not established if PEOE and Vee heuristic strategies have any effect on students' metacognitive awareness, and self-efficacy belief. Likewise, the reviewed study did not also establish if the teaching strategy has any effect on male and female students' achievement, self-efficacy belief and metacognitive awareness specifically in Organic Chemistry. In the same vein, the method of data analysis used in the reviewed study was t-test. However, the present study employed mean and standard deviation to answer the research questions and analysis of covariance was used to test the null hypotheses. Thus, the present study investigated whether Predict-Explain-Observe-Explain and Vee heuristic instructional strategies have any effects on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry in Ekiti State, Nigeria as a study area.

Bajar-Sales, Avilla and Camacho (2015) investigated Predict-Explain-Observe-Explain (PEOE) approach as a tool in relating metacognition to achievement in Biology in Philippines. The study was conducted to investigate the effectiveness of PEOE approach on students' performance in Biology. This study also determined the correlation of metacognition to students' achievement. Students' were assigned to comparison group (CG) and experimental group (EG). Three research questions and four null hypotheses guided the study. The study employed quasi-experimental research design. Instruments such as

Metacognitive Awareness Inventory (MAI) to measure students' metacognitive awareness, and teacher-made summative test in Biology were used. Descriptive statistics was used to determine the average score on each strand and domain from the MAI. Paired samples t-test was used for testing significant differences between pretest and posttest mean scores of both groups. Independent samples t-test was used for testing of significant differences between groups in terms of their pretest and posttest mean scores. Pearson correlation moment was employed to determine the significant relationship between metacognitive awareness and achievement in Biology. Results revealed that both groups had significantly improved posttest scores, with experimental group gaining significantly higher posttest scores. The result also revealed that there is a significant relationship between metacognition awareness and achievement of students.

This implies that students' achievement was determined by the level of metacognitive awareness. Though the reviewed study was carried out in Philippines, the study is similar to the present study in terms of teaching strategy but the reviewed study did not establish if Predict-Explain-Observe-Explain and Vee heuristic have any effect on students' metacognitive awareness, and self-efficacy belief. Likewise, the reviewed study did not also establish if PEOE have any effect on male and female students' achievement, self-efficacy belief and metacognitive awareness specifically in Organic Chemistry. In the same vein, the methods of data analysis used in the reviewed study were t-test and Pearson correlation moment. However, the present study employed mean and standard deviation to answer the research questions and analysis of covariance was used to test the null hypotheses. Thus, the present study investigated if predict-explain-observe-explain and Vee heuristic instructional strategies have any effects on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry in Ekiti State, Nigeria as a study area.

Karamustafaoğlu and Mamlok-Naaman (2015) investigated the understanding electrochemistry concepts using the Predict-Observe-Explain strategy. The study deals with freshman students who study at the Department of Science at the Faculty of Education in Amasya University, Turkey. The aim of the study was to investigate the effect of teaching electrochemistry concepts using Predict-Observe-Explain (POE) strategy. The study was quasi-experimental design using 20 students each in the experimental group (EG) and control group (CG). Two research questions and two null hypotheses guided the study. An Open-Ended Test (OET) and Multiple Choice Test (MCT) were used as pre- and post-test respectively. Mean (M) and Standard Deviation (SD) scores were used to answer the research questions while Analysis of Covariance (ANCOVA) were used to test the hypotheses. The results of the study revealed that using Predict-Observe-Explain strategy significantly enhance students understanding in electrochemistry concepts than lecture method.

Though the reviewed study was carried out in Turkey, the study is similar to the present study in terms of teaching strategy, though the strategy used did not emphasize the important of students' explanation for their prediction and the study did not establish if there is any difference between male and female understanding of Chemistry concept which the present study addressed. Likewise, the reviewed study did not also established if PEOE have any effect on students' metacognitive awareness and self-efficacy belief specifically in Organic Chemistry. Though, the method of data analysis used in the reviewed study is the same with the method of data analysis that was used in the present study but, the reviewed study used freshman students who study at the Amasya University, Turkey. Meanwhile, the present study used senior secondary students in Ekiti State, Nigeria. Thus, the present study investigated if predict-explain-observe-explain and Vee heuristic instructional strategies have any effects on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry in Ekiti State, Nigeria as a study area.

Demircioğlu, Demircioğlu and Aslan (2017) investigated the effect of Predict-Observe-Explain (POE) technique on the understandings of grade 11 Chemistry students about the gases in Trabzon. Quasi-experimental research design was adopted in the study. Two classes in Anatolian high school in Trabzon were randomly selected for the study. One of the classes was randomly assigned as experimental group (N=36), the other was determined as control group (N=37). Gases Concept Test (GCT) consisting of 20 multiple choice items was used. The test' reliability coefficient (KR-20) was found 0.84. Eight activities based on POE technique were developed and applied to the experimental group students. On the other hand, the control group students were taught by traditional approach. Mean and Standard Deviation Score was used to answer the research question and ANCOVA was used test the null hypothesis. The results indicated that the students in experimental group taught using Predict-Observe-Explain technique showed a higher success than the control group students.

The reviewed work is similar to the present study in terms of teaching strategy. Though the strategy used did not emphasized the importance of students' explanation for their prediction and did not establish if there is any difference between male and female understanding of Chemistry concept which the present study addressed. However, the study did not established if Vee heuristic strategy has any effect on students' achievement, metacognitive awareness and self-efficacy belief. Thus, the present study investigated if predict-explain-observe-explain and Vee heuristic instructional strategies have any effects on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry.

Ubi (2015) carried out a study on relative effectiveness of Predict-Observe-Explain (POE) and lecture methods of teaching Basic Science on academic performance of secondary students in Akwa Ibom State, Nigeria. Four research questions and four hypotheses guided the study. The research design was pretest, posttest quasi-experimental design. The sample of the study was made up of 300 randomly sampled students from six public secondary schools in the State. The independent t-test statistical instrument was used in analyzing the data at 0.05 levels of significance. The result revealed that students taught with the POE were superior in terms of performance than those taught using lecture method.

The reviewed study is similar to the present study is terms of teaching strategy. Though, the strategy used did not emphasis the importance of students' explanation for their prediction and did not establish if there is any difference between male and female performance which the present study addressed. However, the study did not establish if Vee heuristic strategy has any effect on students' achievement, metacognitive awareness and self-efficacy belief. In the same vein, the method of data analysis used in the reviewed study was independent t-test. However, the present study employed mean and standard deviation to answer the research questions and analysis of covariance was used to test the null hypotheses. Thus, the present study investigated if predict-explain-observe-explain and Vee heuristic instructional strategies have any effects on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry.

Gernale, Arañes, and Duad (2015) investigated the effects of Predict-Observe-Explain (POE) approach on Students' achievement and attitudes towards Science. This study was conducted in Gonzalo Gatchalian Elementary School in Las Piňas City. The subject of the study consists of two hundred and twenty (220) in Gonzalo Gatchalian Elementary School in Las Piňas City. Science Achievement Test (SAT) and Learning Science Attitude Inventory (LSAI) were the instruments used for data collection. The study found coefficient of alpha

0.82 and 0.74 for SAT and LSAI respectively. Three null hypotheses guided the study. The study employed the repeated measures two factors design. The dependent t-test was used to for data analysis. The results revealed that the gain scores in the achievement and attitude of students in the experimental group (POE approach) performed better than the control group (lecture method).

Though the strategy used did not emphasized the important of students' explanation for their prediction and did not establish if there is any difference between male and female understanding of science, particularly in Organic Chemistry concept which the present study addressed. However, the study did not established if Vee heuristic strategy has any effect on students' achievement, metacognitive awareness and self-efficacy belief. In the same vein, the method of data analysis used in the reviewed study was dependent t-test. However, the present study employed mean and standard deviation to answer the research questions and analysis of covariance was used to test the null hypotheses. Thus, the present study investigated if predict-explain-observe-explain and Vee heuristic instructional strategies have any effects on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry in Ekiti State, Nigeria.

Njue, Kamau and Mwania (2018) investigated the effects of Vee heuristic teaching approach on secondary school students' attitudes towards Biology in Kenya. This study was conducted in public secondary schools in Tharaka Nithi County. Solomon Four-Group Non Equivalent Control Group Design was used. Data was collected from 12 schools randomly sampled from within the county. The sample comprised of 396 from 2 students from four boys, four girls and four co-educational schools. Two hypotheses guided the study. A Biology Attitude Questionnaire was developed and used for data collection. The instruments were pilot-tested in one boy's, one girl's and one co-educational school in Embu East Sub-county to ascertain its reliability. The reliability coefficient was estimated using Cronbach's coefficient alpha. A coefficient value of 0.83 was obtained from the research instruments. Hypotheses were tested using ANOVA and t-test statistics at 0.05 level of significance. Means were separated using least significant. The study found that Vee heuristics teaching approach facilitated students' attitude in biology subject compared to conventional teaching method.

The reviewed work is similar to the present study in terms of teaching strategy. Though in Biology, however the study did not establish if Vee heuristic strategy has any effect on students' achievement, metacognitive awareness and self-efficacy belief. The research design used in the reviewed study was Solomon Four-Group Non Equivalent Control Group Design. Meanwhile, the present study adopted a quasi-experimental non-randomized pre-test, post-test control group design. In the same vein, the methods of data analysis used in the reviewed study were ANOVA and t-test. However, the present study employed mean and standard deviation to answer the research questions and analysis of covariance was used to test the null hypotheses. Thus, the present study investigated the effects of predict-explain-observe-explain and Vee heuristic instructional strategies on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry in Ekiti State, Nigeria.

Mutai, Changeiywo and Okere (2014) investigated the effects of Gowin's Vee heuristic strategy on secondary school students' conceptual understanding and metacognition in the topic of moments in Physics, in Uasin Gishu County, Kenya. Solomon-four quasi-experimental design was used. The experimental groups were taught using Gowin's Vee as treatment and the control groups were taught using conventional methods. Purposive sampling was used to select 134 students to the control and experimental groups. The instruments used were Physics Metacognitive Activity Inventory Questionnaire (PMCAIQ) to test their metacognition and Physics Conceptual Understanding Achievement Test

(PCUAT) to test conceptual understanding. Reliability of instruments was done using the coefficient of alpha for both instruments. The study found coefficient of alpha 0.75 and 0.78 for PCUAT and PMCAIQ respectively. The data was subjected to descriptive statistics such as mean and standard deviation and inferential statistics was done using t-test and one way ANOVA at 0.05 level of significance. The result revealed that Vee heuristic strategy was more effective in enhancing students' conceptual understanding and metacognition in the topic of moments in Physics than conventional method.

Though, the reviewed study is similar to the present study in terms of teaching strategy. But the study was on students' conceptual understanding and metacognition in Physics, and it was carried out in Uasin Gishu County, Kenya. Likewise, the study did not establish if Vee heuristic has any effect on male and female students' achievement and self-efficacy belief specifically in Organic Chemistry. In the same vein, the research design used in the reviewed study was Solomon Four-Group Non Equivalent Control Group Design. Meanwhile, the present study adopted a quasi-experimental non-randomized pre-test, post-test control group design. Thus, the present study investigated whether predict-explain-observe-explain and Vee heuristic instructional strategies have any effects on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry in Ekiti State, Nigeria as a study area.

Fred (2015) investigated the effect of Vee heuristic strategy on students' motivation and achievement in Biology in Secondary Schools in Uasin Gishu district, Kenya. The purpose of the study was to measure the effect of Vee heuristic strategy on students' achievement and motivation in Biology in mixed provincial secondary schools in Uasin Gishu District, Kenya. A Quasi-experimental research based on the Solomon Four group design was used. All students in secondary school in Uasin Gishu District constituted the target population. The accessible population constituted all the form two students. Four mixed schools were sampled and randomly assigned to the experimental and control groups. One form two stream from each school was selected and this gave a total sample size of 144 students. Four research questions and hypothesis guided the study. The research instruments used to collect data included the Biology Achievement Test (BAT) and Students Motivation Questionnaires (SMQ). The data was analyzed using one-way ANOVA and t-test. Hypotheses were tested at alpha is equal to 0.05 level of significance. The results show that students taught using the Vee heuristic strategy had higher motivation and achievement than students taught using the traditional teaching methods. The results also indicated that students' gender did affect achievement in Biology where girls performed better than boys.

The reviewed work is similar to the present study in terms of teaching strategy, though in Biology and it also has gender variable which the present study addressed. However, the study did not establish if Vee heuristic strategy has any effect on students' metacognitive awareness and self-efficacy belief. In the same vein, the research design used in the reviewed study was Solomon Four-Group Non Equivalent Control Group Design. Meanwhile, the present study adopted a quasi-experimental non-randomized pre-test, post-test control group design. Thus, this study investigated the effects of predict-explain-observe-explain and Vee heuristic instructional strategies on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry.

Haruna (2016) investigated the effect of Vee heuristic strategy on students' achievement in Physics among senior secondary students in Akwanga local Government Area of Nasarawa State. The study adopted a quasi-experimental non-randomized pre-test, post-test control group. A sample of 174 Senior Secondary II (SS2) students from six schools out of a population of 4,936 SS2 Physics students was used. A validated 25-item Physics Achievement Test (CAT) was the instrument used for data collection. Three research question and hypothesis guided the study. Mean and standard deviation were used to answer the research questions while Analysis of Covariance (ANCOVA) was used to test the hypotheses at 0.05 level of significance. The result revealed that Vee heuristic strategy was more effective in enhancing students' achievement in Physics. The male students performed better than their female counterparts.

Location and schools type were found to have no significant effects on students' achievement. The reviewed work is similar to the present study in terms of teaching strategy, though in Physics and it also has gender variable which the present study addressed. However, the study did not establish if Vee heuristic strategy has any effect on students' metacognitive awareness and self-efficacy belief. Thus, this study investigated the effects of predict-explain-observe-explain and Vee heuristic instructional strategies on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry in Ekiti State, Nigeria.

Njue and Magana (2016) investigated the effects of Vee heuristic teaching approach on achievement of boys and girls in Biology in Public Secondary Schools in Kenya. Four null hypotheses guided the study. This study was conducted in public secondary schools in Tharaka Nithi County, Kenya. Solomon Four-Group Non Equivalent Control Group Design was used. Data was collected from 12 schools randomly sampled from within the county. The sample comprised of 396 Form 2 students from four boys, four girls and four co-educational schools. A Biology Achievement Tests were developed and used for data collection. The instruments were pilot-tested in one boy's, one girl's and one co-educational school to ascertain its reliability. A reliability coefficient value of 0.83 was obtained. Hypotheses were tested using t-test statistics at 0.05 level of significance. Means were separated using Least Significant Difference (LSD) pair wise post-hoc comparisons.

The study found that Vee heuristic teaching approach facilitated students' achievements in Biology regardless of gender. The reviewed work is similar to the present study in terms of teaching strategy, though in Biology and it also has gender variable which the present study addressed. However, the study did not establish if Vee heuristic strategy has any effect on students' metacognitive awareness and self-efficacy belief. In the same vein, the research design used in the reviewed study was Solomon Four-Group Non Equivalent Control Group Design. Meanwhile, the present study adopted a quasi-experimental non-randomized pre-test, post-test control group design. In the same vein, the method of data analysis used in the reviewed study was t-test. However, the present study employed mean and standard deviation to answer the research questions and analysis of covariance was used to test the null hypotheses. Thus, this study investigated the effects of predict-explain-observe-explain and Vee heuristic instructional strategies on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry in Ekiti State, Nigeria.

Okafor (2016) investigated the effect of Vee Heuristic on students' achievement in Basic Science. The study was carried out in Ebonyi State of Nigeria. The study employed a quasi experimental design. Specifically the pretest posttest non-equivalent control group research design was used. The sample was 153 students selected from two secondary schools drawn from the population through a simple random sampling. One school was used for treatment and the other for control. The treatment group was taught basic science with Vee Heuristic approach while the other was taught with conventional method. Three research questions and three null hypotheses guided the study. Mean, standard deviation and the t-test were used to analyze data. Results showed that Vee Heuristic fosters students' achievement in basic science than conventional method.

It enhances the achievement of both male female students in the subject. In addition there is no interaction between gender and teaching methods on students' achievement in Basic Science. The reviewed work is similar to the present study in terms of teaching strategy, though in Basic Science and it also has gender variable which the present study addressed. However, the study did not establish if Vee heuristic strategy has any effect on students' metacognitive awareness and self-efficacy belief. In the same vein, the method of data analysis used in the reviewed study was t-test. However, the present study employed mean and standard deviation to answer the research questions and analysis of covariance was used to test the null hypotheses. Thus, this study investigated the effects of predict-explain-observe-explain and Vee heuristic instructional strategies on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry in Ekiti State, Nigeria.

2.5 Summary

This study was anchored on three theories which emphasized the fact that predict-explain-observe-explain and Vee heuristic strategies in teaching/learning could improve achievement, metacognitive awareness, and self-efficacy belief. These theories are Ausubel's assimilation learning theory, Piaget's cognitive development theory, and Vygotsky's social development theory. The theories described the process of learning by the active involvement of the learner in knowledge creation to improve learning experiences and metacognitive awareness of such concept which is the aim of this research work.

Conceptual issues such as Predict-Explain-Observe-Explain (PEOE) instructional strategy, Vee heuristic instructional strategy, discussion method, collaborative learning, facilitating collaborative learning using PEOE and Vee heuristic instructional strategies, PEOE, Vee heuristic instructional strategies and information communication and technology (ICT), Organic Chemistry, students' achievement in Chemistry, students' metacognitive awareness in Chemistry, students' self-efficacy belief in Chemistry, gender issues in Chemistry, and interaction effect were discussed in the context of the study.

Achievement of students in Chemistry in general and Organic Chemistry in particular is reported to be generally poor, which attracted the attention of many science educators and researchers. The researcher hoped that Predict-Explain-Observe-Explain (PEOE) and Vee heuristic instructional strategies to learning could bring about improves achievement, metacognitive awareness and self-efficacy belief. Review on gender, achievement, metacognitive awareness, and self-efficacy belief in Chemistry has been included. The comparisons of overall achievement, metacognitive awareness and self-efficacy belief between the entire male and female students from one finding/result to another were in disagreement.

This research study also considered some empirical studies that are relevant to the present study. The review has shown that Predict-Explain-Observe-Explain (PEOE) and Vee heuristic strategies enhance students' achievement, attitude, motivation, and conceptual understanding in science subjects. Scarcity of such studies that bring together students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry using PEOE and Vee heuristic instructional strategies has informed this present study.

In the light of this trend of diverse results in the general findings of those studies provided by the review, the present researcher finds it necessary to investigate if Senior Secondary two (SS2) students' achievement, metacognitive awareness, self-efficacy belief could be enhanced in Organic Chemistry using Predict-Explain-Observe-Explain and Vee heuristic instructional strategies and more so, in Ekiti State, Nigeria as a study area.

CHAPTER THREE
RESEARCH METHOD

3.1 Introduction

This chapter describes the method that was used in carrying out the study. It is discussed under the following sub-headings: research design, area of study, population, sample and sampling, instrumentation, validation of instruments, reliability, method of data collection and method of data analysis.

3.2 Research Design

The study adopted a quasi-experimental non-randomized pre-test, post-test control group design. This design was adopted because it is not possible to have complete randomization of the subject as this may disrupt school organization. The main thrust of the experimental design is to establish cause-and-effect relationship between the dependent (achievement, metacognitive and self-efficacy belief) and independent variables (Predict-Explain-Observe-Explain and Vee Heuristic). The design is considered appropriate because it is the most powerful and valid design which can be used to identify confidently the cause of any given effect (Emaikwu, 2013). The schematic design of this study is as shown:

$$A \longrightarrow T_1 \longrightarrow X_1 \longrightarrow T_2$$

$$B \longrightarrow T_1 \longrightarrow X_2 \longrightarrow T_2$$

$$C \longrightarrow T_1 \longrightarrow X_0 \longrightarrow T_2$$

Fig 3: Schematic design of the Study

Where:

A = Experimental group 1.

B = Experimental group 2.

C = Control group.

T_1 = Administration of Pre-OCAT, Pre-MAI, and Pre-OCSEB.

T_2 = Administration of Post-OCAT, Post-MAI, and Post-OCSEB.

X_1 = Administration of first treatment (Predict-Explain-Observe-Explain Strategy).

X_2 = Administration of second treatment (Vee Heuristic Strategy).

X_0 = Absence of any treatment and use of Discussion method.

3.3 Area of Study

The study area is Ekiti State, Nigeria. Ekiti State is situated entirely within the tropics. It is located between longitudes 40^0 51^1 and 50^0 451^1 East of the Greenwich meridian and latitudes 70^0 151^1 and 80^0 51^1 North of the Equator and covers an area of about 6, 353 square kilometers and the state enjoys tropical climate with two distinct seasons (National Population Commission, 2006). These are the rainy season (April-October) and the dry season (November-March) with annual temperature ranges between 21^0C and 28^0C with high humidity. Ekiti State shares boundaries with Kwara and Kogi State in the South, Osun State in the East, and Ondo State in the East and in the South. Ekiti State was carved out of Ondo State in 1996 with its capital in Ado Ekiti. It has an estimated population of 2,398,957 people (NPC, 2006).

Ekiti State is made up of sixteen Local Government Areas and it is divided into three Zones; Ekiti North, Ekiti Central and Ekiti South with many institutions at all levels. Ekiti North comprised of five Local Government Areas namely: Ido/Osi, Ikole, Ilejemeje, Moba and Oye. Ekiti Central comprised of five Local Government Areas namely: Ado Ekiti, Efon, Ekiti-West, Ijero, and Irepodun/Ifelodun. Ekiti South comprised of six Local Government Areas namely: Ekiti East, Ekiti South-West, Emure, Gbonyin, Ikere and Ise/Orun. Yoruba speaking people are the most populous and ethnic group in Ekiti State. However, other non-indigenous groups such as Akoko, Ijaw, Hausa, Igbo and Igala can also be found in the state.

The inhabitants despite being predominantly farmers have serious love for education and proper educational training of their children. Ekiti State has 541 Primary Schools and 223 Secondary Schools and four Universities namely: Ekiti State University, Ado Ekiti, Federal

University Oye-Ekiti, National Open University of Nigeria, Ado Ekiti and Afe Babalola University, Ado Ekiti. It has two polytechnics namely: Federal Polytechnic, Ado Ekiti, and Crown Polytechnic, Ado Ekiti. It also has one College of Education namely: College of Education, Ikere Ekiti, which are established by Federal and State governments as well as private and corporate bodies (Ekiti State Teaching Service Board, Statistics Unit 2018). The choice of this state for the study was premised on the fact that there was a scarcity of such studies on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry using predict-explain-observe-explain and Vee heuristic instructional strategies in the study area.

3.4 Population

The target population for this study comprises all students offering Chemistry at Senior Secondary two (SS2) numbering 14,753 from all the 223 approved senior secondary schools in the 16 Local Government Areas of Ekiti State, Nigeria. The population of the study consisted of SS2 students made up of 7,768 boys and 6,985 girls (Ekiti State Teaching Service Board, Statistics Unit, 2018) (Appendix G).

3.5 Sample and Sampling

The sample of this study was made up of 308 Senior Secondary two (SS2) students offering Chemistry that were drawn from 9 schools: three schools respectively in Ekiti North, Ekiti Central and Ekiti South of Ekiti State, Nigeria. A multi-stage sampling technique was used in the study. In stage one, three Local Government Areas (LGAs) each were selected out of Ekiti North, Ekiti Central and Ekiti South respectively. One school from each of the nine LGAs was drawn using purposive sampling technique. These schools were selected based on the following conditions:

1. Government grant-aided;
2. Co-educational schools;

3. Chemistry teachers with a minimum qualification of first degree in Chemistry/Education with at least three years of teaching experience;
4. Chemistry Laboratory with at least a laboratory attendant; and
5. Where the school authorities permitted the carrying out of the experiment (Appendix H).

One intact class from each of the nine sampled schools was selected using simple random sampling. They were assigned randomly to experimental group 1, experimental group 2 and control group. The experimental group 1 comprised three intact classes; experimental group 2 comprised three intact classes while the control group also comprised three intact classes respectively (Appendix I).

3.6 Instrumentation

Three instruments were used in this study. They are listed and described as follows:

a. Organic Chemistry Achievement Test (OCAT);

b. Metacognitive Awareness Inventory (MAI); and

c. Organic Chemistry Self-Efficacy Belief Scale (OCSEBS).

(a) Organic Chemistry Achievement Test (OCAT)

Organic Chemistry Achievement Test (OCAT) was adopted from West African Examination Council (WAEC) past examination question papers of 2003-2017. OCAT items were based on WAEC, which is standardized, since the target of the study was to improve the students' achievement, at this level. The test instrument consists two sections. Section A consists bio-data information about the respondents, while section B consists of 40 structured multiple choice objective items with four options (A, B, C, D) drawn from the concepts of Organic Chemistry to which respondents were expected to provide the correct answers by selecting the correct option. The content of OCAT was drawn based on the senior secondary school Chemistry syllabus. Although the test items were standardized, they were still subjected to item analysis, and categorized into six cognitive ability levels, reflecting the percentages of each of the levels covered by the test items as follows; knowledge = 12.5%, comprehension =30.0%, application =45.0%, analysis =7.5%, synthesis =2.5%, evaluation = 2.5%. The table of specification of the test items used in this study revealed that most of the questions were on application (Appendix Q). This agrees with the National Senior Secondary School Chemistry curriculum which suggests that application domain should be predominant at this level (NERDC, 2012).

(b) Metacognitive Awareness Inventory (MAI)

Metacognitive Awareness Inventory (MAI) was adopted from Lai (2011) and Schraw and Dennison (2012). Lai (2011) organized the different types of knowledge of cognition into three types and listed three (3) main terminologies to represent the different types of knowledge of cognition. In the same vein, Schraw and Dennison (2012) also enumerated five (5) terminologies in regulation of cognition. MAI is a forty-item inventory which is expected to determine the frequency of students' metacognitive awareness during Chemistry classes. MAI is a 4-Likert scale with number indicators as 4 (always aware), 3 (frequently aware), 2 (sometimes aware), and 1 (never aware) which was used in the knowledge of cognition while the regulation of cognition has number indicators of 4 (always), 3 (frequent), 2 (sometimes), and 1 (never). Each subcategory comprises five (5) statements (Appendix R).

(c) Organic Chemistry Self-Efficacy Belief Scale (OCSEBS)

Organic Chemistry Self-Efficacy Belief Scale (OCSEBS) is a researcher made 20 items questionnaire which was intended to help students express their confidence or belief in solving Organic Chemistry related problems. Each of the items is a 4-point Likert-rating scale with 4 response options. The options are Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD). OCSEBS is a 4-Likert scale with number indicators as 4 (strongly agree), 3 (agree), 2 (disagree), and 1 (strongly disagree). The items were developed from information acquired through review of relevant literature by the researcher (Appendix S).

(d) Lesson Plans

Eighteen (18) lesson plans were prepared altogether on the six selected Organic Chemistry sub-topics and was taught for six weeks. For each of the six Organic Chemistry sub-topics, six lesson plans were prepared using predict-explain-observe-explain strategy, Vee heuristic strategy and discussion method respectively (Appendices, X, Y & Z).

3.6.1 Validation of Instruments

Organic Chemistry Achievement Test (OCAT), Metacognitive Awareness Inventory (MAI), Organic Chemistry Self-Efficacy Belief Scale (OCSEBS) and instructional packages (lesson plans) were face validated by presenting them to five experts in Science Education and one lecturer that is knowledgeable in test and measurement in the Department of Mathematics and Science Education, Benue State University, Makurdi and one expert in test and measurement in the College of Agricultural and Science Education, Department of Educational Foundations and General Studies, Federal University of Agriculture, Makurdi. OCAT which consisted of 50 multiple choice items are standardized test. However, since standardized tests do have environmental, regional and sociological sensitivity the items were scrutinized by these experts. The experts were asked to assess the instruments in terms of scope of coverage, content relevance, ambiguity, and vagueness of expression. The experts were expected to check whether the answers to OCAT (Appendices, N & P) were correct or not, and the appropriateness of MAI, and OCSEBS (Appendices, R & S). Corrections and suggestions arising from these experts were used to review the instruments and the instructional packages.

In OCAT, Item 4 was initially written as "_____ is the general molecular formula of carboxylic acids" and it was restructured to "Which among these is the general molecular formula of carboxylic acids". Item 7 was initially written as "The following structure signifies" and it was restructured to "The following structure represents". In the same vein, item 15 was initially written as "The action of water on calcium carbide indicates" and it was restructured to "The action of water on calcium carbide shows". In MAI, item 5 was initially written as "I have control on how well I learn" and it was restructured to "I have control over how well I learn". In OCSEBS, Item 3 was initially written as "Organic Chemistry is not one of my strength" and it was restructured to "Organic Chemistry is not one of my favorite topics". Item 5 was initially written as "I usually help my classmates, when they ask me for help in Organic Chemistry related problem" and it was restructured to "I usually help my classmates in Organic Chemistry-related problems". In items 16 and 17 respectively, the word "always" was removed from the sentences (See Appendices K and L respectively for the introductory letter to validate for the validation of the instruments and experts' validation comments respectively).

3.6.2 Reliability

Organic Chemistry Achievement Test (OCAT), Metacognitive Awareness Inventory (MAI) and Organic Chemistry Self-Efficacy Belief Scale (OCSEBS) upon validation were trial-tested to establish the reliability of the instruments by administering OCAT, MAI and OCSEBS to a randomly selected 68 Senior Secondary two (SS2) students of a senior secondary school which is not part of the schools selected for this study. The aim of the study was to test the reliability of the instruments used. Three intact classes SS 2A (Experimental group 1), SS 2B (Experimental group 2), and SS 2C (Control group) randomly selected using random sampling technique was used. This was to ensure that there was no variance in the school organization and setting. Three research assistants were employed and trained by the researcher for three days to teach the instructional units.

The experimental group 1 were taught using predict-explain-observe-explain lesson plans, while the experimental group 2 were taught using Vee heuristic lesson plans and the control group were taught using discussion lesson plans. After 4 weeks of 32 periods of teaching, the OCAT, MAI and OCSEBS were administered with the help of the research assistants. The data collected were used to determine the internal consistency of the instruments. This is because data from a single administration of test is useful to measure the internal consistency of an instrument since it eliminates the effect of first testing and precludes the trait instability (Denga, 2017). Kuder-Richardson (KR-21) formula was used to test internal consistency of OCAT. The instrument (OCAT) gave reliability value of 0.94 (Appendix T).

Cronbach Alpha was used to ascertain the reliability index of MAI and OCSEBS respectively. This gave reliability valves of 0.84 and 0.86 respectively (Appendices, V & W). According to Maduabum (2011), the coefficients of 0.84 and 0.86 indicate that the instruments are reliable. The decision to use KR-21 for testing reliability of OCAT was borne out of the fact that the items were not of equal difficulty and were scored dichotomously, one point for each correct answer and zero for incorrect answer (Nworgu, 2013). Cronbach Alpha was used for MAI and OCSEBS because the items were not dichotomously scored. Emaikwu (2013) also revealed that where two items are not dichotomously scored, the use of Cronbach Alpha becomes very appropriate. Psychometric indices were computed for OCAT and based on that 40 items out of the 50 items that were used in the study were selected to be used in the main study (Appendix U). According to Denga (2017), the basis for selecting these questions was those that have both item difficulty and item discrimination indices of 0.30 and above.

3.7 Method of Data Collection

Organic Chemistry Achievement Test (OCAT), Metacognitive Awareness Inventory (MAI), and Organic Chemistry Self-Efficacy Belief Scale (OCSEBS) were used for data collection. The instruments were administered during the study from which scores were collected and analyzed. The researcher presented a letter of introduction from the Department of Mathematics and Science Education, Benue State University, Makurdi (Appendix A) to the Principals of the sampled schools to seek for permission to carry out the research work.

3.7.1 Experimental procedure

Training for Chemistry teachers for the study: The conduct of the study took place during the school lesson periods. The normal time-table of the schools selected for the study were followed. The researcher used one week for the training of the Chemistry teachers who served as research assistants (Appendix J). The training programme covered the following areas:

i) The purpose of the research;

ii) The Organic Chemistry concepts selected for instruction;

iii) Procedure to teach the instructional packages; and

iv) Procedure for administering the instruments.

The training programme was to ensure the homogeneity of instructional situation across all groups. The training for the experimental groups only differs from that of the control group by the use of predict-explain-observe-explain and Vee heuristic instructional strategies.

3.7.2 Treatment Procedure

Intact classes were assigned to experimental and control groups, after which Organic Chemistry Achievement Test (OCAT), Metacognitive Awareness Inventory (MAI) and Organic Chemistry Self-Efficacy Belief Scale (OCSEBS) were administered as pre-test by the researcher with the assistance of the sampled schools Chemistry teachers. This lasted for one week before actual teaching commences. During lessons, the teachers taught the experimental group 1 Organic Chemistry topics using predict-explain-observe-explain instructional strategy in line with lessons procedure prepared by the researcher (Appendix X) and the experimental group 2 were taught using Vee heuristic instructional strategy in line with lessons procedure prepared by the researcher (Appendix Y). The control group were also taught the same Organic Chemistry topics using the discussion lesson plans (Appendix Z). This lasted for six weeks.

At the end of these actual teaching periods, the pre-OCAT, Pre-MAI and pre-OCSEBS were reshuffled and administered as post-test which lasted for one week and the post test was marked by the research assistants using the marking scheme developed by the researcher (Appendix P). The pre-test score constituted the covariant of the post-test scores.

3.7.3 Control of Extraneous Variables

Extraneous variables that could introduce bias or errors into the study were controlled as follows:

1. Control of effects of pre-test on post-test : The period between the pre-test (pre-OCAT, Pre-MAI and pre-OCSEBS) and the post-test (post-OCAT, Post-MAI and post-OCSEBS) was 6 weeks. These periods are long enough to disallow the pre-test from affecting the post-test scores. The researcher as well ensured that the result of pre-test was collected and concealed from the subjects. This is to minimize pre-test sensitization and avoid being used by students for revision. The pre-test test (pre-OCAT, Pre-MAI and pre-OCSEBS) were reshuffled before administered as post-test (post-OCAT, Post-MAI and post-OCSEBS).
2. Control of initial differences**:** Analysis of Covariance (ANCOVA) was used as the controller of the initial difference across the groups.
3. Observer Effect: Observer effect means faking in the behaviour of the subjects if they are conscious that they are being observed. In order to avoid such effect during the treatment, the researcher used the regular Chemistry teachers of the sample schools as research assistants to do the actual teaching.
4. Instructional Situation Variable: In order to control instructional situation variable, different schools were used for experimental and control groups. In order to ensure that the

instructional situation is the same for all the sampled schools, the researcher prepared three sets of lesson plans, predict-explain-observe-explain lesson plans for the experimental group 1, and Vee heuristic lesson plans for the experimental group 2 and discussion lesson plans for the control group.

3.8 Method of Data Analysis

Descriptive statistics of mean and standard deviation scores were used to answer the research questions, while the inferential statistic of Analysis of Covariance (ANCOVA) were used to test the null hypotheses at 0.05 level of significance. The choice of ANCOVA for the test of hypotheses was due to the fact that it statistically increased precision of data from experimental study. It is expected to control the initial differences if any across the non randomized groups. It also removes the bias that may result from using intact groups whose equivalence is not determined. It also removes differences on the dependent variables which may be due to difference in extraneous variables. ANCOVA also allow probing into the nature of treatment effects after significant main effects of covariates had been obtained (Emaikwu, 2013).

CHAPTER FOUR

ANALYSIS, INTERPRETATION AND DISCUSSION

4.1 Introduction

In this chapter, the results of this study are presented under the following headings: Data analysis, interpretation and discussion of findings.

4.2 Data Analysis and Interpretation

The data collected using the instruments developed for the study were analyzed and interpreted based on the research questions and hypotheses formulated. Tables 1-9 contain results on the research questions while, Tables 10-21 address hypotheses.

4.2.1 Research Question One

What are the mean achievement scores differences among students taught Organic Chemistry using PEOE strategy, VH strategy and discussion method?

Table 1: Mean Achievement and Standard Deviation Scores of Students Taught Organic Chemistry using PEOE Strategy, VH Strategy and Discussion Method

Group	N	PRE- OCAT		POST- OCAT		Mean Gain within Group
		$\tilde{x}$	δ	$\tilde{x}$	δ	
PEOE strategy	104	10.17	3.23	29.32	5.37	19.15
Discussion	103	10.15	3.10	15.56	3.93	5.41
Mean diff. between Groups		0.02		13.76		13.74
VH strategy	101	10.16	3.22	27.91	5.14	17.75
Discussion	103	10.15	3.10	15.56	3.93	5.41
Mean diff. between Groups		0.01		12.35		12.34
PEOE strategy	104	10.17	3.23	29.32	5.37	19.15
VH strategy	101	10.16	3.22	27.91	5.14	17.75
Mean diff. between Groups		0.01		1.41		1.40

Source: Field Survey, 2019

Table 1 reveals the mean achievement and standard deviation scores of students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee Heuristic (VH) strategy and discussion method (DM) on a paired comparative basis. The data in Table 1 show that the overall mean difference between students in PEOE and DM groups was 13.74 in favour of PEOE. This implies that students in PEOE group had higher achievement than students in DM group. Similarly, the overall mean difference between students in VH and DM groups was 12.34 in favour of VH strategy. This implies that students in VH group had higher achievement than those in DM group. In the same vein, the overall mean difference between students in PEOE and VH groups was 1.40. This difference though small is in favour of PEOE. This implies that students in PEOE group had slightly higher achievement than their counterparts in VH group. In conclusion, students taught using PEOE achieved slightly higher than those taught using VH strategy. Meanwhile, students taught using VH strategy achieved higher than those taught using discussion method.

4.2.2 Research Question Two

What is the difference in the mean achievement scores between male and female students taught Organic Chemistry using PEOE strategy?

Table 2: Mean Achievement and Standard Deviation Scores of Male and Female Students Taught Organic Chemistry using PEOE Strategy

Group	Gender	N	PRE- OCAT		POST- OCAT		Mean Gain within Gender
			$\tilde{x}$	δ	$\tilde{x}$	δ	
PEOE strategy	Male	61	10.23	3.41	29.67	5.27	19.44
	Female	43	10.21	2.97	28.81	5.53	18.60
Mean diff. between Gender			0.02		0.86		0.84

Source: Field Survey, 2019

Table 2 reveals the mean achievement and standard deviation scores of male and female students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy. The data in Table 2 show that the pre-test mean scores for male and female students were 10.23 and 10.21 with standard deviation scores of 3.41 and 2.97 respectively while the post-test mean scores were 29.67 and 28.81 with standard deviation scores of 5.27 and 5.53 respectively. The mean difference of both sexes was 0.84. This difference though small is in favour of the male students. This implies that male students achieved slightly higher than their female counterparts in PEOE strategy class.

4.2.3 Research Question Three

What is the difference in the mean achievement scores between male and female students taught Organic Chemistry using VH strategy?

Table 3: Mean Achievement and Standard Deviation Scores of Male and Female Students Taught Organic Chemistry using VH Strategy

Group	Gender	N	PRE- OCAT		POST- OCAT		Mean Gain within Gender
			$\tilde{x}$	δ	$\tilde{x}$	δ	
VH strategy	Male	56	10.23	3.64	28.21	5.25	17.98
	Female	45	10.07	2.66	27.53	5.02	17.46
Mean diff. between Gender			0.16		0.68		0.52

Source: Field Survey, 2019

Table 3 reveals the mean achievement and standard deviation scores of male and female students taught Organic Chemistry using Vee Heuristic (VH) strategy. The data in Table 3 show that the pre-test mean scores for male and female students were 10.23 and 10.07 with standard deviation scores of 3.64 and 2.66 respectively while the post-test mean scores were 28.21 and 27.53 with standard deviation scores of 5.25 and 5.02 respectively. The mean difference of both sexes was 0.52. This difference though small is in favour of the male students. This implies that male students achieved slightly higher than their female counterparts in VH strategy class.

4.2.4 Research Question Four

What is the mean interaction effect of treatments and gender on students' achievement in Organic Chemistry?

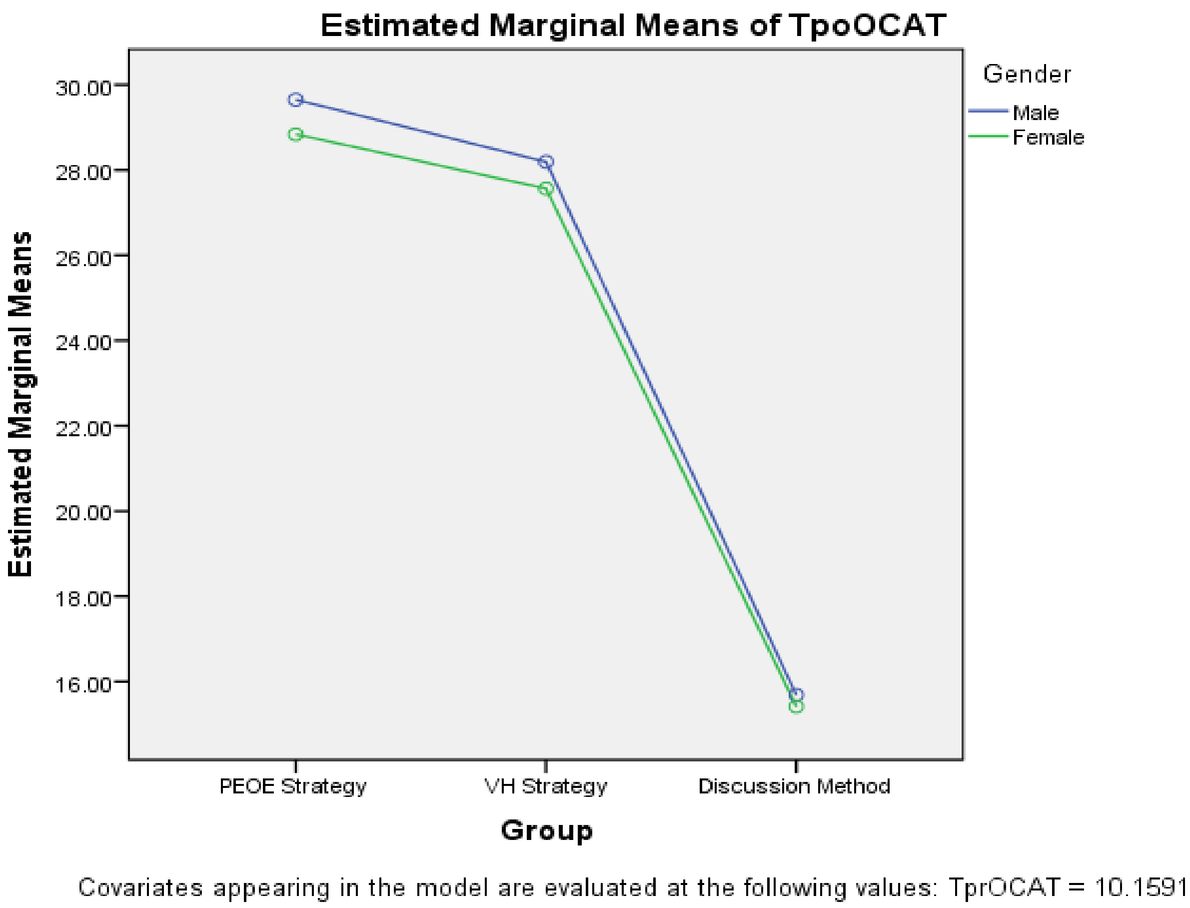


Fig 4: Interaction plot of treatments and gender on students' achievement in Organic Chemistry

Figure 3 presents a graph of the interaction effect of treatments and gender on the mean achievement scores of students in Organic Chemistry. The graph lines for gender did not intercept which suggests that interactive effect of treatments and gender on students' achievement in Organic Chemistry was very minimal.

4.2.5 Research Question Five

What are the mean metacognitive awareness scores differences among students taught Organic Chemistry using PEOE strategy, VH strategy and discussion method?

Table 4: Mean Metacognitive Awareness and Standard Deviation Scores of Students Taught Organic Chemistry using PEOE Strategy, VH Strategy and Discussion Method

Group	N	PRE- MAI		POST- MAI		Mean Gain within Group
		$\tilde{x}$	δ	$\tilde{x}$	δ	
PEOE strategy	104	1.38	0.22	3.86	0.15	2.48
Discussion	103	1.33	0.20	2.16	0.14	0.83
Mean diff. between Groups		0.05		1.70		1.65
VH strategy	101	1.36	0.17	3.83	0.18	2.47
Discussion	103	1.33	0.20	2.16	0.14	0.83
Mean diff. between Groups		0.03		1.67		1.37
PEOE strategy	104	1.38	0.22	3.86	0.15	2.48
VH strategy	101	1.36	0.17	3.83	0.18	2.47
Mean diff. between Groups		0.02		0.03		0.01

Source: Field Survey, 2019

Table 4 reveals the mean metacognitive awareness and standard deviation scores of students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee Heuristic (VH) strategy and discussion method (DM) on a paired comparative basis. The data in Table 4 show that the mean difference between students in PEOE and DM groups was 1.65 in favour of PEOE. This implies that students in PEOE group had higher metacognitive awareness than students in DM group. Similarly, the mean difference between students in VH and DM groups was 1.37 in favour of VH Strategy. This implies that students in VH group had higher metacognitive awareness than those in DM group. In the same vein, the mean difference between students in PEOE and VH groups was 0.01. This difference though small is in favour of PEOE. This implies that students in PEOE group had slightly higher metacognitive awareness than their counterparts in VH group. In conclusion, students taught using PEOE had slightly higher metacognitive awareness than those taught using VH strategy. Meanwhile, students taught Organic Chemistry using VH strategy had higher metacognitive awareness than those taught using discussion method.

4.2.6 Research Question Six

What is the difference in the mean metacognitive awareness scores between male and female students taught Organic Chemistry using PEOE strategy?

Table 5: Mean Metacognitive Awareness and Standard Deviation Scores of Male and Female Students Taught Organic Chemistry using PEOE Strategy

Group	Gender	N	PRE- MAI		POST- MAI		Mean Gain within Gender
			$\tilde{x}$	δ	$\tilde{x}$	δ	
PEOE strategy	Male	61	1.39	0.21	3.87	0.13	2.48
	Female	43	1.36	0.22	3.83	0.19	2.47
Mean diff. between Gender			0.03		0.04		0.01

Source: Field Survey, 2019

Table 5 reveals the mean metacognitive awareness and standard deviation scores of male and female students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy. The data in Table 5 show that the pre-test mean scores for male and female students were 1.39 and 1.36 with standard deviation scores of 0.21 and 0.22 respectively while the post-test mean scores were 3.87 and 3.83 with standard deviation scores of 0.13 and 0.19 respectively. The mean difference of both sexes was 0.01. This difference though small is in favour of the male students. This implies that male students had higher metacognitive awareness than their female counterparts in PEOE strategy class.

4.2.7 Research Question Seven

What is the difference in the mean metacognitive awareness scores between male and female students taught Organic Chemistry using VH strategy?

Table 6: Mean Metacognitive Awareness and Standard Deviation Scores of Male and Female Students Taught Organic Chemistry using VH Strategy

Group	Gender	N	PRE- MAI		POST- MAI		Mean Gain within Gender
			$\tilde{x}$	δ	$\tilde{x}$	δ	
VH strategy	Male	56	1.37	0.20	3.84	0.17	2.47
	Female	45	1.35	0.18	3.81	0.19	2.46
Mean diff. between Gender			0.02		0.03		0.01

Source: Field Survey, 2019

Table 6 reveals the mean metacognitive awareness and standard deviation scores of male and female students taught Organic Chemistry using Vee Heuristic (VH) strategy. The data in Table 6 show that the pre-test mean scores for male and female students were 1.37 and 1.35 with standard deviation scores of 0.20 and 0.18 respectively while the post-test mean scores were 3.84 and 3.81 with standard deviation scores of 0.17 and 0.19 respectively. The mean difference of both sexes was 0.01. This difference though small is in favour of the male students. This implies that male students had slightly higher metacognitive awareness than their female counterparts in VH strategy class.

4.2.8 Research Question Eight

What is the mean interaction effect of treatments and gender on students' metacognitive awareness in Organic Chemistry?

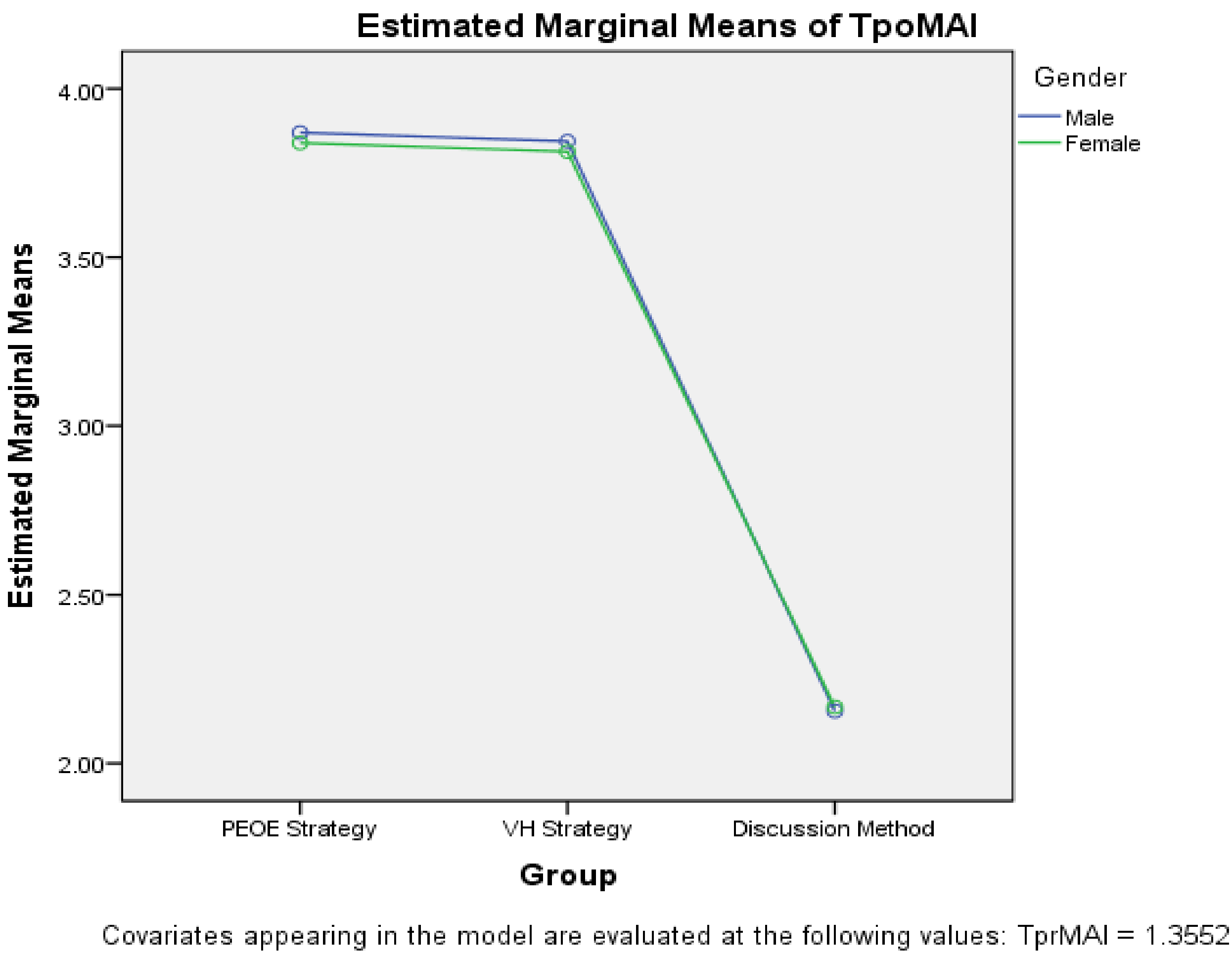


Fig 5: Interaction plot of treatments and gender on students' metacognitive awareness in Organic Chemistry

Figure 4 presents a graph of the interaction effect of treatments and gender on the mean metacognitive awareness scores of students in Organic Chemistry. The graph lines for gender did not intercept which suggests that interactive effect of treatments and gender on students' metacognitive awareness in Organic Chemistry was minimal.

4.2.9 Research Question Nine

What are the mean self-efficacy belief scores differences among students taught Organic Chemistry using PEOE strategy, VH strategy and discussion method?

Table 7: Mean Self-efficacy Belief and Standard Deviation Scores of Students Taught Organic Chemistry using PEOE Strategy, VH Strategy and Discussion Method

Group	N	PRE- OCSEB		POST- OCSEB		Mean Gain within Group
		$\tilde{x}$	δ	$\tilde{x}$	δ	
PEOE strategy	104	1.34	0.21	3.83	0.17	2.49
Discussion	103	1.33	0.17	2.13	0.11	0.80
Mean diff. between Groups		0.01		1.70		1.69
VH strategy	101	1.31	0.22	3.78	0.23	2.47
Discussion	103	1.33	0.17	2.13	0.11	0.80
Mean diff. between Groups		-0.02		1.65		1.67
PEOE strategy	104	1.34	0.21	3.83	0.17	2.49
VH strategy	101	1.31	0.22	3.78	0.23	2.47
Mean diff. between Groups		0.03		0.05		0.02

Source: Field Survey, 2019

Table 7 reveals the mean self-efficacy belief and standard deviation scores of students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee Heuristic (VH) strategy and discussion method (DM) on a paired comparative basis. The data in Table 7 show that the mean difference between students in PEOE and DM groups was 1.69 in favour of PEOE. This implies that students in PEOE group had higher self-efficacy belief than students in DM group. Similarly, the mean difference between students in VH and DM groups was 1.67 in favour of VH strategy. This implies that students in VH group had higher self-efficacy belief than those in DM group. In the same vein, the overall mean difference between students in PEOE and VH groups was 0.02. This difference though small is in favour of PEOE. This implies that students in PEOE group had slightly higher self-efficacy belief than their counterparts in VH group. In conclusion, students taught using PEOE had slightly higher self-efficacy belief than those taught using VH strategy. Meanwhile, students taught Organic Chemistry using VH strategy had higher self-efficacy belief than those taught using discussion method.

4.2.10 Research Question Ten

What is the difference in the mean self-efficacy belief scores between male and female students taught Organic Chemistry using PEOE strategy?

Table 8: Mean Self-Efficacy Belief and Standard Deviation Scores of Male and Female Students Taught Organic Chemistry using PEOE Strategy

Group	Gender	N	PRE- OCSEB		POST- OCSEB		Mean Gain within Gender
			$\tilde{x}$	δ	$\tilde{x}$	δ	
PEOE strategy	Male	61	1.35	0.22	3.85	0.25	2.50
	Female	43	1.33	0.20	3.81	0.21	2.48
Mean diff. between Gender			0.02		0.04		0.02

Source: Field Survey, 2019

Table 8 reveals the mean self-efficacy belief and standard deviation scores of male and female students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy. The data in Table 8 show that the pre-test mean scores for male and female students were 1.35 and 1.33 with standard deviation scores of 0.22 and 0.20 respectively while the post-test mean scores were 3.85 and 3.81 with standard deviation scores of 0.25 and 0.21 respectively. The mean difference of both sexes was 0.02. This difference though small is in favour of the male students. This implies that male students had higher self-efficacy belief than their female counterparts in PEOE strategy class.

4.2.11 Research Question Eleven

What is the difference in the mean self-efficacy belief scores between male and female students taught Organic Chemistry using VH strategy?

Table 9: Mean Self-Efficacy Belief and Standard Deviation Scores of Male and Female Students Taught Organic Chemistry using VH Strategy

Group	Gender	N	PRE- OCSEB		POST- OCSEB		Mean Gain within Gender
			$\tilde{x}$	δ	$\tilde{x}$	δ	
VH strategy	Male	56	1.31	0.22	3.78	0.23	2.47
	Female	45	1.31	0.21	3.79	0.24	2.48
Mean diff. between Gender			0.00		0.01		0.01

Source: Field Survey, 2019

Table 9 reveals the mean self-efficacy belief and standard deviation scores of male and female students taught Organic Chemistry using Vee Heuristic (VH) strategy. The data in Table 9 show that the pre-test mean scores for male and female students were 1.31 and 1.31 with standard deviation scores of 0.22 and 0.21 respectively while the post-test mean scores were 3.78 and 3.79 with standard deviation scores of 0.23 and 0.24 respectively. The mean difference of both sexes was 0.01. This difference though small is in favour of the female students. This implies that female students had higher self-efficacy belief than their male counterparts in VH strategy class.

4.2.12 Research Question Twelve

What is the mean interaction effect of treatments and gender on students' self-efficacy belief in Organic Chemistry?

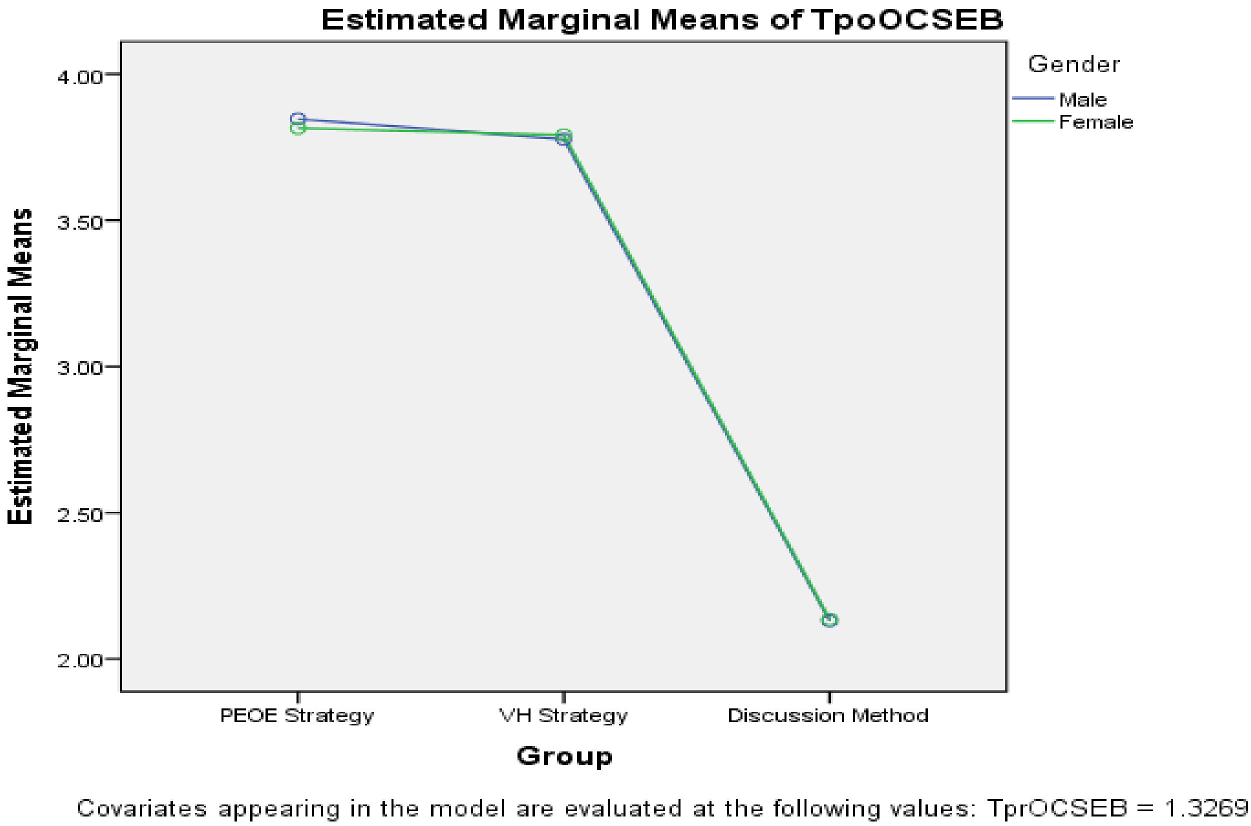


Fig 6: Interaction plot of treatments and gender on students' self-efficacy belief in Organic Chemistry

Figure 5 presents a graph of the interaction effect of treatments and gender on the mean self-efficacy belief scores of students in Organic Chemistry. The graph lines for gender slightly intercept which suggests that interactive effect of treatments and gender on students' self-efficacy belief in Organic Chemistry was very minimal.

Testing Null Hypotheses

The twelve null hypotheses formulated for this study were tested using ANCOVA at 0.05 levels of significance. In all cases, the decision rule was that the null hypothesis is rejected if the p value is less than 0.05 and it is not rejected if the p value is more than 0.05.

Effect size (strength of association) for the hypotheses were also analysed to describe how big and meaningful the statistical effects were. Effect size is a quantitative measure of the magnitude of a phenomenon. Effect size emphasizes the size of difference or relationship. Cohen (1988) cited in Pallant (2014) outlines the guidelines on how to interpret the range of effect size for ANOVA or ANCOVA as follows; Small: 0.01; Medium: 0.059; and Large: 0.138.

4.2.13 Hypothesis One

There is no significant difference in the mean achievement scores of students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee heuristic (VH) strategy and discussion method.

Table 10: Two-Way ANCOVA for Mean Achievement Scores of Students Taught Organic Chemistry using PEOE Strategy, VH Strategy and Discussion Method

Source	Type III sum of squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected model	12185.784[a]	6	2030.964	89.967	.000	.642
Intercept	11702.639	1	11702.639	518.399	.000	.633
TPrOCAT	346.379	1	346.379	15.344	.000	.049
Group	11525.883	2	5762.942	255.284	.000	.629
Gender	24.332	1	24.332	1.078	.300	.004
Group*Gender	3.817	2	1.909	.085	.919	.001
Error	6794.953	301	22.575			
Total	200201.000	308				
Corrected Total	18980.737	307				

a. R squared = .642 (Adjusted R Squared= .635) Source: Field Survey, 2019

Table 10 presents the two-way ANCOVA result for mean achievement scores of students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee Heuristic (VH) strategy and discussion method (DM). The data in Table 10 reveal that the observed mean difference in the achievement scores among the groups was significant [$F_{2, 307}$=255.284, P<0.05]. Hence, the null hypothesis that there is no significant difference in the mean achievement scores of students taught Organic Chemistry using PEOE strategy, VH strategy and DM was rejected. This implies that there is a significant difference in the mean achievement scores among the groups. Meanwhile, the effect size was 0.629 as indicated by the corresponding partial eta squared value is considered as large effect size. This implies that, 62.9% of the difference or variance in the achievement scores among the groups was explained by the treatments. Hence, the difference in the achievement scores among the groups has a large statistical effect size.

Table 11: Bonferroni Post Hoc Comparison for Mean Achievement Scores of Students' Taught Organic Chemistry using PEOE, VH and DM

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sign.
PEOE	DM	13.689*	.667	.000
VH	DM	12.324*	.669	.000
VH	PEOE	-1.365	.671	.128

Source: Field Survey, 2019

Table 11 shows Bonferroni post-hoc comparison for mean achievement scores of students' taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee Heuristic (VH) strategy and discussion method (DM). The results reveal that the mean difference (I-J) between PEOE and DM is 13.689* and this is significant at p<0.05. This implies that there is a significant difference in the mean achievement scores between the students taught Organic Chemistry using PEOE and those taught using DM in favour of students in PEOE class. Likewise, the results reveal that the mean difference (I-J) between VH and DM is 12.324* and this is significant at p<0.05. This implies that there is a significant difference in the mean achievement scores between the students taught Organic Chemistry using VH and those taught using DM in favour of students in VH strategy class.

However, the paired comparison of VH and PEOE showed a mean difference of -1.365 and this is not significant at p>0.05. This indicates no significant difference in the mean achievement scores between students taught using PEOE and VH strategies.

4.2.14 Hypothesis Two

The difference in the mean achievement scores of male and female students taught Organic Chemistry using PEOE strategy is not statistically significant

Table 12: ANCOVA Result for Achievement of Male and Female Students Taught Organic Chemistry using PEOE Strategy

Source	Type III sum of squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected model	903.799[a]	2	451.899	22.127	.000	.305
Intercept	3770.959	1	3770.959	184.642	.000	.646
TPrOCAT	885.224	1	885.224	43.344	.000	.300
Gender	13.589	1	13.589	.665	.417	.007
Error	2062.730	101	20.423			
Total	92355.000	104				
Corrected Total	2966.529	103				

a. R squared = .305 (Adjusted R Squared= .291) Source: Field Survey, 2019

ANCOVA Test result in Table 12 reveals that there is no significant difference between the mean achievement of male and female students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy [$F_{1, 103}$ =.665, P>0.05]. The null hypothesis is therefore not rejected. This means that PEOE strategy enhanced both male and female students' achievement in Organic Chemistry. Meanwhile, the effect size was 0.007 as indicated by the corresponding partial eta squared value is considered as small effect size. This implies that, only 0.7% of the difference in the achievement scores of male and female students taught Organic Chemistry was explained by PEOE. Hence, the difference in the achievement scores of male and female students taught Organic Chemistry using PEOE strategy has very small statistical effect size.

4.2.15 Hypothesis Three

There is no significant difference between the mean achievement scores of male and female students taught Organic Chemistry using VH strategy

Table 13: ANCOVA Result for Achievement of Male and Female Students Taught Organic Chemistry using VH Strategy

Source	Type III sum of squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected model	15.224[a]	2	7.612	.284	.753	.006
Intercept	6811.882	1	6811.882	254.507	.000	.722
TPrOCAT	3.655	1	3.655	.137	.713	.001
Gender	11.231	1	11.231	.420	.519	.004
Error	2622.974	98	26.765			
Total	81319.000	101				
Corrected Total	2638.198	100				

a. R squared = .006 (Adjusted R Squared= -.015) Source: Field Survey, 2019

ANCOVA Test result in Table 13 reveals that there is no significant difference between the mean achievement of male and female students taught Organic Chemistry using Vee Heuristic (VH) strategy [$F_{1,\ 100}$ =.420, P>0.05]. The null hypothesis is therefore not rejected. This means that VH strategy enhanced both male and female students' achievement in Organic Chemistry. Meanwhile, the effect size was 0.004 is considered as very small effect size. This implies that, only 0.4% of the difference in the achievement scores of male and female students taught Organic Chemistry was explained by VH strategy. Hence, the difference in the achievement scores of male and female students taught Organic Chemistry using VH strategy has small statistical effect size.

4.2.16 Hypothesis Four

There is no significant interaction effect of treatments and gender on the mean achievement scores of students in Organic Chemistry.

The data analysis of Table 10 is used to explain hypothesis 4. The table presents a two-way ANCOVA for achievement of students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee Heuristic (VH) strategy and discussion method (DM). The table also presents the interaction effect of instructional strategies and gender. The data in Table 10 reveals that there is no significant interaction effect of treatments and gender on the mean achievement scores of students in Organic Chemistry [$F_{2, 307}$ =.085, P>0.050]. The null hypothesis is therefore not rejected. Meanwhile, the effect size was 0.001 as indicated by the corresponding partial eta squared value which is considered as small effect size. This implies that, only 0.1% of the interaction in the achievement scores among groups was explained by treatments and gender. Hence, the interaction of treatments and gender on students' achievement has small statistical effect size.

4.2.17 Hypothesis Five

There is no significant difference in the mean metacognitive awareness scores of students taught Organic Chemistry using PEOE strategy, VH strategy and discussion method.

Table 14: Two-Way ANCOVA for Mean Metacognitive Awareness Scores of Students Taught Organic Chemistry using PEOE, VH and Discussion Method

Source	Type III sum of squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected model	194.499[a]	6	32.417	1282.860	.000	.962
Intercept	65.585	1	65.585	2595.466	.000	.896
TPrMAI	.009	1	.009	.337	.562	.001
Group	189.144	2	94.572	3742.616	.000	.961
Gender	.020	1	.020	.801	.371	.003
Group*Gender	.030	2	.015	.600	.550	.004
Error	7.606	301	.025			
Total	3515.955	308				
Corrected Total	202.105	307				

a. R squared = .962 (Adjusted R Squared= .962) Source: Field Survey, 2019

Table 14 presents the two-way ANCOVA result for mean metacognitive awareness scores of students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee Heuristic (VH) strategy and discussion method (DM). The data in Table 14 reveal that the observed mean difference in the metacognitive awareness scores among the groups was significant [$F_{2, 307}$=3742.616, P<0.05]. Hence, the null hypothesis that there is no significant difference in the mean metacognitive awareness scores of students taught Organic Chemistry using PEOE strategy, VH strategy and DM was rejected. This implies that there is a significant difference in the mean metacognitive awareness scores among the groups. Meanwhile, the effect size was 0.961 which is considered as large effect size. This implies that, 96.1% of the difference in the metacognitive awareness scores among the groups was explained by the treatments. Hence, the difference in the metacognitive awareness scores among the groups has a large statistical effect size.

Table 15: Bonferroni Post Hoc Comparison for Mean Metacognitive Awareness Scores of Students' Taught Organic Chemistry using PEOE, VH and DM

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sign.
PEOE	DM	1.693*	.022	.000
VH	DM	1.667*	.022	.000
VH	PEOE	-.026	.022	.767

Source: Field Survey, 2019

Table 15 shows Bonferroni post-hoc comparison for mean metacognitive awareness scores of students' taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee Heuristic (VH) strategy and discussion method (DM). The results reveal that the mean difference (I-J) between PEOE and DM is 1.693* and this is significant at $p<0.05$. This implies that there is a significant difference in the mean metacognitive awareness scores between the students taught Organic Chemistry using PEOE and those taught using DM in favour of students in PEOE class. Likewise, the results reveal that the mean difference (I-J) between VH and DM is 1.667* and this is significant at $p<0.05$. This implies that there is a significant difference in the mean metacognitive awareness scores between the students taught Organic Chemistry using VH strategy and those taught using DM in favour of students in VH class. However, the paired comparison of VH and PEOE showed a mean difference of -.026 and this is not significant at $p>0.05$. This indicates no significant difference in the mean metacognitive awareness scores between students taught Organic Chemistry using PEOE and VH strategies.

4.2.18 Hypothesis Six

There is no significant difference between the mean metacognitive awareness scores of male and female students taught Organic Chemistry using PEOE strategy

Table 16: ANCOVA Result for Metacognitive Awareness of Male and Female Students Taught Organic Chemistry using PEOE Strategy

Source	Type III sum of squares	*df*	Mean Square	F	Sig.	Partial Eta Squared
Corrected model	.047[a]	2	.024	.993	.374	.019
Intercept	34.698	1	34.698	1465.031	.000	.936
TPrMAI	.022	1	.022	.912	.342	.009
Gender	.021	1	.021	.874	.352	.009
Error	2.392	101	.024			
Total	1549.220	104				
Corrected Total	2.439	103				

a. R squared = .019 (Adjusted R Squared= .000) Source: Field Survey, 2019

ANCOVA Test result in Table 16 reveals that there is no significant difference between the mean metacognitive awareness of male and female students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy [$F_{1, 103}$ =.874, P>0.050]. The null hypothesis is therefore not rejected. This means that PEOE strategy enhanced both male and female students' metacognitive awareness in Organic Chemistry. Meanwhile, the effect size was 0.009 which is considered as small effect size. This implies that, only 0.9% of the difference in the metacognitive awareness scores of male and female students taught Organic Chemistry was explained by PEOE strategy. Hence, the difference in the metacognitive awareness scores of male and female students taught Organic Chemistry using PEOE strategy has small statistical effect size.

4.2.19 Hypothesis Seven

The difference in the mean metacognitive awareness scores of male and female students taught Organic Chemistry using VH strategy is not statistically significant

Table 17: ANCOVA Result for Metacognitive Awareness of Male and Female Students Taught Organic Chemistry using VH Strategy

Source	Type III sum of squares	*df*	Mean Square	F	Sig.	Partial Eta Squared
Corrected model	.030[a]	2	.015	.466	.629	.009
Intercept	22.356	1	22.356	697.218	.000	.877
TPrMAI	.006	1	.006	.187	.666	.002
Gender	.023	1	.023	.705	.403	.007
Error	3.142	98	.032			
Total	1484.425	101				
Corrected Total	3.172	100				

a. R squared = .009 (Adjusted R Squared= -.011) Source: Field Survey, 2019

ANCOVA Test result in Table 17 reveals that there is no significant difference between the mean metacognitive awareness of male and female students taught Organic Chemistry using Vee Heuristic (VH) strategy [$F_{1, 100}$ =.705, P>0.050]. The null hypothesis is therefore not rejected. This means that VH strategy enhanced both male and female students' metacognitive awareness in Organic Chemistry. Meanwhile, the effect size was 0.007 which is considered as small effect size. This implies that, only 0.7% of the difference in the metacognitive awareness scores of male and female students taught Organic Chemistry was explained by VH strategy. Hence, the difference in the metacognitive awareness scores of male and female students taught Organic Chemistry using VH strategy has small statistical effect size.

4.2.20 Hypothesis Eight

There is no significant interaction effect of treatments and gender on the mean metacognitive awareness scores of students in Organic Chemistry.

The data analysis of Table 14 is used to explain hypothesis 8. The table presents a two-way ANCOVA for metacognitive awareness of students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee Heuristic (VH) strategy and discussion method (DM). The table also presents the interaction effect of instructional strategies and gender. The data in Table 14 reveals that there is no significant interaction effect of treatments and gender on the mean metacognitive awareness scores of students in Organic Chemistry [$F_{2, 307} = .600$, $P>0.050$]. The null hypothesis is therefore not rejected. Meanwhile, the effect size was 0.004 which is considered as small effect size. This implies that, only 0.4% of the interaction in the metacognitive awareness scores among groups was explained by treatments and gender. Hence, the interaction of treatments and gender on students' metacognitive awareness has small statistical effect size.

4.2.21 Hypothesis Nine

The difference in the mean self-efficacy belief scores of students taught Organic Chemistry using PEOE strategy, VH strategy and discussion method is not statistically significant.

Table 18: Two-Way ANCOVA for Mean Self-Efficacy Belief Scores of Students Taught Organic Chemistry using PEOE, VH and Discussion Method

Source	Type III sum of squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected model	192.673[a]	6	32.112	1001.321	.000	.952
Intercept	69.528	1	69.528	2168.028	.000	.878
TProcseb	.094	1	.094	2.919	.089	.010
Group	189.421	2	94.710	2953.260	.000	.952
Gender	.001	1	.001	.032	.858	.000
Group*Gender	.030	2	.015	.476	.622	.003
Error	9.653	301	.032			
Total	3452.457	308				
Corrected Total	202.326	307				

a. R squared = .952 (Adjusted R Squared= .951)   Source: Field Survey, 2019

Table 18 presents the two-way ANCOVA result for mean self-efficacy belief scores of students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee Heuristic (VH) strategy and discussion method (DM). The data in Table 18 reveal that the observed mean difference in the self-efficacy belief scores among the groups was significant [$F_{2,\ 307}$=2953.260, P<0.05]. Hence, the null hypothesis that there is no significant difference in the mean self-efficacy belief scores of students taught Organic Chemistry using PEOE strategy, VH strategy and DM was rejected. This implies that there is a significant difference in the mean self-efficacy belief scores among the groups. Meanwhile, the effect size was 0.952 which is considered as large effect size. This implies that, 95.2% of the difference in the self-efficacy belief scores among the groups was explained by the treatments. Hence, the difference in the self-efficacy belief scores among the groups has a large statistical effect size.

Table 19: Bonferroni Post Hoc Comparison for Mean Self-Efficacy Belief Scores of Students' Taught Organic Chemistry using PEOE, VH and DM

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sign.
PEOE	DM	1.697*	.025	.000
VH	DM	1.651*	.025	.000
VH	PEOE	-.046	.025	.206

Source: Field Survey, 2019

Table 19 shows Bonferroni post-hoc comparison for mean self-efficacy belief scores of students' taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee Heuristic (VH) strategy and discussion method (DM). The results reveal that the mean difference (I-J) between PEOE and DM is 1.697* and this is significant at $p<0.05$. This implies that there is a significant difference in the mean self-efficacy belief scores between the students taught Organic Chemistry using PEOE and those taught using DM in favour of students in PEOE class. Likewise, the results reveal that the mean difference (I-J) between VH and DM is 1.651* and this is significant at $p<0.05$. This implies that there is a significant difference in the mean self-efficacy belief scores between the students taught Organic Chemistry using VH and those taught using DM in favour of students in VH strategy class. However, the paired comparison of VH and PEOE showed a mean difference of -.046 and this is not significant at $p>0.05$. This indicates no significant difference in the mean self-efficacy belief scores between students taught Organic Chemistry using PEOE and VH strategies.

4.2.22 Hypothesis Ten

There is no significant difference between the mean self-efficacy belief scores of male and female students taught Organic Chemistry using PEOE strategy

Table 20: ANCOVA Result for Self-Efficacy Belief of Male and Female Students Taught Organic Chemistry using PEOE Strategy

Source	Type III sum of squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected model	.097[a]	2	.049	1.665	.194	.032
Intercept	32.977	1	32.977	1127.379	.000	.918
TPrOCSEB	.069	1	.069	2.351	.128	.023
Gender	.024	1	.024	.817	.368	.008
Error	2.954	101	.029			
Total	1532.143	104				
Corrected Total	3.052	103				

a. R squared = .032 (Adjusted R Squared= .013) Source: Field Survey, 2019

ANCOVA Test result in Table 20 reveals that there is no significant difference between the mean self-efficacy belief of male and female students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy [$F_{1,\ 103}$ =.817, P>0.050]. The null hypothesis is therefore not rejected. This means that PEOE strategy enhanced both male and female students' self-efficacy belief in Organic Chemistry. Meanwhile, the effect size was 0.008 which is considered as small effect size. This implies that, only 0.8% of the difference in the self-efficacy belief scores of male and female students taught Organic Chemistry was explained by PEOE strategy. Hence, the difference in the self-efficacy belief scores of male and female students taught Organic Chemistry using PEOE strategy has very small statistical effect size.

4.2.23 Hypothesis Eleven

The difference in the mean self-efficacy belief scores of male and female students taught Organic Chemistry using VH strategy is not statistically significant

Table 21: ANCOVA Result for Self-Efficacy Belief of Male and Female Students Taught Organic Chemistry using VH Strategy

Source	Type III sum of squares	*df*	Mean Square	F	Sig.	Partial Eta Squared
Corrected model	.142[a]	2	.071	1.326	.270	.026
Intercept	33.980	1	33.980	634.406	.000	.866
TPrOCSEB	.137	1	.137	2.553	.113	.025
Gender	.005	1	.005	.101	.752	.001
Error	5.249	98	.054			
Total	1450.183	101				
Corrected Total	5.391	100				

a. R squared = .026 (Adjusted R Squared= .006) Source: Field Survey, 2019

ANCOVA Test result in Table 21 reveals that there is no significant difference between the mean self-efficacy belief of male and female students taught Organic Chemistry using Vee Heuristic (VH) strategy [$F_{1, 100}$ =.101, P>0.050]. The null hypothesis is therefore not rejected. This means that VH strategy enhanced both male and female students' self-efficacy belief in Organic Chemistry. Meanwhile, the effect size was 0.001 which is considered as small effect size. This implies that, only 0.1% of the difference or variance in the self-efficacy belief scores of male and female students taught Organic Chemistry was explained by VH strategy. Hence, the difference in the self-efficacy belief scores of male and female students taught Organic Chemistry using VH strategy has very small statistical effect size.

4.2.24 Hypothesis Twelve

There is no significant interaction effect of treatments and gender on the mean self-efficacy belief scores of students in Organic Chemistry.

The data analysis of Table 18 is used to explain hypothesis 12. The table presents a two-way ANCOVA for self-efficacy belief of students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee Heuristic (VH) strategy and discussion method (DM). The table also presents the interaction effect of instructional strategies and gender. The data in Table 18 reveals that there is no significant interaction effect of treatments and gender on the mean self-efficacy belief scores of students in Organic Chemistry [$F_{2, 307}$ =.476, $P>0.050$]. The null hypothesis is therefore not rejected. Meanwhile, the effect size was 0.003 which is considered as very small effect size. This implies that, only 0.3% of the interaction in the self-efficacy belief scores among groups was explained by treatments and gender. Hence, the interaction of treatments and gender on students' self-efficacy belief has very small statistical effect size.

4.3 Discussion of Findings

This study focused on the effects of predict-explain-observe-explain and Vee heuristic strategies on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry in Ekiti state, Nigeria. The study also investigated the interaction effect of treatments and gender on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry. Findings from the study are discussed under the following headings: Predict-explain-observe-explain, Vee heuristic, discussion method, gender and students' achievement in Organic Chemistry; Predict-explain-observe-explain, Vee heuristic, discussion method, gender and students' metacognitive awareness in Organic Chemistry; Predict-explain-observe-explain, Vee heuristic, discussion method, gender and students' self-efficacy belief in Organic Chemistry; and interaction effects of strategies and gender on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry.

4.3.1 Effect of Predict-Explain-Observe-Explain, Vee Heuristic, Discussion Method, Gender and Students' Achievement in Organic Chemistry

Finding of this study revealed that the difference in the achievement scores among students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE), Vee Heuristic (VH) strategy and discussion method was statistically significant. The post-hoc comparison for the achievement scores among the groups revealed that students taught Organic Chemistry using PEOE achieved significantly higher than their counterparts taught using discussion method. This is in line with Gernale, Arañes and Duad (2015) and Teerasong, Chantore, Ruenwongsa and Nacapricha (2016) findings that students improved significantly in their achievement in Science and Elementary Basic Science respectively when taught using PEOE strategy compared to those taught using conventional teaching method.

In another related study, Demircioğlu, Demircioğlu and Aslan (2017) investigated the effect of Predict-Observe-Explain (POE) on the understandings of grade II Chemistry students about gases. Though the strategy used did not emphasize the importance of students' explanation for their prediction, yet, the finding of study revealed that, POE significantly enhanced students' understandings than traditional teaching method. The likely explanation for this outcome may be connected to the fact that the Predict-Explain-Observe-Explain (PEOE) strategy helped the learners to possess a meaningful in-depth knowledge of the content area by finding out their initial ideas and motivating them to want to explore the concept and generate investigation when compared to the discussion method. PEOE strategy helps students to learn meaningfully because it focuses on linking students existing ideas and beliefs relevant to a situation and exploring the appropriateness of these ideas and beliefs.

The post-hoc comparison for the achievement scores among the groups also revealed that students taught Organic Chemistry using Vee Heuristic (VH) strategy achieved significantly higher than their counterparts taught using discussion method. This finding agrees with Fred (2011) who found that students taught Biology using VH strategy had higher achievement than those taught using traditional teaching method. Similarly, this is in line with Haruna (2014), and Njue and Magana (2016) findings that students improved significantly in their achievement in Physics and Biology respectively when taught using VH strategy compared to those taught using lecture method. The likely explanation for this outcome may also be connected to the fact that the use of VH strategy provides a format for students to construct their knowledge about a concept. Students can see how scientific knowledge is developed through the process of reflecting on what they know and the investigation they undertake. Unlike, when compared to discussion method that only promotes passive learning. Therefore, Using VH strategy will make students begin to appreciate practical Chemistry as Vee diagram generated can be used in place of any laboratory report.

The post-hoc comparison for the achievement scores among the groups further revealed that the difference in the achievement scores between students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) and those taught using Vee heuristic (VH) strategy was not statistically significant. There was a scarcity of studies on comparison between PEOE and VH strategies on students' achievement in science subjects before. However, the likely explanation for this outcome may be attributed to the fact that both PEOE and VH strategies are used to help students develop a cognitive structure that enable meaningful learning. The instructional strategies enable students to understand the structure of knowledge and process of knowledge construction.

The study revealed that male students achieved slightly higher than their female counterparts using Predict-Explain-Observe-Explain (PEOE) strategy but ANCOVA test shows that the difference was no significant. This implies that, the difference in the achievement of male and female students taught Organic Chemistry using PEOE strategy was not statistically significant. This means that PEOE strategy enhanced both male and female students' achievement in Organic Chemistry. This finding agrees with Teerasong, Chantore, Ruenwongsa and Nacapricha (2016) who found that the difference in achievement of male female students taught Elementary Basic Science using PEOE is not significant. However, the finding contradicts the finding of Bajar-Sales, Avilla and Camacho (2015) who found that female students' had higher achievement than their male counterparts in Biology using PEOE strategy.

The study also revealed that male students achieved slightly higher than their female counterparts using Vee Heuristic strategy (VH) strategy but ANCOVA test shows that the difference was no significant. This implies that, the difference in the achievement of male and female students taught Organic Chemistry using VH strategy was not statistically significant. This means that VH strategy enhanced both male and female students' achievement in Organic Chemistry. This finding agrees with Njue and Magana (2016) who found that Vee heuristic teaching approach facilitated students' achievements in Biology regardless of gender in Public Secondary Schools in Kenya. However, the finding contradicts the finding of Fred (2011) who found that female students' had higher achievement than their male counterparts in Biology using VH strategy. Therefore, if VH strategy is implemented in classroom, it will enable male and female students to understand how concepts and processes are meaningfully learn because its purpose is to interplay between what is familiar and what they has yet to be known or understood in Chemistry in general and Organic Chemistry in particular.

Thus, if either Predict-Explain-Observe-Explain or Vee Heuristic strategy is implemented in chemistry classroom, it will enhance the teaching and learning of Chemistry in general and Organic Chemistry in particular, thereby enhancing students' achievement in Chemistry in external examinations such as West African Examination Council (WAEC) and National Examinations Council (NECO).

4.3.2 Effect of Predict-Explain-Observe-Explain, Vee Heuristic, Discussion Method, Gender and Students' Metacognitive Awareness in Organic Chemistry

Finding of this study revealed that the difference in the metacognitive awareness scores among students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE), Vee Heuristic (VH) strategy and discussion method was statistically significant. The post-hoc comparison for the metacognitive awareness scores among the groups revealed that students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) Strategy had significantly higher metacognitive awareness than their counterparts taught using discussion method. This is in line with Bajar-Sales, Avilla and Camacho (2015) finding that

PEOE significantly enhance students' metacognitive awareness when compared to conventional teaching approach.

In another related study, Karamustafaoğlu, and Mamlok-Naaman (2015) investigated students' understanding of electrochemistry concepts using Predict-Observe-Explain (POE) strategy. Though the strategy used did not emphasize the important of students' explanation for their prediction, yet, the finding of study revealed that, POE significantly enhanced students' understandings than lecture method. The likely explanation for this outcome may be attributed to the fact that the PEOE strategy helped the learners to explore concept and generate investigation. Furthermore, the students are given the chance to express their schema and experience the science ideas behind the activity to satisfy their curiosity and thinking processes compared to the discussion method.

The post-hoc comparison for the metacognitive awareness scores among the groups also revealed that students taught Organic Chemistry using Vee Heuristic (VH) strategy had significantly higher metacognitive awareness than those taught using discussion method. This finding agrees with Mutai, Changeiywo and Okere (2014) who found that VH strategy was more effective in enhancing students' conceptual understanding and metacognition in the topic of moments in Physics than conventional teaching method. The likely explanation for this outcome may be attributed to the fact that the use of VH strategy provides a format for students to understand the nature of knowledge and construction processes of knowledge. VH strategy is a powerful metacognitive tool as it aid students to make explicit connections between prior and newly acquired information compared to discussion method that only promotes passive learning. Therefore, if VH strategy is implemented in classroom, it will enable students to understand how concepts and processes are meaningfully learned through student-directed, constructivist, and inquiry-based learning, thereby, improving their metacognitive awareness.

The post-hoc comparison for the metacognitive awareness scores among the groups further revealed that the difference in the metacognitive awareness between students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) and those taught using Vee heuristic (VH) strategy was not statistically significant. There was a scarcity of studies on comparison between PEOE and VH strategies on students' metacognitive awareness in science subjects before. However, the likely explanation for this outcome may be connected to the fact that both PEOE and VH strategies are used to help develop a cognitive structure that enable students to see how scientific knowledge is developed through the process of reflecting on what they know and the investigation they undertake.

The study revealed that male students had slightly higher metacognitive awareness than their female counterparts using Predict-Explain-Observe-Explain (PEOE) strategy but ANCOVA test shows that the difference was no significant. This implies that, the difference in the metacognitive awareness of male and female students taught Organic Chemistry using PEOE strategy was not statistically significant. This means that PEOE strategy enhanced both male and female students' metacognitive awareness in Organic Chemistry. This finding agrees with Demircioğlu, Demircioğlu and Aslan (2017) who found that PEOE enhance students' understandings in Chemistry regardless of gender. However, the finding contradicts the finding of Gernale, Arañes, and Duad (2015) who found that female students' had better attitude toward Biology than their male counterparts using Predict-Observe-Explain (POE) strategy. The likely reason for the difference may be because; the POE strategy used did not emphasize the important of students' explanation for their prediction.

The study also found that male students had slightly higher metacognitive awareness than their female counterparts using Vee heuristic (VH) strategy but ANCOVA test shows that the difference was no significant. This implies that, the difference in the metacognitive awareness of male and female students taught Organic Chemistry using VH strategy was not statistically significant. This means that VH strategy enhanced both male and female students' metacognitive awareness in Organic Chemistry. This finding agrees with Njue, Kamau and Mwania (2018) who found that Vee Heuristic strategy enhance students' attitude toward Biology regardless of gender. Hence, if either PEOE or VH strategy is implemented in classroom, it will enhance male and female students' capacities to accomplish Organic Chemistry task and control their thinking processes. Thus, in order to encourage gender equivalence in metacognitive awareness in Organic Chemistry concept, either PEOE or VH strategies should be embraced by Chemistry teachers.

4.3.3 Effect of Predict-Explain-Observe-Explain, Vee Heuristic, Discussion Method, Gender and Students' Self-Efficacy Belief in Organic Chemistry

Finding of this study revealed that the difference in the self-efficacy belief scores among students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE), Vee Heuristic (VH) strategy and discussion method was statistically significant. The post-hoc comparison for the self-efficacy belief scores among the groups revealed that students taught Organic Chemistry using PEOE had significantly higher self-efficacy belief than their counterparts taught using discussion method. Though, there was a scarcity of studies on effect of PEOE strategy on students' self-efficacy belief in science subjects before. But, this finding is in line with Karamustafaoğlu and Mamlok-Naaman (2015) findings that students improved significantly in their understanding of electrochemistry concepts using PEOE compared to those taught using conventional teaching method. Thus, the likely explanation for this outcome may be attributed to the fact that the PEOE strategy helped the learners to possess a meaningful in-depth knowledge of concept; thereby enhancing students' belief or confidence about his/her ability to solve Organic Chemistry related problems compared to discussion method that only promotes passive learning.

The post-hoc comparison for the self-efficacy belief scores among the groups also revealed that students exposed to Vee Heuristic (VH) strategy had significantly higher self-efficacy belief than those taught using discussion method. Though, there was a scarcity of studies on effect of VH strategy on students' self-efficacy belief in science subjects before. But, this finding is in line with Mutai, Changeiywo and Okere (2014) findings that students improved significantly in their conceptual understanding in Physics when taught using VH strategy compared to those taught using conventional teaching method. The likely explanation for this outcome may also be connected to the fact that the use of VH strategy provides a format for students to see how scientific knowledge is developed through the process of reflecting on what they know and the investigation they undertake thereby enhancing students' belief or confidence about his/her ability to solve Organic Chemistry related problems compared to discussion method that only promotes passive learning. Therefore, if VH strategy is implemented in classroom, it will enable students to understand how concepts and processes are meaningfully learned, thereby enhancing students' self-efficacy belief in Organic Chemistry.

It was also found that students exposed to Predict-Explain-Observe-Explain (PEOE) had slightly higher self-efficacy belief than their counterparts using Vee Heuristic (VH) strategy but the post-hoc comparison for the self-efficacy belief scores among the groups further revealed that the difference in the self-efficacy belief scores between students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) and those taught using Vee heuristic (VH) strategy was not statistically significant. There was a scarcity of studies on comparison between PEOE and VH strategies on students' self-efficacy belief in science subjects before. However, the likely explanation for this outcome may be attributed to the fact that both PEOE and VH strategies are used to help students develop a cognitive structure that enable students to understand the structure of knowledge and process of knowledge construction, thereby enhancing students' self-efficacy belief.

The study revealed that male students had slightly higher self-efficacy belief than their female counterparts using Predict-Explain-Observe-Explain (PEOE) strategy but ANCOVA test shows that the difference was no significant. This implies that, the difference in the self-efficacy belief of male and female students taught Organic Chemistry using PEOE strategy was not statistically significant. This means that PEOE strategy enhanced both male and female students' self-efficacy belief in Organic Chemistry. This finding agrees with Demircioğlu, Demircioğlu and Aslan (2017) who found that PEOE enhance students' understandings in Chemistry regardless of gender. However, the finding contradicts the finding of Gernale, Arañes, and Duad (2015) who found that female students' had better attitude toward Biology than their male counterparts using Predict-Observe-Explain (POE) strategy. The likely reason for the difference may be because; the POE strategy used did not emphasize the important of students' explanation for their prediction.

The study also found that female students had slightly higher self-efficacy belief than their male counterparts using Vee heuristic (VH) strategy but ANCOVA test shows that the difference was no significant. This implies that, the difference in the self-efficacy belief of male and female students taught Organic Chemistry using VH strategy was not statistically significant. This means that VH strategy enhanced both male and female students' self-efficacy belief in Organic Chemistry. Therefore, if either Predict-Explain-Observe-Explain (PEOE) or VH strategy is implemented in classroom, it will enhance students' confidence or trust about their ability to solve Organic Chemistry related problems using PEOE and VH strategies irrespective of gender. Thus, in order to encourage gender equivalence in self-efficacy belief in Organic Chemistry concept, either PEOE or VH strategies should be embraced by Chemistry teachers.

4.3.4 Interaction Effects of Strategies and Gender on Students' Achievement, Metacognitive Awareness and Self-Efficacy Belief in Organic Chemistry

The study revealed that the interaction effect between strategies and gender on the achievement of students in Organic Chemistry is very minimal but ANCOVA test shows that the interaction effect was not significant. This implies that there was no significant interaction between strategies and gender on mean achievement scores of students in Organic Chemistry. Hence, either Predict-Explain-Observe-Explain (PEOE) or Vee Heuristic (VH) strategy can be used successfully irrespective of gender in fostering students' achievement. In this case, there is no need for separation of instructional strategy for male and female students, since either PEOE or VH strategy could be used successfully for the three groups.

Finding of this study revealed that the interaction effect between strategies and gender on the metacognitive awareness of students in Organic Chemistry is very minimal but ANCOVA test shows that the interaction effect was not significant. This implies that there was no significant interaction between strategies and gender on mean metacognitive awareness scores of students in Organic Chemistry. This is in line with Bajar-Sales, Avilla and Camacho (2015) who found that there was no significant interaction between strategies and gender on metacognition of students in Biology. Hence, either Predict-Explain-Observe-Explain (PEOE) or Vee Heuristic (VH) strategy can be used successfully irrespective of gender in fostering students' metacognitive awareness. Therefore, there is no need for separation of instructional strategy for male and female students, since either PEOE or VH strategy could be used successfully for the three groups.

The study revealed that the interaction effect between strategies and gender on the self-efficacy belief of students in Organic Chemistry is very minimal but ANCOVA test shows that the interaction effect was not significant. This implies that there was no significant interaction between strategies and gender on mean self-efficacy belief scores of students in

Organic Chemistry. Hence, either Predict-Explain-Observe-Explain (PEOE) or Vee Heuristic (VH) strategy can be used successfully irrespective of gender in fostering students' self-efficacy belief. In this case, there is no need for separation of instructional strategy for male and female students, since either PEOE or VH strategy could be used successfully for the three groups.

Treatment interaction according to Abonyi (2014) generally implies that different learners with different characteristics may profit more from one type of instructional method than from another and that therefore it may be possible to find the best match of learners' characteristic and instructional method in other to maximize learning outcomes. In this case, there is no need for separation of instructional method for male and female since either PEOE or VH strategy could be used successfully for the three groups.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary of this study, conclusion reached based on the findings and recommendations. It also presents the limitation of the study, suggestions for further studies and contributions to knowledge.

5.2 Summary

The purpose of this study was to investigate if Predict-Explain-Observe-Explain (PEOE) and Vee Heuristic (VH) instructional strategies have effects on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry among Senior Secondary two (SS2) students offering chemistry in Ekiti State, Nigeria. Specifically, the study investigated the effects of PEOE and VH strategies on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry in three study groups namely; the control group, experimental group 1 and experimental group 2. It also investigated the effects of PEOE and VH strategies on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry between male and female students. Twelve research questions and twelve null hypotheses were formulated and tested.

Relevant theories of learning such as Ausubel's assimilation learning theory, Piaget's cognitive development theory, and Vygotsky's social development theory were reviewed. The theories described the process of learning by the active involvement of the learner in knowledge creation to improve learning experiences and metacognitive awareness of such concept. Conceptual issues such as Predict-Explain-Observe-Explain (PEOE) instructional strategy, Vee heuristic instructional strategy, discussion method, collaborative learning, facilitating collaborative learning using PEOE and Vee heuristic instructional strategies, PEOE, Vee heuristic Instructional Strategies and Information Communication and Technology (ICT), Organic Chemistry, students' achievement in Chemistry, students' metacognitive awareness in Chemistry, students' self-efficacy belief in Chemistry, gender issues in Chemistry and interaction effect were discussed in the context of the study.

The study adopted a quasi-experimental design of pre-test, post-test, non-randomized control groups. Intact classes in the sampled schools were used since complete randomization of subjects was not possible. 308 Senior Secondary two (SS2) students from 9 schools in the study area were used. Three instruments namely Organic Chemistry Achievement Test (OCAT), Metacognitive Awareness Inventory (MAI), and Organic Chemistry Self-Efficacy Belief Scale (OCSEBS) were used for the study. The descriptive statistics of mean and standard deviation were employed to answer the research questions and inferential statistics of Analysis of Covariance (ANCOVA) were used to test the null hypotheses. Based on the data collected and analyzed, the following findings were made:

1. There was significant difference in the mean achievement scores of students taught Organic Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee heuristic (VH) strategy and discussion method. Students taught Organic Chemistry using PEOE and VH strategies attained higher mean achievement scores than those taught using discussion method.
2. The difference in the mean achievement scores of male and female students taught Organic Chemistry using PEOE strategy was not statistically significant.
3. There was no significant difference between the mean achievement scores of male and female students taught Organic Chemistry using VH strategy.
4. There was no significant interaction effect of treatments and gender on the mean achievement scores of students in Organic Chemistry.

5. There was significant difference in the mean metacognitive awareness scores of students taught Organic Chemistry using PEOE strategy, VH strategy and discussion method. Students taught Organic Chemistry using PEOE and VH strategies attained higher mean metacognitive awareness scores than those taught using discussion method.
6. There was no significant difference between the mean metacognitive awareness scores of male and female students taught Organic Chemistry using PEOE strategy.
7. The difference in the mean metacognitive awareness scores of male and female students taught Organic Chemistry using VH strategy was not statistically significant.
8. There was no significant interaction effect of treatments and gender on the mean metacognitive awareness scores of students in Organic Chemistry.
9. The difference in the mean self-efficacy belief scores of students taught Organic Chemistry using PEOE strategy, VH strategy and discussion method was statistically significant. Students taught Organic Chemistry using PEOE and VH strategies attained higher mean self-efficacy belief scores than those taught using discussion method.
10. There was no significant difference between the mean self-efficacy belief scores of male and female students taught Organic Chemistry using PEOE strategy.
11. The difference in the mean self-efficacy belief scores of male and female students taught Organic Chemistry using VH strategy was not statistically significant.
12. There was no significant interaction effect of treatments and gender on the mean self-efficacy belief scores of students in Organic Chemistry.

5.3 Conclusion

It is evident from the findings of this study that the use of both Predict-Explain-Observe-Explain (PEOE) strategy and Vee heuristic (VH) strategy enhanced students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry than the use of discussion method. No gender disparity exists in the achievement, metacognitive awareness and self-efficacy belief of male and female students taught Organic Chemistry using PEOE and VH instructional strategies respectively. This implies that both PEOE and VH strategies are very rewarding to students' in-terms of achievement, metacognitive awareness and self-efficacy belief regardless of gender. There was no interaction effect between treatments and gender on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry. This implies that there is no need for separation of instructional strategy for male and female since either PEOE strategy or VH strategy could be used successfully.

5.4 Recommendations

Based on the findings and conclusion of this study, the following recommendations were made:

1. Chemistry teacher's trainee should be train on the application of Predict-Explain-Observe-Explain (PEOE) strategy and Vee heuristic (VH) strategy and serving teachers should employ the use of PEOE and VH strategies in teaching to enhance students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry.
2. The curriculum developers should use PEOE and VH strategies to develop and refine the Chemistry curriculum in general and Organic Chemistry in particular.

3. PEOE and VH instructional strategies are not gender sensitive therefore both male and female students should be involved in PEOE and VH activities to enhance their achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry.
4. Ministry of Education, school administrators and professional bodies such as Association of Science Educators (ASE) and Science Teachers Association of Nigeria (STAN) should organize conferences or seminars and workshops to popularize and sensitize Chemistry teachers on the integration of PEOE and VH instructional strategies in teaching Organic Chemistry.

5.5 Limitation

The limitation noted in the course of undertaking this study was inadequate cooperation of school teachers due to what they claimed to be working without pay. However, the researcher patiently persuaded with the teachers in order for them to be trained, do the teaching and administered the instruments which they agreed to the request.

5.6 Suggestions for Further Studies

The following suggestions are made for further studies:

1. There is need to replicate the study using other states in Nigeria to support this study validity.
2. Research works on Predict-Explain-Observe-Explain (PEOE) and Vee heuristic (VH) instructional strategies could also be done in other science subjects.
3. More study should be carried out in order to examine the effects of PEOE and VH strategies on students' attention, motivation and retention in Chemistry using other difficult aspects such as Inorganic Chemistry, and Analytical Chemistry and so on.

5.7 Contributions to Knowledge

This study has contributed to knowledge by prooving the efficacy of Predict-Explain-Observe-Explain (PEOE) and Vee heuristic (VH) instructional strategies, thereby providing teachers with effective methods of teaching Organic Chemistry as students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry were found to be greatly enhanced by the use of PEOE and VH instructional strategies. This study has also contributed to knowledge by establishing that the use of PEOE and VH strategies does not engender gender disparity in students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry. This indicates that the issue of gender disparity could be minimized in science education if the strategies are embraced by teachers and students. It has also contributed by adding to the existing pool of empirical studies in the study area.

REFERENCES

Ababio, O.Y. (2009). *New school chemistry for senior secondary schools*. Onitsha: Africana First Publishers Limited.

Abayomi, M. (2015). Information, communication and technology and classroom. Retrieved on 17th March, 2018 from http://www.visual-edu/class-ict/sciencepdf

Abe, K.E. (2017). *Relative effectiveness of guided inquiry and discussion strategies of teaching chemistry on academic achievement of secondary students in Ekiti State, Nigeria*. Unpublished PhD Thesis, Adekunle Ajasin University, Akungba Akoko.

Abonyi, S.T. (2014). *Effect of experiential approach on students' achievement and retention in geometry*. Unpublished PhD Thesis, Lagos State University, Lagos State.

Acar-Sesen, F. (2017). Preservice science teachers' understanding of surface tension, cohesion and adhesion forces by using computer-mediated predict-explain-observe-explain tasks. Retrieved on 16th March, 2018 from http://www.media-edu/stimul-soc/creativitypdf

Achor, E.E., Wude, M.H., & Duguryil, Z.P. (2013). Do cooperative learning strategies have the potentials to eliminate gender difference in students' achievement in biology? The effect of STAD and Jigsaw cooperative strategies. *Journal of Science, Technology, Mathematics and Education, 10*(1), 136-146.

Ada, D.F. (2011). Controversial issues in chemistry education. *American Chemistry Teacher, 7*(3), 342-351.

Adebayo, S. (2015). *Effect of inquiry approach on students' achievement in chemistry*. Unpublished M.Ed dissertation, Adekunle Ajasin University, Akungba Akoko.

Adebola, J. (2015). Gender differences in Caribean students' performance on a test of errors in biology labeling. *Research in Science and Technological Education, 17*(1), 75-82.

Adewale. S. (2014). Introduction to organic chemistry. Retrieved on 21th March, 2018 from http://www.report-edu/organic-chemistry/sciencepdf

Adewale, L.A. (2017). Teaching methods as determinant of learners' level of metacognitive awareness, problem solving abilities and self-esteem. Retrieved on 22nd January, 2018 from http://www.journals.elsevier.com/method-and-metacognitive-awareness

Adeyemi, A. (2014). Factors affecting students' achievement in senior secondary certificate examination chemistry concepts in Nigeria. Retrieved on 25th March, 2018 from *http://www.ebiblia/ssce/chemistry%20perform*

Afamasaga, F.K. (2013). *Learning to solve mathematics problems through concept mapping and Vee diagramming*. Samoa: National University of Samoa Press.

Ahmed, W. (2016). Reciprocal relationships between math metacognitive awareness and math anxiety, learning and individual differences. Retrieved on 12th January from http://www.journals.elsevier.com/learning-and-individual-differences

Ajah, F.A. (2014). Analysis of students' achievement in science. *Journal of Science Education, 1*(4), 86-92.

Ajayi, O.V. (2016). *Effect of hands-on activities on senior secondary chemistry students' achievement and retention in stoichiometry in Zone C of Benue State*. Unpublished M.Ed. Dissertation, Benue State University, Makurdi.

Ajayi, O.V., & Ogbeba, J. (2017). Effect of gender on senior secondary chemistry students' achievement in stoichiometry using hands-on activities. *American Journal of Educational Research, 5*(8), 839-842.

Akinsola, N. (2011). Education, science, and technology. *Journal of Research in Science Teaching, 10*(2), 12-16.

Akorede, M.K. (2017). Analysis of students' enrolment and performance in chemistry Senior Secondary Certificate. *Journal of Studies in Curriculum 29*(2), 19-25.

Alexander, P.A. & Jetton, J. (2015). Development of metacognition in gifted children: directions for future research. *Developmental Review 15,* 1–37.

Al-Khalili, H., Haidar, K., & Younis, S. (2013). Uncovering students' thinking about thinking using Vee heuristic diagrams. Retrieved on 26th March, 2018 from http://www.mau-edu/vee/diagram/springerlink.pdf

Anaekwu, M.C., & Nnaka, C.V. (2013). Students' enrolment and achievement in science technology and mathematics at senior school certificate examination: Implication for available and utilization of instructional resources. *Proceedings of 47th Annual Conference of Science Teachers Association of Nigeria held at Calabar.*

Anyagh, I.P. (2013). *Effects of formula strategy on students' achievement and interest in algebra*. Unpublished M.Ed. Dissertation, Benue State University, Makurdi.

Archibong, A.U. (2012). Relative effectiveness of student-centered activity-based strategy and lecture method on the cognitive achievements of integrated science students. *Journal of Science Teachers Association of Nigeria*, *32*(2), 37-42.

Arigbabu, A.A., & Ariyo, M. (2009). Is gender a factor in chemistry performance among Nigerian pre-service teachers? Retrieved on 21th April, 2018 from http://www.chem/perform002/Usieni/pre/teacher.pdf

Ausubel, D.P. (1962). *Educational psychology: A cognitive view.* New York: Holt, Rinehart and Winston Inc.

Ayuba, Y. (2016). *Philosophical principles of universal chemistry*. Lagos: Happy Press.

Bajar-Sales, P.A., Avilla, R.A., & Camacho, V.M.I. (2015). Predict-Explain-Observe-Explain (PEOE) approach: Tool in relating metacognition to achievement in chemistry. *Electronic Journal of Science Education, 19*(7), 1-21.

Bandura, A. (2012). Self-efficacy in changing societies. New York: Cambridge University Press.

Banky, G.P., & Wong, K.K. (2014). *Troubleshooting exercises using circuit simulator software: Support for deep learning in the study of electronic circuits*. International Conference on Engineering Education, Coimbra, Portugal.

Basque, J., & Lavoie, M.C. (2016). Collaborative concept mapping in education: major research trends. In Canas, A.J., & Novak, D. (Eds.), Concept Maps: Theory, Methodology, Technology. Proceeding *of the Second International Conference on Concept Mapping, 1*(4), 79-86. San Jose, Costa Rica: Universidad de Costa Rica.

Beaker, H., & Hall, L. (2014). Teacher character and students achievement in elementary schools. *Journal of Urban Economics*. *78*, 104-111.

Bouffard-Bouchard, T., Parent, S., & Larivèe, S. (2014). Influence of self-efficacy on self-regulation and performance among junior and senior high-school aged students. *International Journal of Behavioral Development, 14*, 153-164.

Boxtel, C., Linden, J., & Kanselaar, G. (2016). Collaborative learning tasks and the elaboration of conceptual knowledge. *Learning and Instruction, 10*, 311-330.

Britannica, M.A. (2015). Chemistry of carbon compound. Retrieved on 26th March, 2018 from http://www.ebiblioteka/organic/compound/chem-sketch

Brody, M. (2012). Using cognitive mapping techniques for educating about sexually transmitted diseases with an intelligent tutoring system. *Journal of Artificial Intelligence in Education, 2*(2), 67-82.

Bruning, R.H., Schraw, G.J., & Ronning, R.R, (2012). *Cognitive psychology and instruction* (4th ed.). Columbus, OH: Merrill.

Burçin, A. (2013). Predict-Observe-Explain tasks in chemistry laboratory: Pre-service elementary teachers' understanding and attitudes. *Sakarya University Journal of Education, 6*(2), 184-208.

Calsambis, S. (2014). Gender related differences in acquisition of formal reasoning schemata: pedagogic implication of teaching science using inquiry based strategy. *International Journal of Education. 23*(1), 435-440.

Canas, A.J., Hill, G., Carff, R., & Suri, N. (2015). CmapTools: A knowledge modeling and sharing toolkit. Retrieved on 13th January, 2018 from http://www.cmc.ihm09c.us

Central New Mexico (CNM) (2009). Report on students' achievement in science. Retrieved on 21th October, 2017 from http://www.report1-edu/sciencepdf

Çetin, B. (2015). An investigation of teacher candidates' metacognitive skills according to their year of study at Çanakkale. *Educational Research and Review, 10*(1), 10-16.

Chamol, M., & Kupper, A. (2011). Instruction of metacognitive strategies enhances reading comprehension and vocabulary achievement of third-grade students. *The Reading Teacher Journal, 61*(1), 70-77.

Champagne, A. B., Klopfer, L. E., & Anderson, J. H. (1979). Factors influencing the learning of classical mechanics of physic students in university of Pittsburgh. *American Journal of Physics*, *48*(12), 1074-1079.

Chatzipanteli, A., Grammatikopoulus, V., & Gregoriadis, A. (2014). Development and evaluation of metacognition in early childhood education. Retrieved on 13th January, 2018 from http://www.dx.doi.org.10.1080/03004430.2013.861456

Chiu, C.H., & Hsiao, H.F. (2016). Group differences in computer supported collaborative learning: Evidence from pattern of Taiwanese students' online communication. *Computers and Education*, *20*(10), 427-435.

Chou, C. (2011). *A study on the relationships among english self-efficacy, english learning anxiety, english learning strategies and english learning achievement of senior high school students.* Unpublished PhD thesis, National Taiwan Normal University, Taipei, Taiwan.

Chris, J. (2016). Predict, observe, and explain (POE). Retrieved on February 12, 2018 from http://www.arbs.nzcer.org.nz/strategies/poe.php

Cicognani, A. (2011). Vee heuristic as a collaborative tool for enhanced online learning. Retrieved on 21th March, 2018 from http://www.ebiblioteka/map/Uzsienio%20leidiia

Cihanoglu, M.O. (2012). Metacognitive awareness of teacher candidates in Procedia. *Social and Behavioral Sciences, 46*, 4529-4533.

Coronado-Aliegro, J. (2011). The effect of self-assessment on the self-efficacy of students studying Spanish as a foreign language. Retrieved on 21th March, 2018 from http://dscholarship.pitt.edu/9914/

Conner, M.I. (2015). Introduction to learning styles. Retrieved on 24th August, 2018 from http://agelesslearner.com/intros/Isyleintro.html

Costu, N., Ayas, A.A., & Niaz, O. (2002). Promoting students understanding of science using predict-discuss-explain-observe-discuss-explain (PDEODE). *Review of Research in Education, 26*(8), 23-70.

Coutinho, S.A., & Neuman, G. (2012). A model of metacognition, achievement goal orientation, learning style and self-efficacy. *Learning Environment Research*, *11*(1), 131-151.

Coutinho, S.A. (2014). Self-efficacy, metacognition, and performance. *North American Journal of Psychology, 10*, 1-14.

Coutinho, S.A. (2014). The relationship between goals, metacognition and academic success. *The Journal of Doctoral Research in Education, 1*(7), 39-47.

Cox, D.R. (2014). Interaction. Retrieved on June 27th, 2019 from http://dx.doi.org/10.2304

Curwen, M.S., White-Smith, K.A., & Calfee, R.C. (2013). Increasing teachers' metacognition develops students' higher learning during content area literacy instruction: Findings from the read-write cycle project. *Issues in Teacher Education, 7*(1), 127-135.

Dalziel, J. (2010). *Practical e-teaching strategies for predict-observe-explain problem-based learning and role plays*. Macquarie: Macquarie University Press.

Daudu, S.K. (2017). Poor secondary school students' achievement in West African Examination Council: Implication on science and technology development. *Journal of Education and Research, 8*(8), 234- 241.

Demircioğlu, N., Demircioğlu, L., & Aslan, A. (2017). Effect of predict-observe-explain technique on the understandings of grade 11 students about the gases. *Journal of Educational and Instructional Studies, 7*(4), 2146-2155.

Denga, D.I. (2017). *An introduction to research methods and statistics in education and social sciences.* Calabar: Clearlines Publications Limited.

Desoete, A., & Veenman, M. (2011). Metacognition in mathematics: Critical issues on nature, theory, assessment and treatment. In Desoete, A., & Veenman, V. (Ed.). *Metacognition in mathematics education* (pp.1-10). New York: Nova Science Publishers.

Dillenbourg, P. (2011). What do you mean by collaborative learning? In Dillenbourg, P. (Ed). *Collaborative-learning: cognitive and computational strategies* (pp.1-19). Oxford: UK, Elsevier publishing.

Diovu, C.I. (2012). *Effects of teacher made models and students made models on students' achievement and interest in organic chemistry*. Unpublished Ph.D Thesis, University of Nigeria, Nsukka.

Dodge, Y. (2013). The Oxford dictionary of statistical terms. Oxford: Oxford University Press.

Duffy, T.M., & Jonassen, D. (2013) *Constructivism and the technology of instruction: A conversation*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Eberlein, T., Kampmeier, J., Minderhout, V., Moog, R.S., Platt, T., Varma-Nelson, P., & White, H.B. (2011). Pedagogies of engagement in science, biochemistry and molecular biology. *Journal of Education 36*(4), 262-273.

Edo, E.S. (2016). *Story map, study questions and secondary school students' achievement in prose fiction in Education Zone C of Benue State*. Unpublished Ph.D Thesis, Benue State University Makurdi.

EKSTSB (2018). *Ekiti State teaching service board statistic unit reports on population of chemistry students in Ekiti State*. Ado Ekiti: EKSTSB.

Elliot, E., & Zahn, A.M. (2012). Comparative effect of discussion and lecture method on students' achievement in elementary science. *Journal of Educational Studies*, 2(9), 12-17.

Elliot, S.N., Kratochwill, T.R., Littlefield, C.J., & Travers, J.F. (2012). *Educational psychology*. Boston: McGraw Hill.

Elliot, A.J., & Harackiewicz, J.M. (2013). Approach and avoidance achievement goals and intrinsic motivation: A meditational analysis. *Journal of Personality and Social Psychology, 70,* 461-475.

Emaikwu, S.O. (2013). *Fundamentals of research method and statistics*. Makurdi: Selfers Academic Press Limited.

Engelmann, T., & Hesse, F.W. (2010). How digital concept maps about the collaborators' knowledge and information influence computer-supported collaborative problem solving. *International Journal of Computer-Supported Collaborative Learning, 5*(3), 299-319.

Ericson, J.O., & Ericson, K. (2010). Achievement and gender in Science. *International Journal of Research in Educational Studies*, *2*(5), 23-27.

Ezeugo, N.C. (2012). *Effect of concept mapping on students' achievement and interest in mathematics in Nigeria*. Unpublished Ph.D Thesis, University of Nigeria, Nsukka.

Feden, R.D., & Vogel, R.M. (2015). *Methods of teaching: applying cognitive science to promote student learning*. Boston: McGraw Hill.

Federal Republic of Nigeria (FRN) (2013). *National policy on education*. Lagos: NERDC Press.

Fink, R. (2016). *Why Jane and John couldn't read and how they learned: A look at striving readers.* Newark: International Reading Association.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of psychological inquiry. *American Psychologist, 34,* 906-911.

Flavell, J.H. (1999). Cognitive development: children's knowledge about the mind. *Annual Review of Psychology, 50*, 21-45.

Fred, W.N. (2015). Effect of Vee heuristic strategies on students' motivation and achievement in biology in secondary schools in Uasin Gishu district, Kenya. Retrieved on 14th, March, 2017 from http://www.ken/uniken/fred/conceptmotivati19

Gahungu, V. (2016). Relation of self-efficacy beliefs to academic outcomes: A meta-analytic investigation. *Journal of Counseling Psychology, 38*(1), 30-38.

Gall, M. D., & Gillett, M. (2012). The discussion method in classroom teaching. *Theory into Practice, 19*(1), 98–103.

Gao, H. (2012). Effect of key concept availability and individual preparation in the form of proposition formation in collaborative concept mapping on learning, problem solving and learner attitudes. Retrieved on 10th, January, 2018 from http://www.diginle.lib.fsu.edu/cgi/viewcontent.cgi?article=1593&

Garner, R., & Alexander, P.A. (2013). Metacognition: Answered and unanswered questions. *Educational Psychologist, 24,* 143-148.

Gernale, J.P., Arañes, F.Q., & Duad, V. (2015). Effects of predict-observe-explain (POE) approach on students' achievement and attitudes towards science. *The Normal Lights, 9*(2), 1-23.

Gassner, L. (2009). *Developing metacognitive awareness: A modified model of a problem based learning-tutoria*l. Malmö: Malmö University electronic publishing.

Gassner, R. (2015). *Metacognition and reading comprehension*. Norwood, New Jersey: Ablex.

Gipps, K.S. (2014). Gender inequality. In Therney, H. (Ed.) *Women's studies encyclopedia* (pp.231-238). New Yolk: Peter Bedrick Books.

Gowin, D.B (1995). *The domain of education.* Ithaca, New York: Cornell University.

Gowin, D.B. (2010). The structure of knowledge. *Educational theory, 20,* 319-328.

Hacker, D. H. (2011). Definitions and empirical foundations. In Hacker, D.H., Dunlosky, J. & Graesser, A.C. (Eds.). *Metacognition in educational theory and practice* (pp.75-82). Mahwah, New Jersey: Erlbaum.

Haruna, Y.A.K. (2016). Effect of Vee heuristic strategy on students' achievement in physics among senior secondary students in Akwanga local government area of Nasarawa State. *Journal of Education and Practice, 29*(3), 123-130.

Hernandez, E. (2012). *Predict-Observe-Explain approach and students' achievement in general chemistry laboratory.* Unpublished PhD Thesis, Technological University of the Philippines. Manila.

Hilario, J.S. (2015). The use of Predict-Observe-Explain-Explore (POEE) as a new teaching strategy in general chemistry laboratory. *International Journal of Education and Research, 3*(2), 37-48.

Husseini, A. (2016). *Analyzing of students' misconceptions on chemical equilibrium at senior high school in Medan.* Unpublished PhD Thesis, University of Medan, Medan.

Inikori, G.O. (2013). *Introductory organic chemistry for tertiary institutions.* Zaria: Jodda Press.

Inomesia, E.A., & Unuero, J.U. (2012). Vee mapping: A radical paradigm to guided discovery method in the teaching of science in Nigeria. *Journal of Educational Research and Development*, *2*(1), 111 – 119.

Iskandar, T.M., & Sanusi, Z.M. (2017). Assessing the effect of self-efficacy and task complexity on international control audit judgment: Asian academy of management. *Journal of Accounting and Finance, 7*(1), 29-52.

Jegede, F.A. (2014). *The knowledge base for learning in science and technology education:* African science and technology education in the new millennium; practice, policy and priorities. 151-176. Kenny 1: Jutalsco Limited.

Jegede, O.N., & Inyang, N.E. (2014). Influence of sex difference of students on their achievement in secondary school chemistry. *Jos Journal of Education, 6*(2), 95-100.

Joanne, C.Y.C., & Shui-Fong, L. (2012). Effects of competition on students' self-efficacy in vicarious learning. *British Journal of Educational Psychology. 78*(1), 95-108.

Johnson, D.W., & Johnson, R.T. (2008). Social interdependence theory and cooperative learning: the teacher's role. In Gillies, R.M., Ashman, A., & Terwel, J. (Eds.). *Teacher's role in implementing cooperative learning in the classroom* (pp. 9-37). New York, USA: Retrieved on 10th, February, 2018 from http://www.dx.doi.org/10

Johnson, D.W., & Johnson, R.T., & Smith, M. (2009). *Reaching out: Interpersonal effectiveness and self and collaborative actualization (10th Ed.)*. Boston: Allyn and Bacon.

Johnson, D.W., Johnson, R.T., & Holubec, H. (2008). Cooperative: competitive an Individual learning. *Journal of Research and Development in Education, 12* (1), 3-15.

Jonassen, D.H., Lee, C.B., Young, C.C., & Laffey, J. (2009). The collaborative principle in multimedia learning. Mayer, I.R. (Ed.). *Cambridge handbook of multimedia learning* (pp. 247-270). Cambridge: Cambridge University Press.

Karamustafaoğlu, S.K., & Mamlok-Naaman, R. (2015). Understanding electrochemistry concepts using the predict-observe-explain strategy. *Eurasia Journal of Mathematics, Science and Technology Education, 11*(5), 923-936.

Kate, A. (2016). A comparison of level of understanding of eighth-grade students and science student teachers related to selected chemistry concepts. *Journal of Research in Science Teaching, 42*(6), 638-667.

Kearney, M. (2002). *Classroom use of multimedia-supported predict–observe–explain tasks to elicit and promote discussion about students' physics conceptions.* Unpublished PhD thesis, Curtin University of Technology, Perth, Australia.

Kearney, M. (2013). Classroom use of multimedia-supported predict–observe–explain tasks in a social constructivist learning environment. *Research in Science Education. 34*, 427–453.

Kearney, M., & Young, D.J. (2011). Improving students' comprehension using predict-observe–explain-elaborate-write-evaluate (POE_2WE). *International Journal of Technology in Teaching and Learning*, *2*(3), 17-25.

Keraro, F.N. (2014). *Vee diagramming in collaborative classroom*. Kenya: University Press.

Khataibeh, K.A. (2011). The Vee diagram: a guide for problem solving. Retrieved on March 20, 2018, from http://www.aimsedu.org/puzzle/arrrec/vee.pdf

Kidanemariam, D.A., Atagana, H.I., & Engida, T. (2013). Do learning styles influence students' understanding of chemistry concepts and academic performance in chemistry? *Journal of Educational and Social Research, 3*(5), 167-172.

Kinchin, I.M. (2013) Using concept maps to reveal understanding: A two-tier analysis. *School Science Review, 81*, 41-46.

Kingdon, M.N. (2015). Hand on laboratory experiments. Retrieved on 23rd January 2018 from http://www.handexperience103/chm/experiment

Korau, Y.K. (2006). Educational crises facing Nigerian secondary schools and possible solutions. Being a paper presented at Faculty of Education, University of Ibadan.

Kothari, K (2013). Use of Vee heuristic strategy and computer simulation for meaningful learning. Retrieved on 23rd April, 2018 from http://www.hhanjvee1031/reallifevideo

Kyado, J.J. (2018). *Relative effectiveness of collaborative and individualized concept mapping instructional strategies on achievement of senior secondary 2 students in perceived difficult biology concepts*. Unpublished PhD thesis, Benue State University, Makurdi.

Lara, A. (2011). Self-efficacy and academic performance. *Social Behavioural Journal, 29*(7), 87-93.

Lai, E. (2011). Metacognition: A literature review. Retrieved on 20th July 2018 from http://www.images.pearsonassessments.com/images/tmrs/MetacognitionLiteratureReviewFinal.pdf

Lavrakas, P.J. (2008). Interaction effect: Survey research methods. Retrieved on June 27th, 2019 from http://dx.doi.org/10.4135/9781412963947.n226

Leonard, J. (2012). Application of organic chemistry. Retrieved on March 12th, 2018 from http://*www.chem/edjiaoedu/app/organic/chem*.pdf

Liew, C. (2011). The effectiveness of predict-observe-explain technique in diagnosing students' understanding of science and identifying their level of achievement. Retrieved on January 9, 2018, from: http://www.espace.library.curtin.edu.au/R/?in

Liew, C., & Treagust, T. (2010). A predict-observe-explain teaching sequence for learning about students' understanding of heat and expansion of liquids. *Australian Science Teachers' Journal, 41*, 871-882.

Longman Dictionary of Contemporary English (2009). The living dictionary. Retrieved on April 18, 2018, from http://www.longman.com/idoce/achievement

Mackinnon, J., & Aylward, K. (2014). Information, communication and technology in the 21th century. , Retrieved on April 21, 2018, from http://www.theaste.org/-ict/html.

Maduabum, M.A. (2011). Gender difference in educational participation and performance in science, technology and mathematics: A Nigerian perspective. *International Journal of Women Students*, *3*(6), 217-224.

Margolis, H., & McCabe, P.P. (2016). Improving self-efficacy and motivation: What to do, what to say. *Intervention in School and Clinic, 41*(4), 218–227.

Mehan, H. (2009). *Discussion learning lessons.* Cambridge, MA: Harvard University Press.

Mills, N., Pajares, F., & Herron, C. (2015). Self-efficacy of college intermediate French students. *French Language Learning, 57*(3), 417-442.

Mills, N., Pajares, F., & Herron, C. (2016). A reevaluation of the role of anxiety: self-efficacy, anxiety, and their relation to reading and listening proficiency. *Foreign Language Annals, 39*(2), 276-295.

Mosca, C. (2014). *Relative effectiveness of the predict-observe-explain teaching strategy on students learning outcome.* Unpublished PhD Thesis, Rodriguez Institute of Science and Technology.

Mutai, D.K., Changeiywo, J.M., & Okere, M.I.O. (2014). Effects of Gowin's Vee heuristic strategy on secondary school students' conceptual understanding and metacognition in the topic of moments in physics, in Uasin Gishu County, Kenya. *Journal of Education and Practice, 5*(29), 193-205.

NECO (2016). *Registrar and Chief Executive Examiner's reports for June/July National Examination Council Senior Secondary Certificate Examination.* Minna: NECO.

NECO (2017). *Registrar and Chief Executive Examiner's reports for June/July National Examination Council Senior Secondary Certificate Examination*. Minna: NECO.

NERDC (2012). *Nigerian educational research and development council reports on chemistry curriculum for SSS 1-3*. Abuja: NERDC Press.

Newton, L.D. (2005). *Meeting the standards in secondary science*. London: Routledge.

Njue, A.K., Kamau, L.M., & Mwania, J. (2018). Effects of Vee heuristic teaching approach on secondary school students' attitudes towards Biology in Kenya. *International Organization of Scientific Research Journal of Research and Method in Education, 8*(1), 18-23.

Njue, A.K., & Magana, A.M. (2016). Effects of Vee heuristic teaching approach on achievement of boys and girls in biology in public secondary schools in Kenya. *International Journal of Education and Research, 4*(10), 23-32.

Novak, J.D. (1984). Meaningful learning: The essential factor for conceptual change in limited or inappropriate propositional hierarchies leading to empowerment of learners. *Journal of Science Education, 86*(4), 445-599.

Novak, J. D. (1998). *Learning, creating, and using knowledge: Concept maps as facilitative tools in schools and corporations.* Mahweh, New Jersey: Lawrence Erlbaum Associates.

Novak, J.D., & Gowin, D.B. (1995). *Learning how to learn.* New York: Cambridge University Press.

NPC (2006). *National population commission, data base unit*. Ado Ekiti: NPC.

Nworgu, B.G. (2013). *Educational measurement and evaluation: Theory and practice.* Awka: Hallman Publishers.

Ocho, L.O. (2011). National development and the curriculum.In Oriaifo, S.O., Edozie, G.C., & Ezeh, D. N. (Eds.).*Curriculum issues in contemporary education* (pp.90-96). Benin City: Da Sylra.

Ogunkunle, R.A. (2014). Fostering gender equity in mathematics education for sustainable development. *Journal of International Gender Studies, 4*(1), 14-17.

Okafor, H. (2016). Effects of Vee heuristic on students' achievement in basic science. *Journal of Educational innovations, 3*(8), 23-32.

Okam, C.C. (2013). *Teaching issues: Insight at problems in the social studies education in Nigeria*. Jos: Deka Publisher.

Okebukola, P.A. (2016). The race against obsolescence: science teachers' association of Nigeria (STAN) memorial lecture series, 17. *Enhancing the relevance of science teacher association of Nigeria to national development*. Jos: Plateau State, Nigeria.

Okeke, E.A. (2009). *Gender science and technology for Africa*. A challenge for education. The 2009 Rama mental lecture. Radel Life College.

Okoroafo, S. (2014). Gender difference in secondary school students' academic achievement in Science. *Australian Science Teachers Journal, 23*(6), 23-25.

Olarewaju, A. (2013). Facilitating conceptual change in students' understanding of electrochemistry. *International Journal of Science Education, 24*, 425-439.

Olorundare, A.S. (2012). Learning difficulties in science education: An analysis of the current status and trends. *Kwara State University International Journal of Education, 1*(1), 1-12.

Olorundare, A.S. (2014). Theories and models of instruction: Philosophical foundations of instruction. In Abimbola, I.O., & Abolade, A.O. (Eds) *Fundamental principles and practice of instruction*, (pp. 24-43). Ilorin: Departments of Science Education, Art and Social Science Education, University of Ilorin, Kwara State.

Olorundare, A.S. (2016). *Correlates of poor academic performance of secondary school students in the sciences in Nigeria*. Paper presented at the International Institute for capacity building in higher education, Virginia State University, Virginia, USA. 20th–31st June, 2016.

Olorunyomi, A.A. (2013). *Effects of field-trip teaching strategy on students' achievement and interest in Biology*. Unpublished PhD thesis, Adekunle Ajasin University, Akungba Akoko.

Olorunyomi, A.A. (2016). *Effects of concept mapping teaching strategy on students' achievement and metacognitive awareness in Basic Science*. Unpublished PhD thesis, Ekiti State University, Ado Ekiti.

Ormrod, J.E. (2011). *Human learning: Upper Saddle River*. New Jersey: Pearson Prentice Hall.

Omwirhiren, E.M. (2015). *Elements of organic chemistry for beginners*. Orerokpe: Mouson and Moses Nigeria Limited.

Omwirhiren, E.M. (2015). Enhancing academic achievement and retention in senior secondary school Chemistry through discussion and lecture methods: A case study of some selected secondary schools in Gboko, Benue State, Nigeria. *Journal of Education and Practice. 6*(21), 159-160.

Osaji, E. (2012). Important concepts underlying gender mainstreaming. Retrieved March 23, 2018, from http://www.emory.edu/osaji/factsheets/pdf

Otor, E.E. (2013). Effect of concept mapping strategy on students' achievement in difficult chemistry concepts. *Educational Research, 4*(2), 182-189.

Ozsoy, S. (2015). Pre-service teachers' attitudes toward use of Vee diagrams in general physics laboratory. *International Electronic Journal of Elementary Education, 1*(3), 34-39.

Pajares, F., & Schunk, D.H. (2012). Self-beliefs and school success: Self-efficacy, self-concept, and school achievement. In Riding, R., & Rayner, S. (Eds.). *Perception (*pp. 239-266). London: Ablex Publishing.

Pajares, F., & Urdan, T. (2014). *Self-efficacy of adolescents.* New York: LAP Information Age Publication Incorporated.

Pajares, F. (2015). Overview of social cognitive theory and of self-efficacy. Retrieved January 23, 2018, from http://www.emory.edu/EDUCATION/mfp/eff.html

Pallant, J. (2014). *SPSS: Survival manual*. McGraw Hill: Open University Press.

Panitz, R.E. (2008). *Cooperative learning: Theory, research, and practice*. Boston: Allyn and Bacon.

Passmore, G.G. (2014). Using Vee diagrams to facilitate meaningful learning and misconception. *Radiologic Science and Education*, *4* (1), 11-28.

Phanphech, P., & Tanitteerapan, T. (2017). The developments of a model to promote predict, observe, and explain strategies for teaching about electric circuits in virtual environments. The Asian Conference on Technology in the Classroom 2017 Official Conference Proceedings.

Piaget, J. (1965). *The stage of development of the child.* London: International University Press.

Pontes, A. (2014). Knowledge representation and information, communication in science and technology teacher training. *Journal on Science Education and Spreading, 9*(1), 108-125.

Qilada, M. (2012). Gowin's knowledge Vee: using to improve preservice teachers ability for conducting and directing science investigations. Retrieved on April 21, 2018, from http://www.theaste.org/publications/proceedings/2006proceedings/html.

Rickey, D., & Stacey, A.M., (2009). The role of metacognition in learning chemistry. *Journal of Chemical Education, 77*(7), 915 - 916.

Rickey, D., & Stacey, A.M. (2015). Investigating the effectiveness of a predict-explain-observe-explain-based teaching activity on students' understanding of condensation. *Instruction and Science Journal, 40*(5), 47–67.

Roschelle, J., & Teasley, S.D. (2013). The construction of shared knowledge in collaborative problem-solving. In Malley, C.E.O. (Ed.). *Computer-supported collaborative learning* (pp. 69-97). Berlin: Springer-Verlag.

Saage, O. (2014). Causes of mass failures in chemistry examination among students a commissioned paper presented at government secondary school. Karu Abuja Science Day 1st March. Boocock.

Samba, R.M.O. (2012). The development and use of collaborative concept mapping instructional strategy (CCMIS) in teaching science concepts. In Samba, R.M.O., & Eriba, J.O. (Ed.). *Innovative approaches in teaching difficult science concepts* (pp. 6-22). Makurdi: Destiny Ventures.

Scardamalia, M. (2015). Assimilative processes in composition planning. *Educational Psychologist*, *17*, 165-171.

Schraw, G., & Dennison, R.S. (2012) Assessing metacognitive awareness. *Contemporary Educational Psychology Journal, 19*, 460-475.

Schraw, G., & Moshman, D. (2012). Metacognitive theories. *Educational Psychology Review 7*(4), 351-371.

Schraw, G. (2012). Promoting general metacognitive awareness. *Instructional Science Journal, 26*(12), 113–125.

Schraw, G. (2013). Promoting learners metacognition. In Hartman, H.J. (Eds.). *Metacognition learning and instruction* (pp.3-16). United State of America: Kluwer Academic Publisher.

Schunk, D. (2009). Self regulated learning. *Educational Psychologist, 40*(2), 85–94.

Senese, F. (2013). Introduction to chemistry. Retrieved on 13th March, 2018 from http://www.antoine.frostburg.edu/chem.pdf

Sharan, Y. (2011). *Expanding cooperative learning through group investigation.* New York: Teacher College Press.

Smith, S. M. (2011). Frustrated feelings of imminent recall: On the tip-of-the tongue. In Metcalfe, J., & Shimamura, A.P. (Ed.). *Metacognition: Knowing about knowing* (pp. 27-46). Cambridge: Massachusetts Institute of Technology Press.

Soyibo, K. (2014). Gender differences in Caribean students' performance on a test of errors in biology labeling. *Research in Science and Technological Education, 17*(1), 75-82.

Stoyanova, N., & Kommers, P. (2016). Concept mapping as a medium of shared cognition in computer-supported collaborative problem solving. *Journal of Interactive Learning Research, 13*(1&2), 111-133.

Suther, D.D. (2009). Technology affordances for inter subjective learning: A thematic agenda for CSCL. In Proceedings of the 2009 conference on computer-supported collaborative learning 2009: the next 10 years. *International Society of the Learning Science, 1*(3), 662-671.

Tao, P.K. (2016). The process of conceptual changes in force and motion during computer-supported in physics instruction, *Journal of Research in Science Teaching, 36*(7), 859-882.

Teerasong, S., Chantore, W., Ruenwongsa, P., & Nacapricha, D. (2016). Effect of predict-explain-observe-explain (PEOE) and lecture teaching strategies on achievement of elementary basic science students in Thailand. *The International Journal of Learning, 18*(4), 123-132.

Tracy, D.M. (2016). Toy-play behaviors, sex role orientation spatial ability and science achievement. *Journal of Research in Science Teaching, 27*(7), 18-25.

Ubi, J. (2015). Relative effectiveness of predict-observe-explain (POE) and lecture methods of teaching basic science on academic performance of secondary students in Akwa Ibom State, Nigeria. *International Journal of Science Teaching, 3*(7), 13-19.

Usman, S.S. (2011). Report on students' achievement in chemistry in senior secondary certificate examination. Retrieved on 12th March, 2018 from http://www.report-edu/chemistry/science111

Ventura, F. (2013). Gender, science choice and achievement: A Maltese perspective. *International Journal of Science Education*, *14*(4), 445-461.

Vygotsky, L. (1978). *Mind in society: the development of higher psychological processes*. Cambridge, MA: Harvard University Press.

WAEC (2016). *Chief Examiner's reports for May/June West Africa Senior School Certificate Examination (WASSCE)*. Lagos: WAEC.

WAEC (2017). *Chief Examiner's reports for May/June West Africa Senior School Certificate Examination (WASSCE)*. Lagos: WAEC.

Welch, Z. (2012). *Effects of outdoor activities and genders on students' environmental attitude in Science*. Unpublished M.Phil.Thesis, University Kebangsaan Malaysia.

Wenden, A. (2013). What do second-language learners know about their language learning? *Applied Linguistics Journal, 7*(1), 186-205.

White, R., & Gunstone, R. (1992). *Probing understanding.* Great Britain: Falmer Press.

Wilkinson, A.G. (2016). Psychology of classroom learning: Discussion methods. Retrieved on 12th March, 2018 from http://ebooks.ohiolink.edu.proxy.lib.ohio-state.edu/xtf-

Wright, P. (2016). *Cognitive overheads and prostheses: some issues in evaluating hypertexts*. New York: Association for Computing Machinery (ACM) Press.

Yager, R.E. (2013). A rationale for using personal relevance as a science curriculum focus in schools. *School Science and Mathematics, 89*(2), 144-156.

Young, F. (2015). Metacognitive awareness and academic achievement in college students. *Journal of the Scholarship of Teaching and Learning, 8*(2), 1-10.

Young, D.J. (2016). Creating a low anxiety classroom environment: What does language anxiety research suggest? *The Modern Language Journal, 75*(4), 426-439.

Zaitoun, L.G. (2012). Versatile Vee diagrams. *The Journal of Science Teachers, 68*(1), 28-33.

Zimmerman, B.J., & Schunk, D.H. (2012). *Self-regulated learning and academic achievement: Theoretical perspectives (2nd Ed.)*. Mahwah, New Jersey: Lawrence Erlbaum Associates Incorporated.

APPENDIX B

ANALYSIS OF CHEMISTRY STUDENTS' ACHIEVEMENT IN WASSCE IN NIGERIA (MAY/JUNE 2009-2018)

Year	No. Registered	A1 to C6		D7 to E8		Failure (F9)	
		Total	%	Total	%	Total	%
2018	894,748	359,546	40.18	286,124	31.98	249,078	27.84
2017	846,232	331,977	39.23	241,168	28.50	273,087	32.27
2016	819,469	325,735	39.75	257,328	31.40	236,406	28.85
2015	758,849	293,522	38.68	263,809	34.76	201,518	26.56
2014	719,425	289,784	40.28	239,990	33.36	189,651	26.36
2013	694,957	288,894	41.57	184,965	26.62	221,098	31.81
2012	641,622	276,732	43.13	175,513	27.35	189,377	29.52
2011	575,757	285,230	49.54	154,643	26.86	135,884	23.60
2010	477,573	242,130	50.70	121,797	25.50	113,643	23.80
2009	478,235	208,988	43.70	136,876	28.62	132,371	27.68

Source: *West African Examinations Council (WAEC) Office, Yaba, Lagos (2018)*

APPENDIX C

SUMMARY OF TRENDS OF ACHIEVEMENT IN CHEMISTRY IN WASSCE IN EKITI STATE (MAY/JUNE 2009-2018)

Year	No. Registered	A1 to C6		D7 to E8		Failure (F9)	
		Total	%	Total	%	Total	%
2018	15,113	5702	37.73	5939	39.30	3472	22.97
2017	14,845	5689	38.32	5435	36.61	3721	25.07
2016	14,158	5771	40.76	5427	38.33	2960	20.91
2015	13,668	5459	39.94	4194	30.68	4015	29.38
2014	12,571	5299	42.15	4321	34.37	2951	23.48
2013	12,034	4784	39.75	3601	29.92	3650	30.33
2012	11,564	4842	41.87	4175	36.10	2547	22.03
2011	11,349	4720	41.59	3552	31.30	3077	27.11
2010	10,644	4148	38.97	4365	41.01	2131	20.02
2009	10,243	4536	44.28	3667	35.80	2040	19.92

Source: Ekiti State Ministry of Education, Science and Technology (2018).

APPENDIX D

ANALYSIS OF CHEMISTRY STUDENTS' ACHIEVEMENT IN NECO (JUNE/JULY 2009-2018)

Year	No. Registered	A1 to C6		D7 to E8		Failure (F9)	
		Total	%	Total	%	Total	%
2018	523,647	198,437	37.89	228,987	43.73	96,223	18.38
2017	495,471	189,468	38.24	169,566	34.22	136,437	27.54
2016	484,703	196,159	40.47	185,325	38.23	103,219	21.30
2015	468,022	162,029	34.62	206,381	44.10	99,612	21.28
2014	418,785	155,537	37.14	173,597	41.45	89,651	21.40
2013	409,324	164,344	40.15	123,852	30.26	121,128	29.59
2012	411,202	165,056	40.14	149,327	36.31	96,819	23.55
2011	438,378	174,562	39.82	160,982	36.72	102,834	23.46
2010	398,492	146,087	36.66	138,064	34.65	114,341	28.69
2009	372,224	165,119	44.36	109,889	29.52	97,216	26.11

Source: *National Examination Council (NECO), Office, Minna (2018).*

APPENDIX E

SUMMARY OF TRENDS OF ACHIEVEMENT IN CHEMISTRY IN NECO IN EKITI STATE (JUNE/JULY 2009-2018)

Year	No. Registered	A1 to C6		D7 to E8		Failure (F9)	
		Total	%	Total	%	Total	%
2018	11,317	4819	42.58	4107	36.29	2391	21.13
2017	10,984	4786	43.57	3484	31.72	2714	24.71
2016	10,249	4602	44.90	3989	38.92	1658	16.18
2015	10,004	4559	45.57	3435	34.34	2010	20.09
2014	10,239	4719	46.09	2854	27.87	2666	26.04
2013	9,894	3955	39.97	3303	33.38	2636	26.64
2012	9,799	4369	44.59	3621	36.95	1809	18.46
2011	10,104	4402	43.57	3971	39.30	1731	17.13
2010	9,124	3537	38.77	3374	36.98	2213	24.25
2009	8,789	3683	41.90	3454	39.30	1652	18.80

Source: Ekiti State Ministry of Education, Science and Technology (2018).

APPENDIX F

WAEC CHIEF EXAMINER'S REPORT ON SSCE CHEMISTRY RESULT, MAY/JUNE, 2016-2017

WAEC e-learning

Chemistry Paper 2 (Essay) ,May/June 2017

Questions:		1	2	3	4	5	6	7	8		Main

General Comments
Weakness/Remedies
Strength

WEAKNESS/REMEDIES

The weaknesses associated with candidates' performance include:

- lack of understanding of the demands of the question;
- non-adherence to rubrics;
- poor presentation/communication skills;
- spelling errors;
- inability to write chemical formulae accurately and balance chemical equation;
- inability to answer questions on organic chemistry such as alkanes, alkenes, alkanols, alkynes, ester, and alkanoic acids;
- poor knowledge of electrochemical cell and it related calculations;
- poor knowledge of redox reactions; alkanoic acids.

The following remedies were however suggested

- candidates should familiarize themselves with the required syllabus;
- teachers should emphasize on areas of the syllabus where candidates appear to be weak such as electro chemistry, Organic Chemistry, redox reaction and nuclear reaction;
- teachers should employ effective instructional methods; and experts/professionals should be employed to teach the subject;
- Teachers should be encouraged to attend/participate in marking coordination to update themselves.

WEAKNESS/REMEDIES

The weaknesses associated with candidates' performance include:

- poor computational skill;
- poor comprehension on application of principles;
- poor knowledge of organic chemistry;
- lack of adequate knowledge of some concepts e.g half-life, covalent bonding;
- inability to correctly write some organic equations and structures;
- inadequate understanding of solubility, functional group, activation energy and activated complex;
- poor study habits;
- inability to balance chemical equation.

The following remedies were however suggested

- instructional materials should be provided by schools/improvised by teachers for effective teaching and learning;
- teachers should employ effective innovative instructional methods;
- adequate and effective coverage of syllabus;
- more exposure to practical work;
- parents to provide relevant textbooks and ensure that they make use of them adequately.

APPENDIX G

ENROLMENT FOR SS2 STUDENTS, 2018/2019 SESSION

S/N	Zone(s)	LGA	Boys Enrolled	Girls Enrolled	Total
	Ekiti North				
1.		*Ido/Osi	514	479	993
2.		*Ikole	483	463	946
3.		Ilejemeje	396	368	764
4.		Moba	411	389	800
5.		*Oye	546	498	1044
	Ekiti Central				
6		*Ado	767	613	1380
7.		*Efon	463	437	900
8.		Ekiti-West	476	378	854
9.		Ijero	435	394	829
10		*Irepodun/Ifelodun	428	399	827
	Ekiti South				
11.		Ekiti East	434	397	831
12.		Ekiti South-West	513	479	992
13.		*Emure	453	418	871
14.		*Gbonyin	474	393	867
15.		*Ikere	529	482	1011
16.		Ise/Orun	446	398	844
		Total	**7,768**	**6,985**	**14,753**

Source: Ekiti State Teaching Service Board, Statistics Unit 2018

* = Selected local government for the study

APPENDIX H

SAMPLED SCHOOLS USED FOR THE STUDY

S/N	Zone (s)	LGA(s)	Schools
	Ekiti North		
1.		Ido/Osi	Davies Academy, Ido-Osi Ekiti.
2.		Ikole	Federal Government College, Ikole Ekiti.
3.		Oye	Itapa High School, Itapa Ekiti.
	Ekiti Central		
4.		Ado	Ado Community High School, Ado Ekiti.
5.		Efon	St. Michael’s Catholic Secondary School, Efon.
6.		Irepodun/Ifelodun	Ekiti Baptist High School, Igede Ekiti.
	Ekiti South		
7.		Emure	Emure Model High School, Emure Ekiti.
8.		Gbonyin	Aisegba Community Grammar School, Aisegba.
9.		Ikere	Ansarudeen Comprehensive High School, Ikere.

APPENDIX I

SAMPLE DISTRIBUTION OF SS2 STUDENTS USED

Ekiti State Zone(s)	No of School	Experimental 1 M/F	Experimental 2 M/F	Control M/F	**Total**
Ekiti North	3	21/16	19/14	19/13	59/43
Ekiti Central	3	19/13	21/17	20/16	60/46
Ekiti South	3	21/14	16/14	18/17	55/45
Total	**9**	**104**	**101**	**103**	**308**

APPENDIX J

TRAINING PROGRAMME FOR CHEMISTRY TEACHERS USED AS RESEARCH ASSISTANTS

Chemistry teachers with a minimum qualification of first degree in Education and Chemistry with at least three years of teaching experience were trained and used as research assistants for this study. The training was to make them conversant with the aim of the study. During the training period each of the nine research assistant (Chemistry teachers) were made to do micro-teaching for a minimum of forty minutes on any selected Organic Chemistry concept. The teachers were critiqued and corrections made were necessary. The six teachers for the experimental group 1 and 2 were given relevant lesson plans (Appendices X, Y) and the three teachers for the control group were also given relevant lesson plans (Appendix Z) for the Organic Chemistry concept taught. The training manual for the research assistants was as follows:

(a) Training on Predict-Explain-Observe-Explain (PEOE) was done as follows:

Day One: (2 hours)

Stage 1: The researcher explained to the research assistants the purpose of the research. The researcher further explained the seven-step format for Predict-Explain-Observe-Explain (PEOE) steps outlined by Chris (2016) for PEOE classroom activities. The main PEOE phases which include grouping/elicitation of students' ideas, introducing the experiment; predict, explaining the predictions, observe, and explaining the observations was explained to the research assistants.

Stage 2: The research assistants were given the relevant lesson plans to study

Stage 3: The researcher discussed the model lesson plans with research assistants using the selected Organic Chemistry concepts. The uniqueness of the PEOE was also emphasized. Questions were asked and answered.

Day Two: (2 hours)

Stage 4: Application phase. The research assistants did a mock teaching using PEOE lesson plans. The researcher observed, as constructive criticisms and correction were also made. Questions were asked and answered.

Stage 5: The research assistants were trained on the administration of data gathering instruments. That is, they were trained on the administration of the pre-test and post-test and how to score the test items. Questions were asked and answered.

(b) Training on Vee Heuristic (VH) Strategy was done as follows:

Day One: (2 hours)

Stage 1: The researcher explained to the research assistants the purpose of the research. The researcher further explained that following the steps outlined by Keraro (2014) for effective construction of Vee diagrams. The main VH strategy phases which include formation of group/pooling of ideas, group brainstorming (thinking), group carrying out learning task (doing), presentation of group Vee diagram, and summary and final class Vee diagram were explained to the research assistants.

Stage 2: The research assistant were given the relevant lesson plans to study.

Stage 3: The researcher discussed the model lesson plans with research assistants using the selected Organic Chemistry concepts. The uniqueness of the VH strategy was emphasized. Questions were asked and answered.

Day Two: (2 hours)

Stage 4: Application phase. The research assistants did a mock teaching using VH lesson plans. The researcher observed, as constructive criticisms and correction were made. Questions were asked and answered.

Stage 5: The research assistants were trained on the administration of data gathering instruments. That is, they were trained on the administration of the pre-test, and post-test and how to score the test items. Questions were asked and answered.

(c) Procedure for Predict-Explain-Observe-Explain (PEOE)

There was an in-class instruction done by the teachers, and a predict-explain-observe-explain activity which lasted for 80 minutes. Instructions for the activity were given to the students prior to the activity and each group were given a PEOE worksheet and a pen to writes down their group decision on each phase of the PEOE worksheet, using the steps outlined by Chris (2016). The author proposed the following guidelines for effective PEOE activity in a collaborative setting:

1. Predict phase: The recorder for the group or whoever assigned, writes down their prediction(s) as agreed upon by the group on the PEOE worksheet.
2. Explain phase: The recorder for the group or whoever assigned, writes down the explanation for their prediction(s) as agreed upon by the group on the PEOE worksheet.
3. Observe phase: Students carried out laboratory activities as directed by the teacher. The recorder for the group or whoever is assigned, writes down their observation(s) as agreed upon by the group on the PEOE worksheet.
4. Explain phase: The recorder for the group or whoever assigned, writes down the explanation for their observation(s) as agreed upon by the group on the PEOE worksheet.

(d) Procedure for Vee Diagramming

There was an in-class instruction done by the teachers, and a Vee diagramming activity in a collaborative setting which lasted for 80 minutes. Instructions for the activity were given to the students prior to the activity and each group were given a maker, cardboard paper, ruler, and eraser to construct Vee diagram, using the steps outlined by Keraro (2014). The author proposed the following guidelines for effective construction of Vee diagrams:

The procedures are as follows:

b. Draw a V-shaped diagram and place the focus question at the top center.

c. Write down the key theories that form the basis of the investigation and write them at the top left side of the Vee.

d. Write down the relevant principles and key concepts that are important in this investigation and put them in the appropriate spaces on the left side of the Vee diagram.

e. At the bottom point of the Vee diagram, identify and write the objects/event.

f. As the experiment is conducted, record the information or data generated or collected at the bottom right. This can be done using words, symbols or drawings.

g. Complete the right side of the Vee diagram by recording the knowledge claim, transformations, construct and records.

The groups were photographed while engaged in Predict-Explain-Observe-Explain and Vee Heuristic activities (p.400).

SCHEME OF WORK FOR ORGANIC CHEMISTRY

WEST AFRICAN SENIOR SCHOOL CERTIFICATE EXAMINATION CHEMISTRY	
CONTENT	**NOTES**
11 CHEMISTRY OF CARBON COMPOUNDS	
(a) Classification and nomenclature (i) Root names (ii) Functional groups	(1) Broad classification into straight chain, branched chain, aromatic and alicyclic compounds. (2) Systematic nomenclature of the following compounds: Alkanes, alkenes, alkynes, alkanols, alkanoic acids, alkanoates (esters and salts) and amines.
(b) Separation and purification	Methods to be discussed should include: distillation, crystallization, drying, chromatography.
(c) Determination of empirical and molecular formulae and molecular structures of organic compounds.	
(d) General Properties (i)Homologous series	(1) Gradation in physical properties. (2) Effects on the physical properties by introduction of active groups into the linen alkane
(ii) Isomerism	(1) Examples should be limited to compounds having maximum of five carbon atoms. (2) Differences between structural and geometric/stereo isomerism.
*__(e)Alkanes__ (i) sources and properties	(1) Laboratory and industrial preparations and other sources. (2) Nomenclature and structure (3) Reactivity: (i) Combustion; (ii) Substitution reactions; (iii) Cracking of large alkanes molecules.

CONTENT	NOTES
(ii)Uses	Importance as fuels, as starting materials for synthesis. Uses of haloalkanes and pollution effects.
(iii) Petroleum	(1) Composition (2) Fractional distillation and major products; (3) Cracking and reforming (4) Petrol-chemicals; starting materials of organic synthesis; (5) Quality of petrol. Meaning of octane number.
* **(f)Alkenes:**	
(i) Sources and properties	(1) Laboratory preparation; (2) Nomenclature and structure (3) Addition reactions with halogens, bromine water, hydrogen halides (4) Oxidation Hydroxylation with aqueous $KMnO_4$
(ii) Laboratory detection	Uses of reaction with Br2CCl4 and $KMnO_4$as means of characterizing alkenes
* **(g)Alkynes:** Sources and Uses	(1) Nomenclature and structure; (2) Industrial production of ethyne; (3) Uses of ethyne
(h)Benzene: (i) Structure and physical properties	(1) Resonance in benzene. Stability leading to substitution reactions. Halogenation (mechanism not required)
(ii) Chemical properties	(2) Addition reactions: hydrogenation and halogenation; (3) Compare reactions with those of alkenes

CONTENT	NOTES
* **(i)Alkanols**	(1) Laboratory preparation including hydration of alkanes.
(i) Sources, nomenclature and structure	(2) Industrial and local production of ethanol including alcoholic beverages. Harmful impurities and methods of purification should be mentioned.
(ii) Classification	Primary, secondary and tertiary alkanols
(iii) Physical properties	Including those due to intermolecular hydrogen bonding
(iv) Chemical properties	(1) Reaction with: (i)Na, (ii) alkanoic acids (esterification); (iii) conc. H_2SO_4 (2) Oxidation by (i) $KMnO_{4(aq)}$, (ii) $K_2Cr_2O_{7(aq)}$; (iii) $I_2/NaOH_{(aq)}$
(v) Laboratory test	
* **(j) Alkanoic Acids**	
(i)Sources, nomenclature and structure	
(ii) Physical properties	Including those due to intermolecular hydrogen bonding.
(iii) Chemical properties	Acid properties only: i.e. reactions with H_2O, NaOH, $NaHCO_3$
(iv) Laboratory test	Reaction with$NaHCO_3$,
(v) Uses and properties	Use and properties of ethanoic and phenylmethanoic (benzoic) acids as examples of aliphatic and aromatic acid respectively.

CONTENT	NOTES
***(k)Alkanoates as derivatives of alkanoic acids**	Preparation of alkyl alkanoates (esters) from alkanoic acids
(i) Sources, nomenclature and structure	
(ii) Physical properties	
(iii) Chemical properties	Hydrolysis of esters (mechanism are required).
(l) Fats and Oils Sources, physical and chemical properties	Alkanoates (esters) (1) Saponification, hardening of oils (2) Detergents as soapless detergents. Comparison of soapless detergents with soapy detergents and their action on soft water and hard water.
(m) Amino Acids	Difunctional nature of amino acids.
(n) Natural and synthetic polymers	
(i) Definitions (ii) Important of properties of polymers	(1) Polymerization (2) Addition and condensation polymers; (3) Plastics and resins; (4) Thermoplastic and thermosetting
(iii) Natural polymers Carbohydrates: Formulae properties and uses	(1) Classification as monosaccharide, disaccharides and polysaccharides; reducing and non reducing sugars using glucose, fructose, sucrose/ maltose and starch/cellulose as examples. (2) Hydrolysis of sucrose and starch

Source: *West African Examination Council (WAEC) Office, Yaba, Lagos (2018)*

*=Selected topic for the study

APPENDIX K

A LETTER TO VALIDATOR

Department of Science and Mathematics Education,
Faculty of Education,
Benue State University,
P.M.B 102119,
Makurdi,
Nigeria.

Sir,

REQUEST TO VALIDATE RESEARCH INSTRUMENTS.

I am a PhD research student of the above address. I am conducting a research in Science Education on the topic "Effects of predict-explain-observe-explain and Vee heuristic strategies on students' achievement, metacognitive awareness and self-efficacy belief in Organic Chemistry in Ekiti State, Nigeria".

As a specialist and renowned academic in Science Education/Measurement and Evaluation, I humbly request you to validate (content and face) the attached instruments to enable me conduct the field study on aforementioned topic.

Sir, you are specifically requested to scrutinize the instruments in the area(s) below and make relevant suggestion(s) for improvement.

1. General content validation.
2. Clarity and simplicity of language.
3. Relevance of science concepts and items to research topic.
4. Scope of coverage.
5. Content relevance.
6. Ambiguity and vagueness of expression.
7. The adequacy or appropriateness of the expected PEOE worksheet and Vee diagram

Please, find attached other relevant parts of the work for your necessary guidance.

Yours faithfully,

AJAYI, Oluwatosin Victor

APPENDIX L

COMMENTS FROM VALIDATORS

APPENDIX M

ORGANIC CHEMISTRY ACHIEVEMENT TEST (PRE-TEST)

SECTION A

Name of School...

Sex: Male ( ) Female ( )

SECTION B

Put a tick (√) against the option you consider most appropriate in each question.

Time: 40 minutes

1. Alkanoic acids can be classified into:

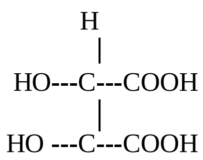
   (a) Aliphatic and aromatic compounds (b) Alkanoic and aromatic compounds

   (c) Acids and bases (d) Aliphatic carboxylic acids and aromatic carboxylic acids

2. Esters, RCOOH; are formed when _____________ reacts with alkanol:

   (a) Carboxylic acid (b) Fats and oil (c) Ethanol (d) Hydrogen

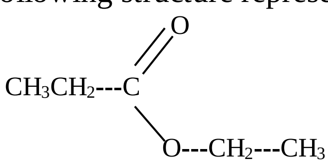
3. The correct name of the compound represented by this structure is:



   (a) 2- methlbutanoic acid (b) Butanedioic acid

   (c) 2, 3- dihydroxy butanedioic acid (d) Cis-butenedioic acid

4. The following structure represents:



   (a) Methyl ethanoate (b) Ethyl ethanoate (c) Methyl butanoate (d) Ethyl butanoate

5. Alkanoates have the general formula:

   (a) CnH_2nO_2 (b) CnH_2n+OH (c) CnH_2n+COOH (d) $CnHnO_2$

6. Esters are the main constituents of many naturally occurring ____ and____

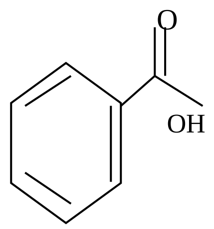
   (a) Acids and base (b) Fats and oils

   (c) Atoms and molecules (d) Saturated and unsaturated fatty acids

7. The boiling point and melting point of propene are _______and ________respectively:

(a) 40^{o}C and -181 ^{o}C (b) -48^{o}C and -185 ^{o}C (c) -80^{o}C and -152 ^{o}C (d) -70^{o}C and -198 ^{o}C

8. The following structure is peculiar to:



(a) Methyl alkanoic acid (b) Benzoic acid (c) Benzene (d) Butanoate acid

9. Alkanes react with the halogens mainly by:

(a) Oxidation (b) Substitution (c) Addition (d) Reduction

10. Which among these is the general molecular formula of carboxylic acids?

(a) –COOH (b) CnH_2n+_1 COOH

(c) CnH_2n+_2 COOH (d) CnHn + $_1$COOH

11. As a weak monobasic acid, ethanoic acid shows all the usual acid properties, except:

(a) $2CH_3COOH(aq) + CaCO_3(S) \rightarrow (CH_3COO)2Ca(aq) + H_2O(L) + CO_2(g)$

(b) $2CH_3COOH(aq) + Mg(s) \rightarrow (CH_3COO)2Mg(aq) + H_2(g)$ $CH_3COOH(aq) + Mg(S)$

(c) $CH_3COOH(aq) + Mg(s) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(L)$

(d) $CH_3COOH(aq) + HCL(aq)$ $CH_3COOCl(aq) + H_2(g)$

12. The boiling point and melting point of ethane are _______and ________respectively:

(a) 0.5^{o}C and -138 ^{o}C (b) 36^{o}C and -130 ^{o}C (c) -89^{o}C and -182 ^{o}C (d) -80^{o}C and -138 ^{o}C

13. Ester is used as: (i) perfumes and cosmetics (ii) artificial flavouring for foods (iii) Solvents for cellulose nitrates (iv) quick-drying substances like paints, nail vanishes, lacquer and adhesives:

(a) Only (i) (b) Only (i) and (ii)

(c) Only (i), (ii) and (iv) (d) All of the above

14. The boiling point and melting point of propene are _______and ________respectively:

(a) 40^{o}C and -181 ^{o}C (b) -48^{o}C and -185 ^{o}C (c) -80^{o}C and -152 ^{o}C (d) -70^{o}C and -198 ^{o}C

15. Alkenes are acids present naturally in:

(a) Palm wine (b) Terpene (c) Vegetable oil (d) Rubber

16. Alcohol is used as: (i) Solvent for resins and fatty acids (ii) Constituent of alcoholic beverages (iii) Artificial flavouring for foods (iv) Sterilizer of wounds and syringes

(a) Only (i) (b) Only (i) and (ii)

(c) Only (i), (ii) and (iv) (d) All of the above

17. Alkane can be prepared by_______

(a) Decarboxylation of fatty acids (b) Hydrogenation of carbon (iv) oxide

(c) Hydrolysis (d) Carboxylation of fatty acids

18. Which of the following compounds is not a raw material for the manufacture of plastics?

(a) Ethane (b) Monochloroethene (c) Propene (d) Butadiene

19. Alkanes are used mainly in:

(a) the production of plastics (b) domestic and industrial fuels

(c) the textile industry (d) the hydrogenation of oils

20. The formula $(CH_3)_3COH$ is that of ______

(a) Polyhydric alkanol (b) Secondary alkanol

(c) Tertiary alkanol (d) Primary alkanol

21. The product of the reaction between C_2H_5OH and concentrated H_2SO_4at 170^oC is:

(a) $(C_2H_5)_2SO_4$ (b) $CH_3CH_2HSO_4$ (c) $(C_2H_5)_2O$ (d) $CH_2=CH_2$

22 Which of the following is a secondary alkanol?

(a) $CH_3(CH_2)_2OH$ (b) $CH_3CH=CHCH_2OH$ (c) $CH_3(CH_2)_3OH$ (d) $CH_3CH(OH)CH_3$

23. The formation of an ester by the reaction between an alkanol and acid is known as:

(a) Saponification (b) Oxidation (c) Esterification (d) Reduction

24. Alkenes undergo the following reactions except:

(a) Addition (b) Hydration (c) Substitution (d) Polymerization

25. What type of reaction do alkynes undergo across triple bond?

(a) Elimination reaction (b) Substitution reaction

(c) Addition reaction (d) Halogenation

26. When alkanols react with sodium, the gas evolved is:

(a) Hydrogen (b) Oxygen (c) Methane (d) Ethyne

27. A tertiary alkanol has a molecular formular $C_4H_{10}O$. What is the structural formula of the compound?

(a) $(CH_3)_2CHCH_2OH$ (b) $CH_3CH_2CH(OH)CH_3$ (c) $(CH_3)_3(OH)$ (d) $CH_3CH_2CH_2CH_2OH$

28. Dehydration of ethanol produces:

(a) Ethanoic acid (b) Propan-1,2,3 triol (c) Ethene (d) Ethanol

29. Which of the following alkanes has the highest boiling point?

(a) Pentane (b) Hexane (c) Ethane (d) Propane

30. What is the product C_xH_y in the following equation?

$$C_{10}H_{22} \longrightarrow C_8H_{18} + C_xH_y$$

(a) Butene (b) Octane (c) Ethene (d) Methane

31. Select the incorrect statement regarding alkanes

(a) It is otherwise known as Paraffin (b) It is an acyclic saturated hydrocarbon

(c) Alkanes has the general formula $CnH2n$ (d) In alkanes, C-C bonds are single

32. Which of the following is most reactive towards bromine?

(a) Methane (b) Benzene (c) Ethyne (d) Hexane

33. Alkynes cannot be prepared from _______

(a) Ketones (b) Alcohols (c) Aldehydes (d) Other alkynes

34. Ethyne undergoes the following reactions except:

(a) Polymerisation (b) Addition (c) Substitution (d) Esterification

35. In Alkenes the Carbon atoms are connected to each other by a ______

(a) Single bond (b) Double bond (c) Triple bond (d) No connected

36. Which of the following compounds will undergo addition reaction?

(a) Ethyne (b) Butane (c) pentane (d) Ethanol

37. Which of the following alcohols would be most soluble in water?

(a) Propanol (b) Hexanol (c) Pentanol (d) Butanol

38. When water is dropped on calcium carbide, the gaseous product is an:

(a) Alkane (b) Alkene (c) Alkyne (d) Alkanol

39. Vinegar contains a carboxylic acid known as_________

(a) Citric acid (b) Ethanoic acid (c) Nitric acid (d) Aromatic acid

40. The hydrocarbon prepared using the action of water on calcium carbide is:

(a) C_2H_6 (b) C_4H_{10} (c) C_2H_4 (d) C_3H_8

APPENDIX N

ORGANIC CHEMISTRY ACHIEVEMENT TEST MARKING SCHEME (PRE-TEST)

1.	D	21.	D
2.	A	22.	D
3.	C	23.	C
4.	B	24.	C
5.	A	25.	C
6.	B	26.	A
7.	B	27.	C
8.	B	28.	A
9.	A	29.	B
10.	D	30.	C
11.	D	31.	C
12.	C	32.	C
13.	D	33.	B
14.	B	34.	D
15.	B	35.	B
16.	C	36.	A
17.	A	37.	C
18.	A	38.	C
19.	B	39.	B
20.	C	40.	D

APPENDIX O

ORGANIC CHEMISTRY ACHIEVEMENT TEST (POST-TEST)

SECTION A

Name of School..

Sex: Male ( ) Female ( )

SECTION B

Put a tick (√) against the option you consider most appropriate in each question.

Time: 40 minutes

1. The formula $(CH_3)_3COH$ is that of ______

   (a) Polyhydric alkanol (b) Secondary alkanol

   (c) Tertiary alkanol (d) Primary alkanol

2. Ester is used as: (i) perfumes and cosmetics (ii) artificial flavouring for foods (iii) Solvents for cellulose nitrates (iv) quick-drying substances like paints, nail vanishes, lacquer and adhesives:

   (a) Only (i) (b) Only (i) and (ii)

   (c) Only (i), (ii) and (iv) (d) All of the above

3. In Alkenes the Carbon atoms are connected to each other by a ______

   (a) Single bond (b) Double bond (c) Triple bond (d) No connected

4. Dehydration of ethanol produces:

   (a) Ethanoic acid (b) Propan-1,2,3 triol (c) Ethene (d) Ethanol

5. The boiling point and melting point of propene are _______and ________respectively:

   (a) 40^oC and $-181\ ^oC$ (b) -48^oC and $-185\ ^oC$ (c) -80^oC and $-152\ ^oC$ (d) -70^oC and $-198\ ^oC$

6. As a weak monobasic acid, ethanoic acid shows all the usual acid properties, except:

   (a) $2CH_3COOH(aq) + CaCO_3(S) \rightarrow (CH_3COO)2Ca(aq) + H_2O(L) + CO_2(g)$

   (b) $2CH_3COOH(aq) + Mg(s) \rightarrow (CH_3COO)2Mg(aq) + H_2(g)$ $CH_3COOH(aq) + Mg(S)$

   (c) $CH_3COOH(aq) + Mg(s) + NaOH(aq) \rightarrow CH_3COONa\ (aq) + H_2O(L)$

   (d) $CH_3COOH(aq) + HCL(aq)$ $CH_3COOCl(aq) + H_2(g)$

7. Alkanoates have the general formula:

   (a) CnH_2nO_2 (b) $CnH_2n{+}OH$ (c) $CnH_2n{+}COOH$ (d) $CnHnO_2$

8. Alkenes are acids present naturally in:

(a) Palm wine (b) Terpene (c) Vegetable oil (d) Rubber

9. The hydrocarbon prepared using the action of water on calcium carbide is:

(a) C_2H_6 (b) C_4H_{10} (c) C_2H_4 (d) C_3H_8

10. The formation of an ester by the reaction between an alkanol and acid is known as:

(a) Saponification (b) Oxidation (c) Esterification (d) Reduction

11. Esters are the main constituents of many naturally occurring ____ and____

(a) Acids and base (b) Fats and oils

(c) Atoms and molecules (d) Saturated and unsaturated fatty acids

12. The boiling point and melting point of ethane are _______and ________respectively:

(a) 0.5^{o}C and -138 ^{o}C (b) 36^{o}C and -130 ^{o}C (c) -89^{o}C and -182 ^{o}C (d) -80^{o}C and -138 ^{o}C

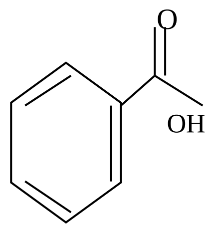
13. Esters, RCOOH; are formed when ____________ reacts with alkanol:

(a) Carboxylic acid (b) Fats and oil (c) Ethanol (d) Hydrogen

14. Which of the following compounds is not a raw material for the manufacture of plastics?

(a) Ethane (b) Monochloroethene (c) Propene (d) Butadiene

15. The following structure is peculiar to:



(a) Methyl alkanoic acid (b) Benzoic acid (c) Benzene (d) Butanoate acid

16. Alcohol is used as: (i) Solvent for resins and fatty acids (ii) Constituent of alcoholic beverages (iii) Artificial flavouring for foods (iv) Sterilizer of wounds and syringes

(a) Only (i) (b) Only (i) and (ii)

(c) Only (i), (ii) and (iv) (d) All of the above

17. Alkane can be prepared by_______

(a) Decarboxylation of fatty acids (b) Hydrogenation of carbon (iv) oxide

(c) Hydrolysis (d) Carboxylation of fatty acids

18. The boiling point and melting point of propene are _______and ________respectively:

(a) 40°C and -181 °C (b) -48°C and -185 °C (c) -80°C and -152 °C (d) -70°C and -198 °C

19. Alkanes are used mainly in:

(a) the production of plastics (b) domestic and industrial fuels

(c) the textile industry (d) the hydrogenation of oils

20. Alkanoic acids can be classified into:

(a) Aliphatic and aromatic compounds (b) Alkanoic and aromatic compounds

(c) Acids and bases (d) Aliphatic carboxylic acids and aromatic carboxylic acids

21. Ethyne undergoes the following reactions except:

(a) Polymerisation (b) Addition (c) Substitution (d) Esterification

22 What is the product C_xH_y in the following equation?

$$C_{10}H_{22} \longrightarrow C_8H_{18} + C_xH_y$$

(a) Butene (b) Octane (c) Ethene (d) Methane

23. Which among these is the general molecular formula of carboxylic acids?

(a) –COOH (b) CnH_2n+_1 COOH

(c) CnH_2n+_2 COOH (d) CnHn + $_1$COOH

24. Alkenes undergo the following reactions except:

(a) Addition (b) Hydration (c) Substitution (d) Polymerization

25. When water is dropped on calcium carbide, the gaseous product is an:

(a) Alkane (b) Alkene (c) Alkyne (d) Alkanol

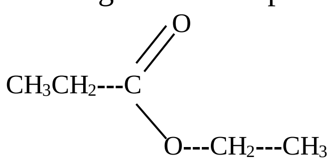
26. When alkanols react with sodium, the gas evolved is:

(a) Hydrogen (b) Oxygen (c) Methane (d) Ethyne

27. Alkynes cannot be prepared from _______

(a) Ketones (b) Alcohols (c) Aldehydes (d) Other alkynes

28. The following structure represents:



(a) Methyl ethanoate (b) Ethyl ethanoate (c) Methyl butanoate (d) Ethyl butanoate

29. Select the incorrect statement regarding alkanes

(a) It is otherwise known as Paraffin (b) It is an acyclic saturated hydrocarbon

(c) Alkanes has the general formula CnH2n (d) In alkanes, C-C bonds are single

30. Which of the following is a secondary alkanol?

(a) $CH_3(CH_2)_2OH$ (b) $CH_3CH=CHCH_2OH$ (c) $CH_3(CH_2)_3OH$ (d) $CH_3CH(OH)CH_3$

31. Which of the following alkanes has the highest boiling point?

(a) Pentane (b) Hexane (c) Ethane (d) Propane

32. Which of the following is most reactive towards bromine?

(a) Methane (b) Benzene (c) Ethyne (d) Hexane

33. A tertiary alkanol has a molecular formular $C_4H_{10}O$. What is the structural formula of the compound?

(a) $(CH_3)_2CHCH_2OH$ (b) $CH_3CH_2CH(OH)CH_3$ (c) $(CH_3)_3(OH)$ (d) $CH_3CH_2CH_2CH_2OH$

34. The product of the reaction between C_2H_5OH and concentrated H_2SO_4at 170^oC is:

(a) $(C_2H_5)_2SO_4$ (b) $CH_3CH_2HSO_4$ (c) $(C_2H_5)_2O$ (d) $CH_2=CH_2$

35. The correct name of the compound represented by this structure is:

```
        H
        |
 HO---C---COOH
        |
HO ---C---COOH
```

(a) 2- methlbutanoic acid (b) Butanedioic acid

(c) 2, 3- dihydroxy butanedioic acid (d) Cis-butenedioic acid

36. Which of the following compounds will undergo addition reaction?

(a) Ethyne (b) Butane (c) pentane (d) Ethanol

37. Which of the following alcohols would be most soluble in water?

(a) Propanol (b) Hexanol (c) Pentanol (d) Butanol

38. What type of reaction do alkynes undergo across triple bond?

(a) Elimination reaction (b) Substitution reaction

(c) Addition reaction (d) Halogenation

39. Vinegar contains a carboxylic acid known as_________

(a) Citric acid (b) Ethanoic acid (c) Nitric acid (d) Aromatic acid

40. Alkanes react with the halogens mainly by:

(a) Oxidation (b) Substitution (c) Addition (d) Reduction

APPENDIX P

ORGANIC CHEMISTRY ACHIEVEMENT TEST MARKING SCHEME (POST-TEST)

1.	C	21.	D
2.	D	22.	C
3.	B	23.	D
4.	A	24.	C
5.	B	25.	C
6.	D	26.	A
7.	A	27.	B
8.	B	28.	B
9.	D	29.	C
10.	C	30.	D
11.	B	31.	B
12.	C	32.	C
13.	A	33.	C
14.	A	34.	D
15.	B	35.	C
16.	C	36.	A
17.	A	37.	C
18.	B	38.	C
19.	B	39.	B
20.	D	40.	A

APPENDIX Q

TABLE OF SPECIFICATION FOR ORGANIC CHEMISTRY ACHIEVEMENT TEST (PRE-TEST)

Unit	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
	Items	Items	Items	Items	Items	Items
Alkanes	1(18)	2(17,29)	3(12, 19, 9)		1(31)	
Alkenes	1(14)	2(24, 7)	3(15, 30, 35)	1(40)		
Alkynes		2(21,34)	3(38, 28, 25)	2(36, 33)		
Alkanols	1(16)	2(27, 22)	3(20, 26, 37)			
Alkanoic acids (carboxylic acids)	1(1)	2(3, 39)	3(11,32, 10)			1(8)
Alkanoates (esters)	1(2)	2(13,6)	3(4, 5, 23)			
Total	**05**	**12**	**18**	**03**	**01**	**01**
Percentage	**12.5%**	**30.0%**	**45.0%**	**7.5%**	**2.5%**	**2.5%**

APPENDIX R

METACOGNITIVE AWARENESS INVENTORY (MAI)

SECTION A

Name of School..

Sex: Male ( ) Female ( )

SECTION B

Instruction: The following is a list of items to ascertain your level of metacognitive awareness in Organic Chemistry. Please read the statements carefully and tick against the column AA (Always Aware), FA (Frequently Aware), SA (Sometimes Aware), and NA (Never Aware)

S/No		**AA**	**FA**	**SA**	**NA**
1.	I know what kind of information is most important to learn.				
2.	I am good at organizing information.				
3.	I know what the teacher expects me to learn.				
4.	I am a good judge of how well I understand Organic Chemistry topics.				
5.	I have control over how well I learn.				
6.	I try to use various strategies that have worked in the past.				
7.	I know how to use a specific strategy with purpose on the accomplishment of each task.				
8.	I know how to track my learning progress and completion of the task.				
9.	I know how to evaluate the strategy that I used after Chemistry class.				
10.	I know how to learn best in Organic Chemistry				
11.	I learn best when I know something about Organic Chemistry topic.				

12.	I know when to use different learning strategies depending on the situation.				
13.	I can motivate myself to learn when I need to.				
14.	I use my intellectual strengths to compensate for my weakness.				
15.	I know when each strategy I use will be most effective.				
Instruction: Please read the statements carefully and tick against the column A (Always), F (Frequent), S (Sometimes), and N (Never).					
		A	**F**	**S**	**N**
16.	I consciously focus my attention on important information				
17.	I focus on the meaning and significance of new information.				
18.	I create my own examples to make information more meaningful.				
19.	I translate new information into my own words.				
20.	I focus on overall meaning rather than specifics				
21.	I ask for help when I don't understand something in Organic Chemistry				
22.	I change strategies when I fail to understand.				
23.	I re-evaluate my assumptions when I get confused.				
24.	I stop and go back over new information that is not clear.				
25.	I stop and re-read my Organic Chemistry when I get confused				
26.	I think about what I really need to learn before I begin a task.				
27.	I ask myself questions about the materials before I begin a task.				
28.	I read instructions carefully before I begin a task.				

29.	I organize my time to accomplish my goals.				
30.	I think of several ways to solve a problem and choose the best one.				
31.	I ask myself periodically if I am meeting my goals.				
32.	I periodically review to help me understand important relationships.				
33.	I find myself analyzing the usefulness of strategies while I study.				
34.	I find myself pausing regularly to check my comprehension.				
35.	I ask myself questions about how well I am doing while learning something new.				
36.	I ask myself if there was an easier way to do things after I finish a task.				
37.	I ask myself how well I accomplish my goals once I am finished.				
38.	I ask myself if I learned as much as I could have once I finish a task.				
39.	I summarize what I have learned after I finish a task.				
40.	I know how well I did once I finish a task.				

APPENDIX S

ORGANIC CHEMISTRY SELF-EFFICACY BELIEF SCALE (OCSBS)

Section A:

Name of School..

Students Sex: Male Female

Section B:

Instruction: (Self-efficacy belief is one's belief about one's capability to successfully accomplish a task in Organic Chemistry). The following is a list of items to ascertain your level of self-efficacy belief in Organic Chemistry. Please read the statement carefully and put a tick (√) against the column for Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD).

S/N		**SA**	**A**	**D**	**SD**
1.	I am one of the best students in Organic Chemistry.				
2.	Compared to other students, I am a weak student in Organic Chemistry.				
3.	I have the ability to successfully perform well in school examination in Organic Chemistry.				
4.	I have no confidence in performing well in school Organic Chemistry examination.				
5.	I know the steps necessary to solve Organic Chemistry related problems effectively.				
6.	I have difficulties in carrying out experiments related to Organic Chemistry.				
7.	I do not feel sure about myself in solving problems related to Organic Chemistry.				
8.	I believe that I have a lot of weakness in Organic Chemistry.				
9.	I could usually solve any Organic Chemistry problem.				
10.	I have confidence in my ability to do school work in Organic Chemistry.				
11.	I have all the skills needed to do very well in Organic Chemistry.				

12.	Organic Chemistry is not one of my favorite topics.				
13.	I can solve most problems in Organic Chemistry if I invest the necessary effort.				
14.	I have no confidence that I could deal efficiently with unexpected questions in Organic Chemistry.				
15.	When I start solving a problem related to Organic Chemistry, I usually feel that I would not manage to get a solution.				
16.	I am in trouble because I cannot think of a solution to any Organic Chemistry question.				
17.	I can help my classmates in Organic Chemistry-related problem.				
18.	When I am confronted with a problem in Organic Chemistry, I cannot find a solution to it.				
19.	Thanks to my resourcefulness, I know how to handle unforeseen situations in Organic Chemistry.				
20.	I can manage to solve difficult problems in Organic Chemistry, if I try hard enough.				

OCAT Scores for Reliability Test

S/N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	Total
1	1	1	1	0	1	1	1	1	0	1	1	0	1	1	1	1	1	1	0	1	1	0	1	1	0	1	0	1	1	0	0	1	0	1	1	0	1	1	1	1	1	0	1	0	1	0	1	1	1	1	**36**
2	1	0	1	0	1	1	1	1	1	1	0	1	1	1	0	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	**41**
3	1	0	0	1	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**12**
4	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	**46**
5	1	0	1	0	0	1	1	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	0	1	0	1	1	1	1	**38**
6	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	**6**
7	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	**11**
8	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**5**
9	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	0	1	1	1	0	1	0	1	1	1	1	**42**
10	0	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	0	0	1	0	1	0	1	0	0	1	**37**
11	1	0	1	0	1	1	1	1	0	1	0	0	1	1	0	0	0	0	0	1	1	1	1	1	0	1	0	1	1	0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**21**
12	1	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	**9**
13	1	0	1	0	1	0	1	1	0	1	0	0	1	1	0	0	0	0	0	0	1	0	1	1	0	1	0	1	1	0	0	1	0	1	1	0	1	1	0	0	0	0	0	1	0	0	1	0	0	1	**22**
14	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	0	1	0	1	0	1	1	**14**
15	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	**43**
16	1	1	0	0	1	0	1	0	0	1	0	0	1	1	0	0	1	0	0	1	0	1	1	1	0	1	0	0	1	0	0	1	0	0	1	0	1	1	1	0	0	0	1	0	1	0	1	1	0	1	**24**
17	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	**47**
18	0	1	0	0	1	0	1	1	0	1	1	0	0	1	0	0	1	0	0	0	0	1	1	1	1	0	0	1	0	0	0	0	1	0	1	0	1	0	1	0	0	0	1	0	1	0	1	0	1	0	**21**
19	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	**45**
20	1	0	1	0	1	0	0	0	0	0	1	0	1	1	0	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1	1	0	1	0	0	0	**16**
21	1	0	1	0	1	0	1	0	1	1	1	0	1	0	1	0	1	0	1	1	0	0	1	0	0	1	1	1	1	1	0	1	0	1	1	0	1	0	1	0	1	0	1	0	0	0	1	1	0	1	**28**
22	0	1	0	1	0	1	0	1	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0	**15**
23	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	0	**10**
24	0	1	1	1	0	0	1	1	0	1	1	1	0	0	1	0	1	0	1	1	1	0	0	1	1	1	1	0	0	0	1	0	0	0	0	1	1	0	1	1	0	0	0	0	1	0	1	0	1	1	**26**
25	1	1	0	1	1	0	1	0	1	1	0	0	1	1	0	0	1	0	0	1	0	1	1	1	0	1	0	1	1	0	0	1	0	0	1	0	1	1	1	0	0	0	1	0	1	0	1	1	0	1	**27**
26	1	0	1	0	1	0	1	1	0	1	0	0	1	1	0	1	0	1	0	0	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	0	0	1	0	0	1	0	0	1	0	0	1	**29**
27	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	0	1	0	1	0	1	1	**15**
28	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**4**
29	1	0	0	0	1	0	1	0	0	0	0	0	1	1	0	0	1	0	0	1	0	1	1	1	0	1	0	0	1	0	0	1	0	0	1	0	1	1	1	0	0	0	1	0	1	0	1	1	0	1	**22**
30	0	1	0	1	0	1	1	1	0	1	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	0	1	0	0	1	0	1	0	1	0	1	0	1	1	0	1	0	0	1	0	1	**30**
31	1	0	1	0	1	0	1	0	0	1	0	0	1	0	0	0	1	0	0	1	0	1	1	1	0	1	0	0	1	0	0	1	0	0	1	0	1	1	1	0	0	0	1	0	1	0	1	1	0	1	23
32	0	1	0	1	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**8**
33	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
34	1	0	0	1	1	0	1	0	1	0	1	0	1	0	0	1	0	1	0	0	1	0	1	1	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**17**

35	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	**10**
36	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0	1	1	0	1	**12**
37	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	**39**
38	0	0	1	0	1	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	1	0	1	1	0	0	1	0	1	1	0	1	1	0	0	0	0	0	1	0	0	1	0	0	1	**18**
39	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	**48**
40	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	**45**
41	1	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	1	0	1	1	0	1	1	1	0	0	0	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	0	1	0	1	1	1	1	**30**
42	1	1	1	0	1	0	1	1	0	1	0	0	1	1	0	1	0	1	0	0	1	0	1	1	0	1	1	1	1	0	0	1	0	1	0	1	1	1	0	0	0	0	0	1	0	0	1	0	0	1	**26**
43	1	0	1	0	1	1	1	1	1	1	0	1	1	1	0	0	0	0	0	1	1	1	1	1	0	1	0	1	1	0	0	1	0	1	1	0	1	1	1	0	0	0	1	0	1	0	1	0	0	0	**28**
44	1	1	1	0	1	0	1	1	0	1	0	0	1	1	0	1	0	1	0	0	1	0	1	1	0	1	1	1	1	0	0	1	0	1	0	1	1	1	0	0	0	0	0	1	0	0	1	0	0	1	**26**
45	1	0	1	0	0	1	1	0	1	1	1	1	0	0	0	1	0	1	0	0	1	1	0	0	1	1	1	1	1	0	1	0	1	0	1	0	0	0	1	1	0	0	0	1	0	0	1	0	0	1	**25**
46	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	0	1	0	0	0	1	0	**13**
47	1	0	1	0	1	1	1	1	0	1	0	0	1	1	0	1	1	0	1	1	1	1	1	1	0	1	0	1	1	0	1	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**25**
48	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	1	1	1	1	0	1	1	1	0	1	0	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	**35**
49	1	0	1	1	1	0	1	1	0	1	1	0	1	1	1	0	1	0	0	1	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	0	1	0	0	0	1	0	0	0	1	0	1	**31**
50	1	0	0	1	0	1	1	0	1	0	1	0	0	1	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1	0	0	1	0	0	0	0	0	**15**
51	0	0	1	0	0	1	0	1	0	1	0	0	1	0	1	1	1	1	0	1	1	1	1	0	0	1	0	1	1	1	1	1	0	1	1	0	1	1	1	1	0	1	1	0	1	0	1	1	1	1	**32**
52	0	1	1	0	1	0	0	1	0	1	0	0	1	1	0	0	0	1	1	0	0	0	0	1	0	1	1	0	1	0	0	1	0	1	1	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0	**20**
53	0	1	0	1	0	1	1	0	0	0	0	1	0	0	1	1	1	0	1	1	1	0	1	0	1	0	0	1	0	0	1	0	0	1	0	1	0	1	0	1	0	1	1	0	1	0	0	1	0	1	**24**
54	0	0	0	0	1	0	1	1	0	1	1	0	0	1	0	0	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	1	0	1	0	1	0	0	0	1	0	1	0	1	0	1	0	**19**
55	1	0	1	0	1	1	1	1	0	1	0	0	1	1	0	0	0	0	0	1	1	1	1	1	0	1	1	0	1	0	0	1	0	1	1	0	1	1	1	0	0	0	1	0	1	0	1	0	0	0	**40**
56	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	**44**
57	1	0	1	0	0	1	0	0	0	1	0	0	1	1	0	1	1	1	1	1	0	1	0	1	0	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	0	1	0	1	1	1	1	**33**
58	1	1	0	1	0	1	1	1	0	1	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	0	1	0	0	1	0	1	0	1	0	1	0	1	1	0	1	0	0	1	0	1	**31**
59	1	0	1	0	1	0	1	1	0	1	0	0	1	1	0	1	0	1	1	0	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	0	1	0	0	1	0	1	1	0	1	1	**33**
60	0	0	1	1	0	1	1	0	0	1	1	1	0	1	1	1	1	0	0	1	0	1	0	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	0	0	1	0	1	0	1	0	0	1	**32**
61	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**50**
62	1	0	1	0	0	0	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	**34**
63	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	0	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	**40**
64	1	1	0	0	1	0	1	0	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	0	1	0	0	1	1	0	1	1	1	1	1	1	0	1	1	0	1	0	1	1	0	1	**35**
65	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**49**
66	0	1	1	1	0	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	0	1	0	0	1	0	1	0	1	0	1	1	1	1	0	1	1	1	1	1	1	**36**
67	1	0	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	0	1	0	1	0	1	0	1	1	1	1	1	1	1	0	38
68	1	0	0	1	0	0	1	0	0	1	0	1	0	1	0	0	0	0	1	0	1	0	1	0	1	0	1	0	0	1	0	1	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	1	17

OCAT Scores Re-arranged to Upper Group and Lower Group for Item Analysis

S/N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	Total
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**50**
2	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**49**
3	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	**48**
4	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	**47**
5	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	**46**
6	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	**45**
7	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	**45**
8	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	**44**
9	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	**43**
10	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	0	1	1	1	0	1	0	1	1	1	1	**42**
11	1	0	1	0	1	1	1	1	1	1	0	1	1	1	0	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	**41**
12	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	0	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	**40**
13	1	0	1	0	1	1	1	1	0	1	0	0	1	1	0	0	0	0	0	1	1	1	1	1	0	1	1	0	1	0	0	1	0	1	1	0	1	1	1	0	0	0	1	0	1	0	1	0	0	0	**40**
14	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	**39**
15	1	0	1	0	0	1	1	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	0	1	0	1	1	1	1	**38**
16	1	0	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	0	1	0	1	0	1	0	1	1	1	1	1	1	1	0	38
17	0	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	0	0	1	0	1	0	1	0	0	1	**37**
18	0	1	1	1	0	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	0	1	0	0	1	0	1	0	1	0	1	1	1	1	0	1	1	1	1	1	1	**36**
19	1	1	1	0	1	1	1	1	0	1	1	0	1	1	1	1	1	1	0	1	1	0	1	1	0	1	0	1	1	0	0	1	0	1	1	0	1	1	1	1	1	0	1	0	1	0	1	1	1	1	**36**
20	1	1	0	0	1	0	1	0	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	0	1	0	0	1	1	0	1	1	1	1	1	1	0	1	1	0	1	0	1	1	0	1	**35**
21	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	1	1	1	1	0	1	1	1	0	1	0	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	**35**
22	1	0	1	0	0	0	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	**34**
23	1	0	1	0	0	1	0	0	0	1	0	0	1	1	0	1	1	1	1	1	0	1	0	1	0	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	0	1	0	1	1	1	1	**33**
24	1	0	1	0	1	0	1	1	0	1	0	0	1	1	0	1	0	1	1	0	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	0	1	0	0	1	0	1	1	0	1	1	**33**
25	0	0	1	0	0	1	0	1	0	1	0	0	1	0	1	1	1	1	0	1	1	1	1	0	0	1	0	1	1	1	1	1	0	1	1	0	1	1	1	1	0	1	1	0	1	0	1	1	1	1	**32**
26	0	0	1	1	0	1	1	0	0	1	1	1	0	1	1	1	1	0	0	1	0	1	0	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	0	0	1	0	1	0	1	0	0	1	**32**
27	1	0	1	1	1	0	1	1	0	1	1	0	1	1	1	0	1	0	0	1	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	0	1	0	0	0	1	0	0	0	1	0	1	**31**
28	1	1	0	1	0	1	1	1	0	1	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	0	1	0	0	1	0	1	0	1	0	1	0	1	1	0	1	0	0	1	0	1	**31**
29	1	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	1	0	1	1	0	1	1	1	0	0	0	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	0	1	0	1	1	1	1	**30**
30	0	1	0	1	0	1	1	1	0	1	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	0	1	0	0	1	0	1	0	1	0	1	0	1	1	0	1	0	0	1	0	1	**30**
31	1	0	1	0	1	0	1	1	0	1	0	0	1	1	0	1	0	1	0	0	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	0	0	1	0	0	1	0	0	1	0	0	1	**29**
32	1	0	1	0	1	0	1	0	1	1	1	0	1	0	1	0	1	0	1	1	0	0	1	0	0	1	1	1	1	1	0	1	0	1	1	0	1	0	1	0	1	0	1	0	0	0	1	1	0	1	**28**
33	1	0	1	0	1	1	1	1	1	1	0	1	1	1	0	0	0	0	0	1	1	1	1	1	0	1	0	1	1	0	0	1	0	1	1	0	1	1	1	0	0	0	1	0	1	0	1	0	0	0	**28**
34	1	1	0	1	1	0	1	0	1	1	0	0	1	1	0	0	1	0	0	1	0	1	1	1	0	1	0	1	1	0	0	1	0	0	1	0	1	1	1	0	0	0	1	0	1	0	1	1	0	1	**27**

35	0	1	1	1	0	0	1	1	0	1	1	1	0	0	1	0	1	0	1	1	1	0	0	1	1	1	1	0	0	0	1	0	0	0	0	1	1	0	1	1	0	0	0	0	1	0	1	0	1	1	**26**
36	1	1	1	0	1	0	1	1	0	1	0	0	1	1	0	1	0	1	0	0	1	0	1	1	0	1	1	1	1	0	0	1	0	1	0	1	1	1	0	0	0	0	0	1	0	0	1	0	0	1	**26**
37	1	1	1	0	1	0	1	1	0	1	0	0	1	1	0	1	0	1	0	0	1	0	1	1	0	1	1	1	1	0	0	1	0	1	0	1	1	1	0	0	0	0	0	1	0	0	1	0	0	1	**26**
38	1	0	1	0	0	1	1	0	1	1	1	1	0	0	0	1	0	1	0	0	1	1	0	0	1	1	1	1	1	0	1	0	1	0	1	0	0	0	1	1	0	0	0	1	0	0	1	0	0	1	**25**
39	1	0	1	0	1	1	1	1	0	1	0	0	1	1	0	1	1	0	1	1	1	1	1	1	0	1	0	1	1	0	1	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**25**
40	1	1	0	0	1	0	1	0	0	1	0	0	1	1	0	0	1	0	0	1	0	1	1	1	0	1	0	0	1	0	0	1	0	0	1	0	1	1	1	0	0	0	1	0	1	0	1	1	0	1	**24**
41	0	1	0	1	0	1	1	0	0	0	0	1	0	0	1	1	1	0	1	1	1	0	1	0	1	0	0	1	0	0	1	0	0	1	0	1	0	1	0	1	0	1	1	0	1	0	0	1	0	1	**24**
42	1	0	1	0	1	0	1	0	0	1	0	0	1	0	0	0	1	0	0	1	0	1	1	1	0	1	0	0	1	0	0	1	0	0	1	0	1	1	1	0	0	0	1	0	1	0	1	1	0	1	23
43	1	0	1	0	1	0	1	1	0	1	0	0	1	1	0	0	0	0	0	0	1	0	1	1	0	1	0	1	1	0	0	1	0	1	1	0	1	1	0	0	0	0	0	1	0	0	1	0	0	1	**22**
44	1	0	0	0	1	0	1	0	0	0	0	0	1	1	0	0	1	0	0	1	0	1	1	1	0	1	0	0	1	0	0	1	0	0	1	0	1	1	1	0	0	0	1	0	1	0	1	1	0	1	**22**
45	1	0	1	0	1	1	1	1	0	1	0	0	1	1	0	0	0	0	0	1	1	1	1	1	0	1	0	1	1	0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**21**
46	0	1	0	0	1	0	1	1	0	1	1	0	0	1	0	0	1	0	0	0	0	1	1	1	1	0	0	1	0	0	0	0	1	0	1	0	1	0	1	0	0	0	1	0	1	0	1	0	1	0	**21**
47	0	1	1	0	1	0	0	1	0	1	0	0	1	1	0	0	0	1	1	0	0	0	0	1	0	1	1	0	1	0	0	1	0	1	1	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0	**20**
48	0	0	0	0	1	0	1	1	0	1	1	0	0	1	0	0	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	1	0	1	0	1	0	0	0	1	0	1	0	1	0	1	0	**19**
49	0	0	1	0	1	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	1	0	1	1	0	0	1	0	1	1	0	1	1	0	0	0	0	0	1	0	0	1	0	0	1	**18**
50	1	0	0	1	1	0	1	0	1	0	1	0	1	0	0	1	0	1	0	0	1	0	1	1	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**17**
51	1	0	0	1	0	0	1	0	0	1	0	1	0	1	0	0	0	0	1	0	1	0	1	0	1	0	1	0	0	1	0	1	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	1	17
52	1	0	1	0	1	0	0	0	0	0	1	0	1	1	0	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1	1	0	1	0	0	0	**16**
53	0	1	0	1	0	1	0	1	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0	**15**
54	1	0	0	1	0	1	1	0	1	0	1	0	0	1	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1	0	0	1	0	0	0	0	0	**15**
55	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	0	1	0	1	0	1	1	**15**
56	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	0	1	0	1	0	1	1	**14**
57	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	0	1	0	0	0	1	0	**13**
58	1	0	0	1	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**12**
59	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0	1	1	0	1	**12**
60	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	**11**
61	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	**10**
62	0	1	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	**10**
63	1	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	**9**
64	0	1	0	1	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**8**
65	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	**6**
66	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**5**
67	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**4**
68	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**

APPENDIX T

RELIABILITY OF ORGANIC CHEMISTRY ACHIEVEMENT TEST (OCAT)

Class Interval	f	X	fx	$/x-\bar{x}/^2$	$f/x-\bar{x}/^2$
1-5	3	3	9	564.06	1692.18
6-10	5	8	40	351.56	1757.80
11-15	8	13	104	189.06	1512.48
16-20	6	18	108	76.56	459.36
21-25	9	23	207	14.06	126.54
26-30	9	28	252	1.56	14.04
31-35	9	33	297	39.06	351.54
36-40	8	38	304	126.56	1012.48
41-45	6	43	258	264.06	1584.36
46-50	5	48	240	451.56	2257.80
Total	68		1819		10768.58

$$\bar{x} = \frac{\Sigma fx}{\Sigma f}$$

$$\bar{x} = \frac{1819}{68}$$

$$\bar{x} = 26.75$$

$$\delta^2 = \frac{\Sigma f /x-\bar{x}/2}{\Sigma f}$$

$$\delta^2 = \frac{10768.58}{68}$$

$$\delta^2 = 158.36$$

Mean = 26.75

Variance = 158.36

Applying Kuder-Richardson formula (KR-21)

$$r\alpha = \frac{\mathrm{n}}{\mathrm{n}-1}\left(1 - \frac{\bar{x}(n-\bar{x})}{n\delta^2}\right)$$

Where $r\alpha$ = reliability coefficient

n = No of Items

$\bar{x}$ = Mean of the test scores

δ^2 = Variance (variance of total test scores)

$\bar{x} = 26.75$

Variance of total score δ^2= 158.36 Hence,

$$r\alpha = \frac{\mathrm{n}}{\mathrm{n}-1}\left(1 - \frac{\bar{x}(n-\bar{x})}{n\delta^2}\right)$$

$$r\alpha = \frac{50}{50-1}\left(1 - \frac{\bar{x}(n-\bar{x})}{n\delta^2}\right)$$

$$r\alpha = \frac{50}{50-1}\left(1 - \frac{26.75(50-26.75)}{50(158.36)}\right)$$

$$r\alpha = \frac{50}{49}\left(1 - \frac{(1337.5-715.56)}{7918}\right)$$

$$r\alpha = 1.02\left(1 - \frac{621.94}{7918}\right)$$

$$r\alpha = 1.02(1-0.079)$$

$$r\alpha = 1.02(0.921)$$

$$r\alpha = .93942$$

$$r\alpha = .94$$

An internal consistency index of 0.94 as calculated indicates a high degree of intra-item coherence in interpretation and answers by the respondents. Hence, the instrument is reliable.

APPENDIX U

SUMMARY OF PSYCHOMETRIC INDICES FOR ORGANIC CHEMISTRY ACHIEVEMENT TEST (OCAT)

S/N	Item Difficulty Index (I.D)	Item Discrimination Index (D.I)	Distractor Index				Remark
			A	B	C	D	
1.	.69	.26	-.34	-.24	-.22	*	Selected
2.	.43	-.03	-.19	*	-.15	-.29	Not Selected
3.	.59	.47	-.36	-.21	*	-.30	Selected
4.	.41	.17	-.02	*	-.09	.00	Not Selected
5.	.60	.09	.00	-.02	*	-.12	Not Selected
6.	.50	.47	-.52	-.37	*	-.40	Selected
7.	.75	.38	-.25	*	-.23	-.22	Selected
8.	.63	.26	-.32	-.40	*	-.24	Selected
9.	.34	.38	*	-.36	-.24	-.29	Selected
10.	.69	.41	-.23	*	-.42	-.24	Selected
11.	.40	.20	-.34	*	-.30	-.28	Selected
12.	.36	.44	-.42	*	-.29	-.34	Selected
13.	.66	.53	-.24	*	-.44	-.29	Selected
14.	.65	.26	*	-.13	-.25	-.24	Selected
15.	.40	.62	*	-.49	-.20	-.12	Selected
16.	.47	.59	*	-.22	-.29	-.20	Selected
17.	.51	.44	-.10	-.29	-.15	*	Selected
18.	.50	.53	-.27	-.34	*	-.17	Selected
19.	.50	.35	-.34	.14	-.12	*	Selected
20.	.57	.41	-.38	*	-.20	-.15	Selected
21.	.57	.44	-.15	*	-.21	-.44	Selected
22.	.47	.44	-.34	-.32	*	-.37	Selected
23.	.66	.44	-.49	-.32	*	-.10	Selected
24.	.76	.17	*	.00	-.15	.00	Not Selected
25.	.47	.47	*	.31	-.34	-.28	Selected
26.	.65	.41	-.26	*	-.15	-.39	Selected

27.	.46	.44	-.24	-.28	*	-.18	Selected
28.	.63	.50	-.15	-.27	-.29	*	Selected
29.	.75	.50	-.41	-.34	-.31	*	Selected
30.	.38	.64	-.29	*	-.27	-.24	Selected
31.	.33	.38	*	-.29	-.29	-.15	Selected
32.	.57	.50	-.34	*	-.37	-.21	Selected
33.	.35	.47	-.21	-.09	*	-.33	Selected
34.	.63	.53	-.33	*	-.27	-.23	Selected
35.	.63	.53	*	-.29	-.21	-.24	Selected
36.	.41	.18	*	.00	-.14	.00	Not Selected
37.	.69	.41	-.34	-.44	*	-.17	Selected
38.	.60	.53	*	-.24	-.44	-.15	Selected
39.	.57	.56		*	.22	.25	Selected
40.	.43	-.08	-.20	-.14	*	.00	Not Selected
41.	.29	.44	.00	*	.00	-.18	Not Selected
42.	.40	.47	-.19	-.34	*	-.31	Selected
43.	.22	.61	*	-.49	-.47	.00	Not Selected
44.	.26	.31	.00	-.32	-.26	*	Not Selected
45.	.66	.48	*	-.20	-.24	-.29	Selected
46.	.24	.47	*	-.44	-19	-.24	Not Selected
47.	.70	.35	-.37	-.41	*	-.32	Selected
48.	.41	.41	-.19	-.10	*	-.15	Selected
49.	.46	.38	-.18	-.31	-.16	*	Selected
50.	.68	.35	-.27	-.22	-.29	*	Selected

Note:

* Denotes correct answer

$$\text{Item difficulty (I.D)} = \frac{\text{Total number of students that got item right}}{\text{Total number of students that took the test}}$$

Discrimination index (D.I) =

$$\frac{\text{Proportion of Upper group that got item right} - \text{Propoortion of lower group that got item right}}{\frac{1}{2}\,\text{Total number included in the item analysis}}$$

MAI Ratings for Reliability Test

S/N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	4	3	3	4	3	4	4	3	4	4	3	3	3	3	4	4	3	4	3	4	3	4	4	3	2	4	4	4	4	4	3	3	4	3	4	3	4	4	3	4
2	2	1	2	4	2	2	2	1	1	2	2	2	2	2	1	2	3	2	2	2	1	1	3	2	1	2	2	2	1	1	2	2	1	2	2	2	1	2	1	3
3	3	4	3	3	3	3	4	3	4	3	4	4	3	4	3	4	4	3	3	4	3	4	3	3	3	3	4	3	3	4	4	3	4	4	4	3	4	4	3	4
4	1	1	2	3	2	1	2	1	2	1	1	2	1	1	1	2	2	1	2	2	1	1	3	3	1	3	2	2	1	3	2	2	1	2	2	2	1	2	1	3
5	4	3	4	3	1	4	4	3	1	2	1	3	3	3	3	3	2	3	1	2	4	3	4	3	1	4	4	3	1	2	1	3	3	3	3	3	1	3	1	2
6	2	1	2	4	2	2	2	1	1	2	2	2	2	2	1	2	3	2	2	2	1	1	3	2	1	2	2	2	1	1	2	2	1	2	2	2	1	2	1	3
7	3	4	4	2	3	4	4	3	4	3	4	3	3	2	3	4	2	3	3	4	3	4	3	4	3	3	3	3	4	4	3	3	4	3	4	3	4	4	4	4
8	2	3	4	3	2	4	3	3	1	3	1	3	4	3	4	3	4	3	1	3	4	3	4	3	4	4	4	3	2	3	1	3	3	3	3	3	1	3	1	2
9	2	2	2	3	2	2	1	1	1	2	3	2	2	2	1	2	1	2	2	2	1	1	3	2	1	4	2	2	1	2	2	2	1	2	2	2	1	2	1	3
10	3	4	3	3	3	3	4	3	4	3	3	3	3	4	3	4	3	3	3	3	3	4	3	3	3	3	4	3	3	4	3	3	4	3	3	3	4	4	3	3
11	3	3	3	3	3	4	4	3	4	3	4	3	4	3	3	4	3	3	3	4	3	4	4	3	3	4	4	3	4	4	3	4	4	3	4	4	3	4	3	4
12	2	2	2	4	3	2	3	2	1	2	3	2	2	1	1	2	3	4	2	1	1	2	3	2	2	2	3	2	1	1	2	4	1	2	2	1	1	2	1	3
13	4	4	3	4	3	3	4	3	4	3	4	3	3	3	4	2	4	2	3	4	3	4	3	4	3	3	4	4	3	4	4	3	4	4	4	3	4	4	3	4
14	4	3	3	4	4	4	3	3	4	3	3	4	3	4	4	4	3	4	4	4	4	4	4	3	3	4	4	4	4	4	3	4	4	3	4	3	4	4	3	3
15	2	1	3	3	1	2	2	3	1	2	1	3	3	3	3	2	1	3	1	2	4	3	4	3	1	4	4	3	1	2	1	3	3	3	3	3	1	3	1	2
16	3	4	3	4	4	4	3	3	3	4	4	3	3	3	3	3	3	4	3	4	3	3	4	3	3	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4
17	3	3	3	3	3	3	3	3	4	3	4	3	3	4	3	4	3	3	3	4	3	3	3	3	3	3	4	3	3	3	4	3	4	4	4	3	3	4	3	2
18	2	2	2	2	2	2	2	1	1	2	2	2	2	2	1	2	3	2	2	3	1	1	3	2	3	2	2	2	1	1	2	3	1	2	1	2	1	1	1	1
19	4	3	4	4	3	4	4	4	4	4	3	3	3	3	4	4	3	4	3	4	3	4	4	3	4	4	4	4	4	4	3	3	4	3	4	3	4	4	3	4
20	4	4	3	4	3	4	4	3	4	3	4	4	3	3	3	4	3	3	4	4	3	4	3	4	3	3	4	3	4	4	4	3	4	4	4	4	2	3	3	4
21	2	2	2	3	2	2	1	1	1	2	2	1	2	2	1	2	2	2	2	1	1	1	3	2	1	2	1	2	1	1	2	2	1	2	2	1	1	2	1	3
22	3	4	3	3	4	3	4	3	4	3	4	4	3	4	3	4	4	4	4	4	3	4	3	3	4	3	4	3	3	4	4	3	4	4	4	3	4	4	3	4
23	2	1	2	4	2	2	2	1	1	2	2	2	2	2	1	2	3	2	2	2	1	1	3	2	1	2	2	2	1	1	2	2	1	2	2	2	1	2	1	3
24	4	4	4	4	4	4	4	2	4	4	3	3	3	3	4	4	3	4	3	3	3	3	4	3	2	3	4	3	4	4	4	3	4	4	4	3	4	4	4	4
25	3	3	3	4	3	3	3	3	4	3	4	4	3	4	3	4	3	3	3	4	3	4	3	3	3	3	3	3	3	4	3	3	4	3	4	3	4	3	3	4
26	3	4	4	4	3	4	3	3	4	4	3	4	3	4	4	4	3	4	4	4	3	4	4	3	3	4	4	4	3	4	3	3	4	3	3	3	3	4	3	3
27	3	2	2	4	2	2	3	3	2	2	2	2	2	2	2	2	3	2	2	2	1	3	3	2	1	2	3	2	1	1	2	3	1	2	2	2	1	1	1	2
28	4	3	3	4	3	4	4	3	4	4	3	3	4	3	4	4	4	4	3	4	4	4	4	4	2	4	4	4	4	4	3	3	4	3	4	3	4	4	3	4
29	3	4	3	3	4	3	4	3	4	3	4	4	3	4	4	4	4	3	3	4	4	4	3	4	4	3	4	3	3	4	4	3	4	4	4	3	3	4	4	4
30	1	1	2	2	3	2	2	1	2	2	1	2	1	2	3	4	3	2	3	2	2	2	3	2	1	3	2	2	3	1	2	3	3	2	2	3	1	2	1	3
31	3	3	3	4	3	4	4	3	4	4	3	4	3	4	3	3	3	4	3	4	3	3	4	3	3	4	4	4	4	4	3	3	4	3	4	3	4	4	3	3
32	4	4	3	3	4	3	4	3	4	2	4	4	3	4	3	4	2	3	3	4	3	1	3	3	3	1	4	3	3	4	2	3	4	4	4	1	4	4	2	4
33	3	2	2	2	2	2	2	1	2	2	2	3	2	1	3	1	3	2	3	1	1	1	2	1	1	2	2	2	1	2	2	1	1	2	3	2	1	3	1	3
34	3	4	3	3	2	3	4	3	4	3	4	3	3	4	3	3	4	3	3	1	3	4	3	3	2	3	4	3	4	4	3	3	4	4	4	3	4	4	4	4

35	3	1	2	4	2	2	2	1	1	2	2	3	1	3	3	2	3	2	4	2	1	3	3	2	2	2	1	2	1	3	2	2	1	2	2	3	1	3	1	2
36	4	4	4	4	4	4	4	3	4	4	4	3	3	4	4	4	3	4	3	4	3	4	4	3	2	4	4	4	4	4	3	3	4	3	4	3	4	4	4	4
37	4	2	2	4	2	2	3	1	2	2	2	2	2	2	2	2	3	2	2	3	1	1	3	2	2	2	2	2	3	1	2	2	1	2	3	2	2	2	1	3
38	4	3	3	3	4	4	4	4	4	4	4	3	3	3	3	3	4	3	4	3	3	3	4	4	3	2	4	4	3	4	3	3	3	4	3	4	3	3	4	3
39	4	4	3	4	3	3	4	4	4	2	4	4	3	4	3	4	4	2	3	4	3	4	2	3	3	3	4	3	1	4	4	4	4	4	4	1	4	2	3	1
40	3	1	2	4	2	2	2	1	3	2	2	2	2	2	1	2	3	2	2	2	1	3	3	2	1	2	2	2	2	1	2	2	1	2	2	2	3	2	1	4
41	4	3	3	4	3	4	4	3	4	4	3	3	3	3	4	4	3	4	3	4	3	4	4	3	2	4	4	4	4	4	3	3	4	3	4	3	4	4	3	4
42	3	4	3	3	3	4	4	3	4	3	4	4	3	4	4	4	4	3	4	4	3	4	3	4	3	4	4	3	3	4	3	3	4	3	4	3	3	4	3	4
43	3	1	2	4	2	2	1	1	3	2	2	2	3	2	1	2	3	2	3	2	1	1	3	2	1	1	2	1	1	1	2	2	1	2	2	2	1	2	1	3
44	3	4	3	3	1	3	4	4	2	3	2	3	3	4	3	3	3	4	2	1	3	3	3	3	2	3	4	3	2	1	2	3	3	4	3	3	3	4	2	1
45	2	3	4	4	1	4	3	3	2	3	1	2	4	4	4	4	1	4	1	1	2	3	4	4	1	4	3	3	2	3	1	2	4	4	4	4	1	4	1	3
46	2	1	2	4	2	2	2	2	3	2	2	2	3	2	1	2	3	2	2	3	2	1	3	2	3	2	2	2	3	1	2	2	1	2	2	2	1	2	1	3
47	4	3	4	3	2	4	3	3	1	2	3	3	3	3	3	3	3	3	2	2	4	3	3	3	2	4	4	3	1	2	1	3	3	3	4	3	1	4	1	3
48	3	3	3	3	3	4	4	3	3	2	2	3	3	2	3	3	1	3	1	2	2	3	4	3	1	4	2	3	1	2	1	4	3	3	3	3	1	3	1	2
49	4	3	4	3	1	4	4	3	1	2	1	3	3	3	3	3	1	3	1	2	4	3	4	3	3	4	4	3	1	2	1	3	3	3	3	3	2	3	1	2
50	3	1	2	3	2	2	3	1	1	2	2	2	2	3	1	2	3	2	2	2	1	2	3	2	1	2	3	2	1	1	2	2	1	2	3	2	3	2	1	3
51	4	3	4	3	3	4	4	3	1	2	3	3	4	3	3	4	2	3	3	2	4	3	4	4	3	4	4	3	1	2	1	3	3	3	3	3	3	3	1	2
52	2	2	2	2	2	2	2	1	3	2	2	2	3	2	1	2	3	2	2	2	1	3	3	2	1	2	3	2	3	1	2	2	1	2	2	2	1	2	1	3
53	4	4	3	4	3	3	4	4	4	3	4	4	3	4	4	4	4	4	4	4	3	4	3	3	3	3	4	3	4	4	4	3	4	4	3	4	3	4	3	3
54	2	3	2	4	2	2	2	3	1	2	2	2	2	2	1	2	3	2	2	2	1	1	3	2	1	2	3	2	3	1	2	2	1	1	2	2	1	2	1	1
55	4	3	3	3	3	4	3	3	4	3	3	3	3	3	4	3	3	4	3	4	3	4	4	3	2	4	4	3	4	3	3	3	4	3	4	3	4	4	3	3
56	2	1	2	3	2	1	2	1	1	2	2	1	2	1	1	2	3	2	2	1	1	1	3	2	1	2	1	2	1	1	1	2	1	2	2	1	1	2	1	1
57	3	4	3	3	3	3	4	4	4	3	4	4	3	4	3	4	4	3	4	4	3	4	3	4	3	3	4	3	3	4	4	3	4	4	4	4	4	4	3	4
58	4	3	4	4	3	4	4	4	3	4	3	4	3	3	4	4	3	4	3	4	3	4	4	2	2	4	4	4	4	3	3	3	4	3	4	3	3	4	3	4
59	4	3	4	3	1	4	4	3	3	2	1	3	3	3	3	3	1	3	1	2	4	3	4	3	1	4	4	3	1	2	1	3	3	3	3	3	1	3	1	2
60	3	4	3	3	3	2	4	3	4	3	4	4	3	2	3	4	4	3	2	4	3	3	3	3	3	3	4	3	3	4	3	3	4	4	4	3	4	4	3	4
61	3	1	2	1	2	2	2	2	3	2	2	3	2	2	1	2	3	2	2	2	1	1	3	2	1	2	2	3	1	1	2	2	1	2	3	2	1	3	1	3
62	3	4	3	4	4	3	4	3	4	3	4	4	3	4	4	4	4	3	4	4	3	4	3	3	4	3	4	3	4	4	4	3	4	4	4	3	4	4	3	4
63	4	4	4	4	3	4	4	3	4	4	3	4	3	4	4	4	3	4	3	4	3	4	4	3	3	4	4	4	4	4	3	2	4	3	2	3	4	2	3	2
64	3	4	3	3	3	3	4	3	3	3	4	3	3	4	3	4	4	3	3	3	3	4	3	3	4	3	4	3	4	4	4	3	4	4	3	3	4	3	3	3
65	1	1	2	4	2	1	2	1	1	2	2	1	2	2	1	2	1	2	2	2	1	1	1	2	1	2	2	2	1	1	2	3	1	2	3	2	1	3	1	2
66	3	3	3	3	3	4	4	3	1	2	3	3	3	3	3	4	3	3	1	3	4	3	4	4	3	4	4	3	2	4	1	3	3	3	3	3	1	3	1	2
67	2	2	2	3	2	2	2	1	1	3	2	2	1	2	1	2	1	2	1	2	2	2	3	2	1	3	2	1	1	2	2	2	2	2	3	2	1	1	1	4
68	1	2	1	4	1	2	1	1	1	2	1	1	1	2	2	2	2	2	2	3	2	2	4	2	2	4	2	1	2	3	2	3	2	2	3	2	1	2	2	3

APPENDIX V

RELIABILITY OF METACOGNITIVE AWARENESS INVENTORY (MAI)

{Dataset}:c:\Users\Documents\01\Ajayi_victor.sav

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	68	100.0
	Excluded[a]	0	.0
	Total	68	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of items
.844	.851	40

Item Statistics

	Mean	Std. Deviation	N
Item1	3.6723	1.30519	68
Item2	3.8233	1.45652	68
Item3	3.4596	1.34421	68
Item4	3.6767	1.46293	68
Item5	3.4879	1.23932	68
Item6	3.7604	1.39909	68
Item7	3.7208	1.29309	68
Item8	3.4750	1.37158	68
Item9	3.7117	1.32827	68
Item10	3.4583	1.39909	68
Item11	3.6208	1.31862	68
Item12	3.2229	1.32916	68
Item13	3.4206	1.37196	68
Item14	3.4375	1.39909	68
Item15	3.7916	1.41235	68
Item16	3.5248	1.28128	68
Item17	3.1751	1.39029	68

Item18	3.3710	1.28499	68
Item19	3.6709	1.39909	68
Item20	3.6678	1.23317	68
Item21	3.7680	1.35451	68
Item22	3.6612	1.34224	68
Item23	3.6750	1.49291	68
Item24	3.3453	1.23732	68
Item25	3.4543	1.31209	68
Item26	3.4731	1.32919	68
Item27	3.5672	1.35118	68
Item28	3.6782	1.32855	68
Item29	3.8723	1.35911	68
Item30	3.5701	1.42862	68
Item31	3.4522	1.36916	68
Item32	3.6921	1.43176	68
Item33	3.7322	1.41909	68
Item34	3.2134	1.42235	68
Item35	3.5432	1.37128	68
Item36	3.6311	1.41022	68
Item37	3.4322	1.24499	68
Item38	3.6231	1.36901	68
Item39	3.5323	1.35724	68
Item40	3.6643	1.42317	68

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum/ Minimum	Variance	N of Items
Item Means	3.448	3.175	3.872	1.141	1.366	.087	40
Item Variances	1.621	.412	2.131	1.634	3.932	.134	40

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Item1	128.1512	337.883	.477	.782	.833
Item2	128.3550	344.595	.472	.682	.844
Item3	128.1979	342.834	.393	.595	.843
Item4	128.4167	353.172	.362	.665	.861
Item5	128.7042	378.436	.483	.637	.852
Item6	128.6537	369.923	.359	.756	.823
Item7	128.6647	362.427	.326	.691	.844
Item8	128.9479	389.587	.286	.853	.847
Item9	128.4467	370.688	.528	.732	.837
Item10	128.3437	351.423	.823	.662	.843
Item11	128.4596	347.010	.299	.625	.843
Item12	128.7729	338.174	.346	.765	.844
Item13	128.4062	341.738	.463	.637	.840
Item14	128.6537	368.432	.476	.686	.823
Item15	128.6417	346.882	.188	.793	.865
Item16	128.3437	362.575	.201	.824	.849
Item17	128.4271	379.426	.288	.812	.847
Item18	128.5529	387.526	.469	.717	.835
Item19	128.2132	354.923	.457	.653	.843
Item20	128.8875	338.301	.188	.745	.850
Item21	128.6042	344.536	.637	.734	.863
Item22	128.3637	358.923	.472	.816	.834
Item23	128.1432	347.527	.397	.743	.840
Item24	128.7470	354.587	.365	.827	.823
Item25	128.3767	364.686	.286	.681	.875
Item26	128.9312	375.783	.358	.732	.833
Item27	128.7750	364.595	.354	.696	.840
Item28	128.3979	357.734	.289	.854	.843
Item29	128.3167	343.172	.520	.587	.861
Item30	128.2842	378.836	.856	.616	.852
Item31	128.7437	394.923	.232	.743	.821
Item32	128.6437	333.723	.343	.664	.847
Item33	128.6479	354.587	.467	.722	.848
Item34	128.6367	384.788	.854	.653	.846
Item35	128.3437	362.923	.143	.815	.823
Item36	128.2896	356.883	.203	.781	.843
Item37	128.2729	396.795	.284	.713	.844

Item38	128.4362	349.834	.467	.796	.840
Item39	128.3437	331.772	.353	.778	.855
Item40	128.3417	384.536	.284	.687	.848

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
133.8643	314.782	23.58430	40

OCSEB Rating for Reliability Test

S/N	it1	it2	it3	it4	it5	it6	it7	it8	it9	it10	it11	it12	it13	it14	it15	it16	it17	it18	it19	it20
1	3	1	4	2	4	1	2	1	3	4	3	1	3	1	1	1	4	1	3	4
2	1	2	2	1	1	2	1	4	1	1	1	4	1	4	3	4	1	4	1	2
3	3	1	3	1	4	1	1	1	4	3	3	1	3	2	1	1	3	1	4	4
4	1	1	1	2	2	1	1	3	2	2	1	3	1	3	4	4	1	4	1	1
5	4	2	3	1	3	2	1	2	3	4	3	1	4	1	2	1	4	2	3	4
6	4	1	4	2	4	2	1	1	4	4	4	1	4	2	1	1	4	1	4	4
7	2	2	2	2	2	2	2	3	2	2	2	4	2	4	4	4	1	3	1	2
8	4	1	4	3	4	2	2	1	3	4	4	1	4	1	1	2	4	2	3	4
9	3	1	3	1	3	1	1	1	3	3	3	1	3	2	1	1	3	1	4	3
10	1	1	1	1	1	1	1	4	1	1	1	4	1	4	4	4	1	4	1	1
11	3	3	4	2	4	3	2	3	3	4	3	2	3	1	2	2	4	2	3	3
12	3	1	3	2	4	2	3	1	4	3	3	1	3	2	2	1	3	1	3	4
13	1	2	2	1	2	2	2	3	2	2	1	4	1	3	4	3	2	3	2	2
14	4	2	4	2	4	1	2	1	3	4	3	1	3	1	1	1	4	1	3	4
15	4	1	4	1	4	1	2	1	4	3	3	1	3	2	1	1	3	1	4	4
16	1	2	2	1	1	2	1	4	1	1	1	4	1	4	4	4	1	4	1	2
17	3	1	4	2	4	1	2	1	3	4	3	1	3	1	1	1	4	1	3	4
18	4	2	3	2	2	3	2	2	4	4	4	1	4	2	2	1	3	1	3	4
19	2	2	2	2	2	2	2	3	2	1	2	3	1	3	3	3	1	3	1	2
20	3	1	4	2	4	1	1	2	3	3	3	2	3	2	1	2	3	2	3	4
21	4	2	4	2	4	2	2	2	4	4	4	1	4	1	1	1	4	1	4	4
22	1	2	2	1	1	2	1	4	1	1	1	4	1	4	4	4	1	4	1	2
23	4	1	4	2	3	1	2	1	3	4	3	1	4	1	1	2	4	1	3	4
24	4	1	3	1	3	2	1	1	4	3	4	1	3	2	1	1	4	2	3	3
25	1	1	1	1	1	2	2	4	1	1	1	3	1	4	4	3	1	4	1	1
26	3	3	4	2	4	3	2	3	3	4	3	3	3	1	3	1	4	1	3	4
27	3	1	3	1	3	1	1	1	4	3	3	1	3	2	1	1	3	1	4	4
28	2	2	2	1	1	2	1	3	1	1	1	3	1	3	4	4	1	3	1	2
29	3	2	4	1	4	1	2	1	3	4	3	1	4	1	1	1	4	1	3	3
30	3	1	3	1	4	1	1	2	4	4	3	1	3	2	2	1	3	2	4	3
31	1	2	2	1	1	2	1	4	1	1	1	4	1	3	4	4	1	4	1	2
32	3	1	4	2	4	2	2	2	3	4	3	1	3	1	2	1	4	1	3	4
33	4	2	3	1	3	1	1	1	4	3	4	1	3	2	1	2	3	1	4	3
34	1	2	1	1	1	2	1	3	1	1	1	4	2	4	3	4	1	4	1	1

35	3	1	3	2	4	1	2	1	3	4	3	1	4	1	2	1	4	1	3	4
36	4	2	3	1	4	1	1	1	4	3	3	2	3	2	1	1	3	2	4	4
37	2	2	2	2	1	2	1	4	2	1	1	4	1	4	4	4	1	3	1	2
38	4	2	4	2	4	1	2	1	3	4	3	1	3	1	1	1	4	1	4	4
39	4	1	3	1	4	1	1	2	4	3	3	1	3	2	1	2	4	1	4	4
40	1	2	2	1	2	2	1	4	1	1	1	4	1	4	4	4	1	4	1	2
41	3	1	4	2	4	1	2	1	3	3	3	1	4	1	2	1	4	2	3	4
42	3	1	4	1	4	1	1	1	4	3	3	1	3	2	1	1	2	1	4	4
43	2	2	2	1	1	2	1	4	1	1	1	4	1	4	4	4	1	4	1	2
44	4	1	4	2	4	1	2	1	3	4	3	1	3	1	1	1	4	1	3	4
45	3	2	3	1	4	1	2	1	4	3	4	2	3	2	1	2	3	1	4	4
46	2	2	2	1	1	2	1	4	1	1	1	4	1	4	4	4	1	4	1	2
47	3	1	4	2	4	1	2	1	3	4	3	1	3	1	1	1	4	1	3	4
48	1	1	1	1	1	2	1	4	1	1	1	4	1	4	4	4	1	4	1	2
49	3	1	3	1	3	1	1	2	4	3	3	1	3	2	1	1	3	1	4	4
50	4	2	4	2	4	1	1	1	3	4	3	2	4	1	1	2	4	1	3	4
51	1	2	2	1	2	2	2	4	1	1	2	4	1	3	4	4	1	4	1	2
52	3	1	3	1	4	2	1	1	4	3	4	1	3	1	1	1	3	2	4	4
53	4	3	4	2	4	1	2	1	3	4	3	1	3	1	1	1	4	1	3	4
54	3	1	3	1	4	1	1	1	4	3	3	1	3	2	3	2	3	2	4	4
55	2	2	2	2	2	2	2	4	2	2	2	4	2	4	4	4	2	3	1	2
56	3	2	4	2	4	1	2	1	2	4	3	1	3	1	1	1	4	1	3	4
57	1	2	2	1	1	2	3	4	1	1	1	4	1	4	4	4	1	4	1	2
58	2	1	2	2	1	1	2	4	1	1	2	3	1	4	3	4	1	4	1	2
59	3	1	3	1	4	1	1	1	4	3	3	1	3	2	1	1	3	1	4	4
60	4	2	4	1	2	2	2	1	4	3	4	2	3	2	2	1	3	1	4	4
61	1	1	1	1	1	1	1	4	1	1	1	3	1	4	4	4	1	3	1	1
62	3	1	4	2	4	1	3	2	4	3	2	1	3	1	1	1	4	1	3	3
63	4	1	3	1	4	1	1	1	4	3	3	1	3	2	1	1	3	1	4	4
64	1	1	2	1	1	2	1	4	1	1	1	4	1	4	4	4	1	4	1	2
65	3	1	4	2	4	1	2	1	3	4	4	1	3	1	2	1	4	1	3	4
66	3	1	3	1	3	2	1	2	4	3	3	2	4	2	1	2	3	2	4	4
67	4	2	4	2	3	1	2	1	3	4	3	1	2	1	1	1	4	1	3	3
68	1	2	3	2	4	3	2	1	4	3	4	2	4	2	3	2	3	1	3	4

APPENDIX W

RELIABILITY OF ORGANIC CHEMISTRY SELF-EFFICACY BELIEF SCALE (OCSEBS)

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	68	100.0
	Excluded[a]	0	.0
	Total	68	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of items
.862	.871	20

Item Statistics

	Mean	Std. Deviation	N
Item1	3.6722	1.33569	68
Item2	3.8234	1.41672	68
Item3	3.4598	1.38431	68
Item4	3.6763	1.44253	68
Item5	3.4873	1.22932	68
Item6	3.7601	1.39311	68
Item7	3.7206	1.24389	68
Item8	3.4753	1.38168	68
Item9	3.8118	1.34857	68
Item10	3.4584	1.37959	68
Item11	3.6201	1.38842	68
Item12	3.3220	1.28936	68
Item13	3.4207	1.35126	68
Item14	3.4376	1.35913	68
Item15	3.7917	1.42232	68
Item16	3.5242	1.26138	68
Item17	3.1724	1.38049	68
Item18	3.3718	1.33401	68
Item19	3.6705	1.35421	68
Item20	3.6674	1.34337	68

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum/ Minimum	Variance	N of Items
Item Means	3.776	3.172	3.823	1.151	1.369	.069	20
Item Variances	1.422	.211	2.147	1.749	4.952	.154	20

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Item1	92.1311	387.383	.543	.454	.863
Item2	92.4750	294.495	.492	.655	.864
Item3	92.1479	386.134	.393	.773	.837
Item4	92.4267	313.772	.232	.721	.846
Item5	92.2141	308.836	.486	.682	.862
Item6	92.2338	378.023	.350	.718	.863
Item7	92.3437	378.223	.459	.789	.866
Item8	92.0479	399.487	.387	.632	.867
Item9	92.5167	390.388	.528	.798	.847
Item10	92.5437	378.323	.450	.621	.866
Item11	92.4996	217.210	.351	.619	.860
Item12	93.1729	398.374	.341	.723	.861
Item13	92.4362	391.638	.461	.755	.856
Item14	92.4137	378.823	.350	.713	.863
Item15	92.0413	216.182	.448	.670	.835
Item16	92.3937	303.375	.395	.781	.859
Item17	92.4273	399.526	.469	.668	.864
Item18	92.0759	397.326	.469	.771	.835
Item19	92.2132	278.623	.550	.664	.841
Item20	92.7874	304.701	.381	.713	.868

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
97.7504	242.128	17.53420	20

APPENDIX X

PREDICT-EXPLAIN-OBSERVE-EXPLAIN LESSON PLANS FOR EXPERIMENTAL GROUP 1

LESSON 1:

School:	As Applicable
Subject:	Chemistry (Organic Chemistry)
Specific Topic:	Alkanes
Class:	SS II
Number in class:	As Applicable
Average Age:	16 Years
Sex:	Mixed
Time:	80 minutes
Date:	As Applicable

Behavioural objectives: By the end of the lesson, students should be able to:

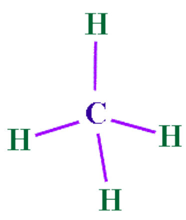
1. define the term alkanes;
2. write general formula of alkanes;
3. identify at least three sources of methane;
4. mention at least four physical properties of some alkanes;
5. draw the structure of methane accurately;
6. clearly describe the chemical properties of methane;
7. correctly carryout the laboratory preparation of methane; and
8. mention at least five uses of methane.

Instructional Materials: Sodium acetate, sodium hydroxide, bunsen burner, beaker, cardboard paper, blades, gums, makers and PEOE worksheet.

Previous knowledge: Students have studied hydrocarbon.

Lesson Presentation

Content Development	Time (mins)	Teacher's activities	Students' activities
Step 1 Introduction/ Checking Previous Knowledge	5	Arouses students' interest and motivates them to learn by telling them that the best group will be given a gift. Tell students the objectives of the lesson. Probes into students' prior knowledge through questions such as: what are the two classes of hydrocarbon? What are alkanes? Makes known to the students the teaching technique and its demand on them Explains that the simplest member of alkane family is methane (CH_4) and other members are ethane (C_2H_6),	Answers the questions verbally. They are encouraged to write down their right ideas. (Two or three students say their ideas for class to correct. They are encouraged to write down or take note of the corrected ideas) Expected answers: The two classes of hydrocarbon are saturated and unsaturated hydrocarbon Alkanes are saturated hydrocarbons that is to say compounds of carbon and hydrogen which only have single, covalent, bonds holding the atoms together. with general molecular formula C_nH_{2n+2} and functional group of C-C and it prefix is "-ane" Jot down some points as the teacher speaks. May ask questions for clarification.

		propane (C_3H_8), butane (C_4H_{10}), pentane (C_5H_{12}), hexane (C_6H_{14}), and so on.	
Step 2 Grouping/ Elicitation of Students' ideas	15	Divides students into groups of 4-7; asks them to assume the role of captain, recorder, time-keeper and so on. Elicits ideas from the students. Asks the students to mention the sources of alkanes they know? Asks students to draw the structure of methane	Move into different groups and assume different roles as agreed by members. Give responses to the questions based on prior knowledge. Expected answers: i. Petroleum: petroleum is a complex mixture of alkanes and other hydrocarbons ii. Natural gas: methane is a major constituent of the natural gas and occur along with petroleum in the earth's sedimentary traps iii. Destructive distillation of wood and coal Students answer the question by drawing it on pieces of papers. Expected answer: The structure of methane is as follows:  Methane

		Asks students to mention the physical properties of methane they know	Answer the question verbally. They are encouraged to write down the right ideas. Expected answers: i. Methane is a colourless, odourless, and tasteless non poisonous gas. ii. Methane is sparingly soluble in water but dissolves readily in alcohol and ether. iii. Methane is lighter than air. iv. Methane melts at -184^{o}C and boils atomic -161.4^{o}C. it is neutral to litmus v. Methane like carbon dioxide also traps infrared radiations (heat radiations) reflected by the earth.
		Asks students to mention the uses of methane they know	Answer the question verbally and they are encouraged to write down their right ideas. Expected answers: i. Methane is important for electricity generation by burning it as a fuel in a gas turbine or stream generator. ii. Methane is used for the production of certain important compounds such as carbon black, hydrogen, alkynes, carbon disulphide, and hydrochloric acid. iii. Alkanes such as pentane is used as a propellant for aerosol

Briefly outlines the physical properties of the first few members of the alkane listing the formula, boiling point, melting point and density as follows:

Name	Formula	Boiling Point	Melting point	Density
Methane	CH_4	-162°C	-183	Gas
Ethane	C_2H_6	-89 °C	-182	Gas
Propane	C_3H_8	-42 °C	-188	Gas
Butane	C_4H_{10}	-0.5 °C	-138	Gas
Pentane	C_5H_{12}	36 °C	-130	0.626

Describe the chemical properties of methane as follows:

i. With alkalis methane does not react. Chemically, methane is very stable and remains unaffected when treated with $KMnO_4$, $K_2Cr_2O_7$ etc. under normal condition.

ii. With trioxonitrate (V) acid vapour: methane is nitrated at 300°C.

$$CH_4 + HNO_3 \longrightarrow CH_3NO_2 + H_2O$$

sprays, as a filling of low temperature thermometer

iv. Alkanes such as hexane serve as a solvent in the laboratory and for fast-drying lacquers and glues.

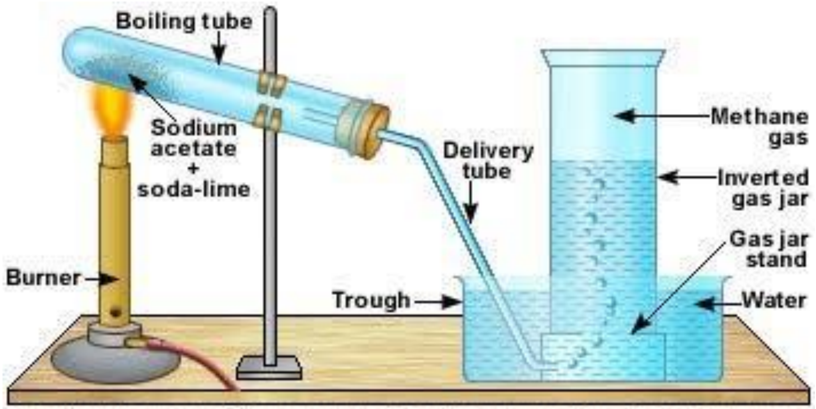
Listen to teacher's explanation and they are asked to increase their list of fact and concepts on alkanes as the lesson progresses as well as write out responses to the questions asked by the teacher.

May ask questions for clarification.

		iii. With stream: Methane is oxidized by stream in the presence of metallic Nickel catalyst to carbon (II) oxide and hydrogen. $CH_4 + O_2 \rightarrow CO + 3H_2$ iv. Combustion: methane burns in excess of air or oxygen with a pale-blue non luminous flame to give carbon dioxide and water. v. Reaction with chlorine: methane reacts slowly at ordinary temperature with chlorine in the presence of light to form a mixture of products- light acts as catalyst (the reaction is photo-catalysis)	
Step 3 Introducing the Experiment	5	Introduces the experiment thus; the purpose of the experiment that will be carry out later during this lesson is to prepare sample of a member alkanes by using sodium acetate and sodium hydroxide reagents and then to perform various tests on the product obtained to examine it properties.	Listen to the teacher and jot down some points as the teacher speaks, and asks questions for clarification.
Step 4 **<u>P</u>**redict **(P)**	10	At this step, before doing the experiment. Asks the students to predict the answers to some questions based on the earlier introduced experiment (noting that the answers to the questions can be addressed through the experiment that follows in step 6).	Captain directs discussion based on questions and the directives given by the teacher to guide their actions. Students spread out their individually written predictions on a flat surface (desk), where it can easily be read. Have a look at each other's predictions, and make quick comments. Then, the recorder for the

		Asks students to predict answers to questions or events such as; 1. If you mix sodium acetate and sodium hydroxide together in a test tube, what do you think will happen? 2. What do you think the equation for the reaction would be? 3. If you place the mixture on a bunsen burner, what do you think will happen? 3. If the product is ignited, it would burn with a particular colour and odour, what do you think the colour and odour would be? 4. What do you think the name of the product would be? Each member of the group is expected to write out their prediction on pieces of papers supplied them. They are to compare individual answers and collectively brainstorm to come out with group ideas on all questions raised thus far. Predictions are to be written down on the PEOE worksheet supplied to them by the recorder are those agreed upon by the entire group Goes round various groups to supervise the activities.	group or whoever is assigned, write down their prediction(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet

Step 5: **<u>E</u>**xplaining the Predictions **(E)**	10	Instructs each member of the group to write out their explanation for their prediction on pieces of papers supplied to them. Compare individual explanations and collectively brainstorm to come out with group explanations to predictions. explanations to predictions are to be written down on the PEOE worksheet supplied to them by the recorder are those agreed upon by the entire group Teacher goes round various groups to supervise the activities. (While students are writing, you might stroll around so as to prepare yourself for the discussion that will follow).	Students spread out their individually written explanation to their predictions on a flat surface (desk), where it can easily be read. Have a look at each other's predictions, and make quick comments. Then, the recorder for the group write down the explanation for their prediction(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet Share their PEOE worksheet containing both their predictions and the explanation for their predictions in full-class discussion
		Asks each group to present their PEOE worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the PEOE worksheet only contains highlight of the predictions and explanations for each group). After this has been done, the teacher might discuss with the class which predictions and reasons or explanations they now think are best.	Team leaders or selected group representatives makes their respective presentations in full class discussion (When students reconsider their reasons, some may begin to change their minds and reconstruct their thinking. Immediately prior to the experiment, it's often fun and illuminating to have a straw vote about the outcome).

Step 6 **<u>O</u>bserve (O)**	20	Instructs the students to carry out the laboratory activities for the preparation of X (methane) using sodium acetate and sodium hydroxide reagents as follows: 1. Measure 5grams of anhydrous sodium acetate (CH_3COONa) (reagent A) into a beaker. 2. Then add 2.5 grams of pulverized sodium hydroxide (reagent B) and mix them thoroughly in a beaker or porcelain dish. 3. Transfer the mixture into a hard glass test-tube boiling tube 4. Seal the test-tube with a stopper with a gas-delivery tube. The gas-delivery tube should look upwards. 5. Fix the test-tube on the stand 6. Heat the test-tube gently with the cold part of the flame to avoid local overheating keep the flame in motions. 7. Record your observation 8. Prepare an empty test-tube. Collect some gas keeping this test-tube on top of the gas delivery tube then ignite it 9. Record your observation and inference	Carry out the activities as directed by the teacher. They follow the instructions step by step and record their observation and inference and write down the chemical equation representing the preparation Spread out their individually written observations on a flat surface (desk), where it can easily be read. Have a look at each other's observations, and make quick comments. Then, the recorder for the group or whoever is assigned, write down their observation(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet Expected laboratory set-up:  Labelled diagram of the apparatus for the preparation of methane gas.

		(Teacher views the observations written down by the respective groups)	
Step 7 **<u>E</u>**xplaining the Observations **(E)**	10	Each member of the group is expected to write out their explanation for their observation on pieces of papers supplied them. They are to compare individual explanations and collectively brainstorm to come out with group explanations to observations. explanations to their observations are to be written down on the PEOE worksheet supplied to them by the recorder are those agreed upon by the entire group Goes round various groups to supervise the activities. (While students are writing, you might stroll around so as to prepare yourself for the discussion that will follow). Then, asks each group to present their PEOE worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the PEOE worksheet contains highlights of the predictions-explanations-observations-explanations for each group). After this has been done, teacher might discuss with the class which observation and explanations or reasons they now think are best. At this stage, teacher then engages	Students spread out their individually written explanation to their observations on a flat surface (desk), where it can easily be read. Have a look at each other's explanations, and make quick comments. Then, the recorder for the group write down the explanation for their observation(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet. Students to share their PEOE worksheet containing their predictions, explanation for their predictions, observations and explanations for their observation in full-class discussion Team leaders or selected group representatives makes their respective presentations in full class discussion At this stage, students are expected to compare their prediction and observation in order to reconcile any conflict between their predictions and observations in a brief full class discussion.

		the students to correlate their prediction with their observation so as to reconstruct their thinking and also reconcile any conflict between their predictions and observations. Ask the students to disengage from their groupings	Students move to their respective sits.
Total	**75**		

Summary: (5 minutes)

Teacher summarizes the lesson thus;

The alkanes can exist as gases, liquids, or solids at room temperature. The unbranched alkanes such as methane, ethane, propane and butane are gases; pentane through hexadecane is liquids; the homologues larger than hexadecane are solids. Branched alkanes normally exhibit lower boiling points than unbranched alkanes of the same carbon content. This occurs because of the greater van der Waals forces that exist between molecules of the unbranched alkanes.

Assignment:

Teacher gives the students take home assignment due for submission the next class

i. What is the boiling point of butane
ii. Give two reasons why soda lime is used instead of caustic soda in the preparation of methane

Expected answers to the assignment questions:

i. -0.5^0C
ii. Soda lime does not attack glass apparatus unlike caustic soda; and soda lime is not deliquescent unlike caustic soda

PEOE WORKSHEET FOR ALKANE

Group________________________ Date________________________

Predict
(What do you think will happen?)

1. If you mix sodium acetate and sodium hydroxide together in a test tube, what do you think will happen? <u>There may be no reaction until it is heated</u>
2. If the solution is heated, what do you think the equation for the reaction would be? $NaOH+CH_3COONa \xrightarrow{heat} CH_4 + Na_2CO_3$
3. If you place the mixture on a bunsen burner, what do you think will happen? <u>After a while methane gas will start liberating</u>
4. If the gas is ignited, it would burn with a particular colour and odour, what do you think is the colour and odour? <u>The gas is likely to burn with a blue fire and odourless.</u>
5. What do you think the name of the gas would be? <u>The unknown gas is likely to be methane</u>

Explain
(Why do you think that will happen)

1. Because it requires heat for the salts of carbonic acids to melt with alkalis (sodium hydroxide) for it to release alkane (methane)

3. Due to the interaction between sodium acetate and hydroxide

4. Methane undergoes complete combustion and it is an odourless gas. In this regard, a blue gas flame indicates complete combustion while red or yellow gas flame may be a sign of incomplete combustion.

Observe
What actually happened?

Test	Observation	Inference
CH_3COONa+ $NaOH$ + Heat	After a while unknown gas starts liberating	
Unknown gas + ignition	The unknown gas burn with a blue fire with colourless and odourless gas	Methane is produced

Explain
(Why did that happen?)

The unknown gas burns with a blue frame, indicate it undergoes complete combustion and it is an odourless gas. In this regard, the unknown gas is methane.

Fig 7: Expected PEOE worksheet for Alkane

LESSON 2:	**FOR EXPERIMENTAL GROUP 1 (PREDICT-EXPLAIN-OBSERVE-EXPLAIN)**
School:	As Applicable
Subject:	Chemistry
Specific Topic:	Alkenes
Class:	SS II
Number in class:	As Applicable
Average Age:	16 Years
Sex:	Mixed
Time:	80 minutes
Date:	As Applicable

Behavioural objectives: By the end of the lesson, students should be able to:

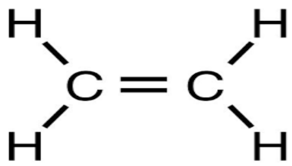
1. define the term alkenes;
2. write general formula alkenes;
3. identify the at least two sources of alkenes;
4. mention at least four physical properties of some alkenes;
5. draw the structure of ethene accurately;
6. clearly describe the chemical properties of ethene;
7. correctly carryout the laboratory preparation of ethene; and
8. mention at least four uses of ethene.

Instructional Materials: Ethanol (C_2H_5OH), aluminum oxide, lime water, bromine water, acidified potassium permanganate solution, water, test-tubes, glass wool, bunsen burner, beakers, measuring cylinder and PEOE worksheet.

Previous knowledge: Students have studied alkane

Lesson Presentation

Content Development	Time (mins)	Teacher's activities	Students' activities
Step 1 Introduction/ Checking Previous Knowledge	5	Arouses students' interest and motivates them to learn. Tell students the objectives of the lesson. Probes into students' prior knowledge through questions such as: what are alkanes? What are alkenes?	Answer the questions verbally. They are encouraged to write down their right ideas. (Two or three students say their ideas for class to correct. They are encouraged to write down or take note of the corrected ideas) Expected answers: Alkanes are saturated hydrocarbons that is to say compounds of carbon and hydrogen which only have single, covalent, bonds holding the atoms together. With general molecular formula CnH_2n_{+2} and functional group of C-C. Alkenes are unsaturated hydrocarbon that contains at least one carbon-carbon double bond with general molecular formula CnH_2n and functional group of C=C and it prefix is "-ene"
		Makes known to the students the teaching technique and its demand on them	Jot down some points as the teacher speaks. May ask questions for clarification.
		Explains that the simpler member of alkene family is ethene (C_2H_4) and other members are propene (C_3H_6), butene (C_4H_8), pentene (C_5H_{10}), hexene (C_6H_{12}), heptene (C_7H_{14}).	

Step 2 Grouping/ Elicitation of Students' ideas	15	Divides students into groups of 4-7; asks them to assume the role of captain, recorder, time-keeper and so on. Elicits ideas from the students. Asks the students to mention the sources of alkenes they know? Asks students to draw the structure of ethene Ask students to mention the physical properties of ethene they known	Move into different groups and assume different roles as agreed by members. Give responses to the questions based on prior knowledge. Expected answers: i. Terpene: Is the main source of natural alkene. ii. Fruits: It is found in fruits such as raw apricots Students answer the question by drawing it on pieces of papers. Expected answer: The structure of ethene is as follows:  Students answer the question verbally. They are encouraged to write down the right ideas. Expected answers; i. Ethene is a colourless gas with a faint sweetish smell. ii. It has a melting of -169^{0}C and boiling points of 104^{0}C iii. It is slightly less dense than air iv. It is insoluble in water but soluble in alcohol and ether. v. It is neutral to litmus paper.

		Asks students to mention some uses of alkenes they know? Explains that ethene undergo ionic addition reaction and further describe the chemical properties of ethene as follows: i. Hydrogenation: Ethene is converted to ethane by the	Students answer the question verbally. They are encouraged to write down the right ideas. Expected answers: i. Ethene is extremely important in the manufacture of plastic. All plastics are in some way related to alkenes ii. Ethene is used as fuel and illuminant. iii. Ethene is used in the manufacture of glycerol and detergent. iv. For the manufacturing of a wide variety of polymers e.g., polyethene, polyvinylchloride (PVC) and teflon and so on. v. As raw materials for the manufacture of industrial chemicals such as alcohols, aldehydes, and so on. vi. Alkenes are used for artificial ripening of fruits, as a general anesthetic, for making poisonous mustard gas and ethylene-oxygen flame. vii. It is used for the production of synthetic rubber such as styrene-butadiene rubber. viii. It is used to prepare other important chemicals such as ethyl alcohol (C_2H_5OH). Listen to teacher's explanation and they are asked to increase their list of fact and concepts on alkanes as the lesson progresses as well as write out responses to the questions asked by the teacher. May ask questions for clarification.

addition of 1 mole of hydrogen gas in the presence of nickel catalyst at suitable temperature and pressure

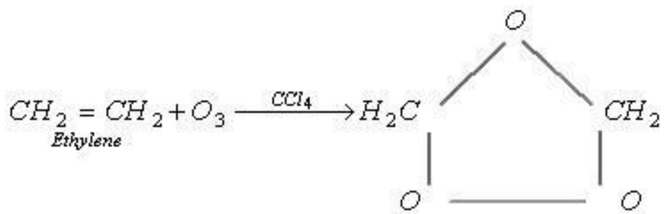
$$C_2H_4+H_2 \longrightarrow C_2H_6$$

ii. With halo water: At room temperature, the double bond in ethene is converted to single bond when halowater is added.

(a) $C_2H_4+Cl_2H_2O \longrightarrow C_2H_4HOCl$

(b) $C_2H_4+Br_2H_2O \longrightarrow C_2H_4HOBr$

iii. With Ozone: Ozone is passed into the solution of ethene in trichloromethane (chloroform) to give ethene ozonide.



iv. With Conc. Tetraoxosulphate (vi) acids: ethene is passed into a concentrated tetraoxosulphate (vi) acid to give ethyl hydrogen sulphate at 170°C

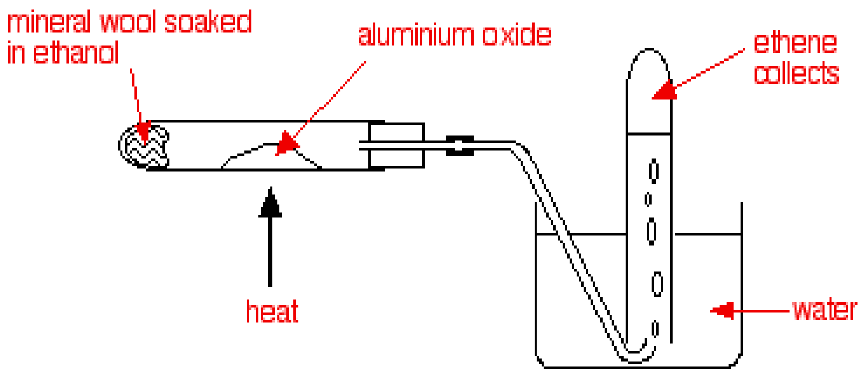
$$C_2H_2 + H_2SO_4 \longrightarrow CH_3\text{-}CH_2\text{-}SO_4\text{-}H$$

ethyl hydrogen sulphate

Step 3 Introducing the Experiment	5	Introduces the experiment thus; the purpose of the experiment that would be carry out later during this lesson is to prepare sample of a member alkenes by dehydrating ethanol using aluminiun oxide as a dehydrating agent and catalyst and then to perform various tests on the product obtained to examine it properties.	Listen to the teacher and jot down some points as the teacher speaks, and asks questions for clarification.
Step 4 **P**redict **(P)**	10	At this step, before doing the experiment, the teacher asks the students to predict the answers to some questions based on the earlier introduced experiment (noting that the answers to the questions can be addressed through the experiment that follows in step 6). Asks students to predict answers to questions such as; 1. If you mix ethanol, glass wool and aluminum oxide together in a boiling tube, what do you think will happen? 2. What do you think the equation for the reaction would be? 3. If you light the bunsen burner and adjust it to a blue flame and heat the aluminum oxide, ethanol will produce an unknown gas, what do you think has happened to ethanol?	Captain directs discussion based on questions and the directives given by the teacher to guide their actions. Spread out their individually written predictions on a flat surface (desk), where it can easily be read. Have a look at each other's predictions, and make quick comments. Then, the recorder for the group or whoever is assigned, write down their prediction(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet

		4. If lime water, is added to the unknown gas, what do you think will happen? 5. If bromine is added to the unknown gas in another test tube, what do you think will happen? 6. What do you think the name of the gas would be? Each member of the group is expected to write out their prediction on pieces of papers supplied them. They are to compare individual answers and collectively brainstorm to come out with group ideas on all questions raised thus far. Predictions are to be written down on the PEOE worksheet supplied to them by the recorder are those agreed upon by the entire group Goes round various groups to supervise the activities.	
Step 5: Explaining the Predictions **(E)**	10	Instructs each member of the group is expected to write out their explanation for their prediction on pieces of papers supplied to them. Compare individual explanations and collectively brainstorm to come out with group explanations to predictions. explanations to predictions are to be written down on the PEOE worksheet supplied to them by the recorder are those agreed upon by the entire group	Spread out their individually written explanation to their predictions on a flat surface (desk), where it can easily be read. Have a look at each other's predictions, and make quick comments. Then, the recorder for the group write down the explanation for their prediction(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet Share their PEOE worksheet containing both their predictions and the explanation for their predictions in full-class discussion

		Goes round various groups to supervise the activities. (While students are writing, you might stroll around so as to prepare yourself for the discussion that will follow). Teacher then, asks each group to present their PEOE worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the PEOE worksheet only contains highlight of the predictions and explanations for each group). After this has been done, the teacher might discuss with the class which predictions and reasons or explanations they now think are best.	Team leaders or selected group representatives makes their respective presentations in full class discussion (When students reconsider their reasons, some may begin to change their minds and reconstruct their thinking. Immediately prior to the experiment, it's often fun and illuminating to have a straw vote about the outcome).
Step 6 __O__bserve **(O)**	20	Instructs the students to carry out the laboratory activities for the preparation of X (ethene) by dehydrating ethanol using it as a dehydrating agent and catalyst sodium as follows: 1. Pour some ethanol into the boiling tube to a 2-3cm depth. 2. Add some glass wool to soak up the ethanol, using a glass rod to push the wool down the tube. 3. Clamp the boiling tube in a horizontal position using a retort stand.	Carry out the activities as directed by the teacher. They follow the instructions step by step and record their observation and inference and write down the chemical equation representing the preparation Students spread out their individually written observations on a flat surface (desk), where it can easily be read. Have a look at each other's observations, and make quick comments. Then, the recorder for the group or whoever is assigned, write down their observation(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet

		4. Put a small amount of aluminum oxide about half way along the boiling tube. 5. Light the bunsen burner, adjust it to a blue flame and heat the aluminum oxide (make sure the test tube is filled with water when you start to collect the gas produced) 6. As the aluminum oxide gets hot the heat reaches the ethanol at the end of the tube. The ethanol then change to vapour passes over the hot aluminum oxide and it is dehydrated to produce an unknown gas. 7. Let the bubbles produced escape for a short time (these are mainly bubbles of displaced air). Collect 3 test tube of the gas and put a stopper on each tube when it is filled. 8. When the test tube have all been filled, loosen the resort stand and raise the apparatus so that the delivery tube no longer dips into the water. Then turn off the bunsen burner. 9. Test each gas collected through addition of lime water, bromine, and addition of acidified $KMnO_4$ respectively. Then, record your observation and inference	Expected laboratory set-up: 

Step 7 **<u>E</u>**xplaining the Observations **(E)**	10	Each member of the group is expected to write out their explanation for their observation on pieces of papers supplied them. They are to compare individual explanations and collectively brainstorm to come out with group explanations to observations. explanations to their observations are to be written down on the PEOE worksheet supplied to them by the recorder are those agreed upon by the entire group Goes round various groups to supervise the activities. (While students are writing, you might stroll around so as to prepare yourself for the discussion that will follow). Then, asks each group to present their PEOE worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the PEOE worksheet contains highlights of the predictions-explanations-observations-explanations for each group). After this has been done, teacher might discuss with the class which observation and explanations or reasons they now think are best. At this stage, teacher then engages the students to correlate their prediction with their observation so as to reconstruct their thinking and also reconcile any	Students spread out their individually written explanation to their observations on a flat surface (desk), where it can easily be read. Have a look at each other's explanations, and make quick comments. Then, the recorder for the group write down the explanation for their observation(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet. Students to share their PEOE worksheet containing their predictions, explanation for their predictions, observations and explanations for their observation in full-class discussion Team leaders or selected group representatives makes their respective presentations in full class discussion At this stage, students are expected to compare their prediction and observation in order to reconcile any conflict between their predictions and observations in a brief full class discussion.

		conflict between their predictions and observations. Ask the students to disengage from their groupings	Students move to their respective sits
Total	**75**		

Summary: (5 minutes)

Teacher summarizes the lesson thus;

Ethene can be prepared by the cracking of petroleum (ethene is a bye product of petroleum). Teacher also emphasize that ethene is extremely important in the manufacture of plastic. All plastics are in some way related to alkenes and it is also used as fuel and illuminant.

Assignment:

Teacher gives the students take home assignment due for submission the next class

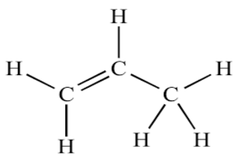
i. What is the melting and boiling points of tran-but-2-ene?

ii. Draw the structure of propene

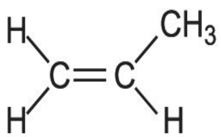
Expected answer to assignment question:

i. Tran-but-2-ene has a melting and boiling points -139^{0}C and 1^{0}C respectively

ii.



Or



PEOE WORKSHEET FOR ALKENE

Group________________________ Date________________________

Predict
(What do you think will happen?)

1. If you mix ethanol, glass wool and aluminum oxide together in a boiling tube, what do you think will happen? There will be no reaction yet until it is heated
2. What do you think the equation for the reaction would be?

$$CH_3CH_2OH \xrightarrow{Al_2O_3} CH_2{=}CH_2 + H_2O$$

3. If you light the bunsen burner and adjust it to a blue flame and heat the aluminum oxide, ethanol will produce an unknown gas, what do you think has happened to ethanol? ethanol has been dehydrated
4. If lime water is added to the unknown gas, what do you think will happen? Lime water will likely turn milky
5. If bromine is added to the unknown gas in another test tube, what do you think will happen? The brown bromine water may turn to colourless
6. What do you think the name of the gas would be? Is likely to be ethene

Explain
(Why do you think that will happen)

1. Because it requires heat for the water of ethanol to dehydrate
2. The gas would likely burns in air to produce carbon dioxide and it is also insoluble which produce a milky white precipitate.
3. Ethene will turn brown bromine water colourless as it reacts with the double bond unlike in alkanes.

Observe
What actually happened?

Test	Observation	Inference
Unknown gas + lime water + Heat (combustion)	The gas burned with a luminous flame and limewater turned milky and carbon dioxide was also formed	The unknown gas produced is ethene
Unknown gas + bromine	The brown colour of the bromine water turned to colourless	The gas produce is ethene
Addition of $KMnO_4$ to the unknown gas	The purple colour of the permanganate solution turned to colourless	Present of ethene

Explain
(Why did that happen?)

The gas insoluble which produce a milky white precipitate.

The unknown gas turns brown bromine water colourless as it reacts with the double bond.

Fig 8: Expected PEOE worksheet for Alkene

LESSON 3: **FOR EXPERIMENTAL GROUP 1 (PREDICT-EXPLAIN-OBSERVE-EXPLAIN)**

School:	As Applicable
Subject:	Chemistry (Organic Chemistry)
Specific Topic:	Alkynes
Class:	SS II
Number in class:	As Applicable
Average Age:	16 Years
Sex:	Mixed
Time:	80 minutes
Date:	As Applicable

Behavioural objectives: By the end of the lesson, students should be able to:

1. define the term alkynes;
2. write general formula of alkynes;
3. identify at least two sources of alkynes;
4. mention at least four physical properties of some alkynes;
5. draw the structure of ethyne accurately;
6. clearly describe the chemical properties of ethyne;
7. correctly carryout the laboratory preparation of ethyne; and
8. mention at least five uses of ethyne.

Instructional Materials: Calcium dicarbide, calcium oxide, bunsen burner, beaker, and PEOE worksheet.

Previous knowledge: Students have studied alkenes

Lesson Presentation

Content Development	Time (mins)	Teacher's activities	Students' activities
Step 1 Introduction/ Checking Previous Knowledge	5	Arouses students' interest and motivates them to learn. Tell students the objectives of the lesson. Probes into students' prior knowledge through questions such as: what are alkenes? What are alkynes? Makes known to the students the teaching technique and its demand on them Explains that the simplest member of alkynes family is ethyne (C_2H_2) and other members are propyne (C_3H_4), butyne (C_4H_6), pentyne (C_5H_8), hexyne (C_6H_{10}), heptyne (C_7H_{12}), and so on.	Answer the questions verbally. They are encouraged to write down their both wrong and right ideas. (Two or three students say their ideas for class to correct. They are encouraged to write down or take note of the corrected ideas) Expected answers: Alkenes an unsaturated hydrocarbon that contains at least one carbon-carbon double bond with general molecular formula C_nH_{2n} and functional group of C=C and it prefix is "-ene" Alkynes an unsaturated hydrocarbon that contains at least one carbon-carbon triple bond with general molecular formula C_nH_{2n-2} and functional group of C=C and it prefix is "-yne". Jot down some points as the teacher speaks. May ask questions for clarification.

Step 2 Grouping/ Elicitation of Students' ideas	15	Divides students into groups of 4-7; asks them to assume the role of captain, recorder, time-keeper and so on. Elicits ideas from the students. Asks the students to mention the sources of alkynes they know? Asks the students to draw the structure of ethyne Asks students to mention some physical properties of ethyne they know?	Move into different groups and assume different roles as agreed by members. Give responses to the questions based on prior knowledge. Expected answers: i. Crude oil and natural gas: small amount of alkynes are in crude oil and natural gas ii. Alkynes are also found in nature in plants and in some animals possess physiological functions Answer the question by drawing it on pieces of papers. Expected answer: The structure of ethyne is as follows: H ---C ≡C---H Answer the question verbally. They are encouraged to write down the right ideas. Expected answers: i. Ethyne is a colourless gas with a characteristic sweet smell when pure ii. It is lighter than air iii. Ethyne has faint garlic odour iv. Ethyne is slightly soluble in water

v. Ethyne is completely soluble in organic solvents.

vi. It has a melting point of -81°C and a boiling point of -84°C.

vii. It is unstable and may explode on compression to a liquid.

Asks the students to mention some uses of ethyne they know?

Expected answers:

i. Ethyne is useful for artificial ripening and preservation of fruits.

ii. It is useful in acetylene lamps to generate light.

iii. Ethyne is used to prepare various organic compounds

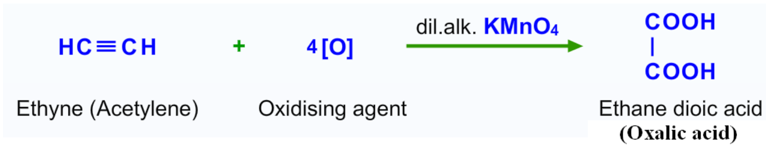
iv. It is useful to manufacture important organic compounds like acetic acid, acetaldehyde, ethyl alcohol and polymers

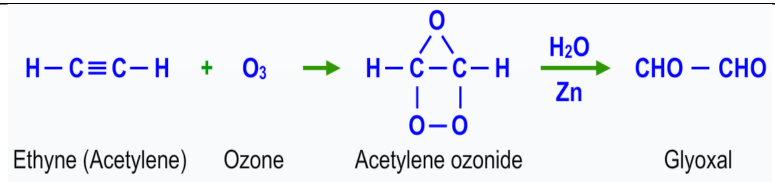
Briefly outlines the physical properties of the first few members of the alkyne listing the formula, boiling point, melting point and density as follows:

Name	Formula	Boiling Point	Melting point	Density
Ethyne	C_2H_2	-83°C	-183	Gas
Propyne	C_3H_4	-23 °C	-182	Gas
Butyne	C_4H_6	9 °C	-188	Gas
Pentyne	C_5H_8	27 °C	-138	Gas
Hexyne	C_6H_{10}	40 °C	-130	0.626

Listen to teacher's explanation and they are asked to increase their list of fact and concepts on alkynes as the lesson progresses as well as write out responses to the questions asked by the teacher.

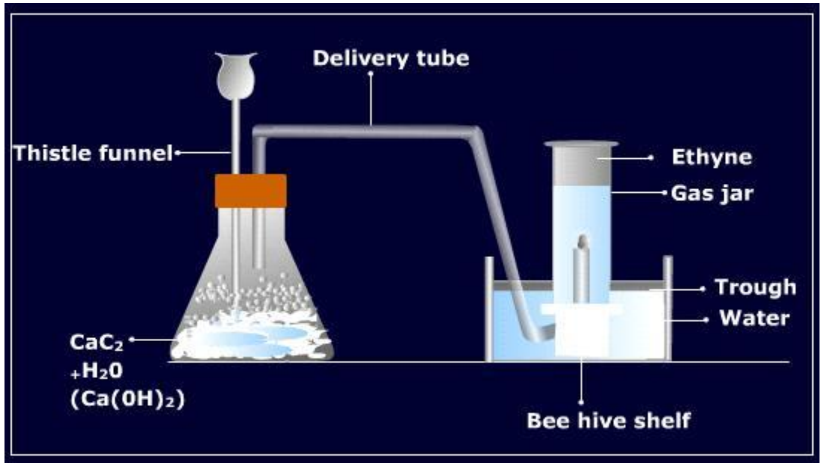
May ask questions for clarification.

		Describe the chemical properties of ethyne as follows: (i). Combustion: Ethyne burns in air with sooty flame and gives carbon dioxide, water and heat. $2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$ + heat (ii) Addition of hydrogen: Ethyne on addition with hydrogen forms initially ethene and finally forms ethane. $CH{\equiv}CH + H_2 \rightarrow CH_2{=}CH_2 + H_2 \rightarrow CH_3{-}CH_3$ (iii) Reaction with halogens: Ethyne reacts with halogen acids to form 1,2-Tetra halo ethanes. $CH{\equiv}CH + 2X_2 \rightarrow CHX_2{-}CHX_2$ (iv) Oxidation of ethyne: Ethyne undergoes oxidation or combustion reactions. Ethyne is oxidized to form Oxalic acid in the presence of dilute $KMnO_4$  . Ozonolysis: Ethyne reacts with ozone to produce acetylene ozonide which further hydrolysed in presence of Zinc to form Glyoxal	

			
Step 3 Introducing the Experiment	5	Introduces the experiment thus; the purpose of the experiment that will be carry out later during this lesson is to prepare sample of a member alkynes by using the action of water on calcium carbide and then to perform various tests on the product obtained to examine it properties.	Listen to the teacher and jot down some points as the teacher speaks, and asks questions for clarification.
Step 4 **P**redict **(P)**	10	At this step, before doing the experiment, the teacher asks the students to predict the answers to some questions based on the earlier introduced experiment (noting that the answers to the questions can be addressed through the experiment that follows in step 6). Asks students to predict answers to questions such as; 1. If you place pieces of calcium carbide in a flash, then add few drop water until it react to produce an unknown gas, what do you think has happened to calcium carbide? 2. What do you think the equation for the reaction would be? 3. If you collect 3 test tube of the gas, then you ignite, add bromine water, add $KMnO_4$, respectively to each of the 3	Captain directs discussion based on questions and the directives given by the teacher to guide their actions. Students spread out their individually written predictions on a flat surface (desk), where it can easily be read. Have a look at each other's predictions, and make quick comments. Then, the recorder for the group or whoever is assigned, write down their prediction(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet

		test tube containing the unknown gas, what do you think will happen? 4. What do you think the name of the gas would be? Each member of the group is expected to write out their prediction on pieces of papers supplied to them. They are to compare individual answers and collectively brainstorm to come out with group ideas on all questions raised thus far. Predictions are to be written down on the PEOE worksheet supplied to them by the recorder are those agreed upon by the entire group Goes round various groups to supervise the activities.	
Step 5: **E**xplaining the Predictions **(E)**	10	Each member of the group is expected to write out their explanation for their prediction on pieces of papers supplied to them. They are to compare individual explanations and collectively brainstorm to come out with group explanations to predictions. explanations to predictions are to be written down on the PEOE worksheet supplied to them by the recorder are those agreed upon by the entire group Goes round various groups to supervise the activities. (While students are writing, you might stroll around so as to prepare yourself for the discussion that will follow).	Students spread out their individually written explanation to their predictions on a flat surface (desk), where it can easily be read. Have a look at each other's predictions, and make quick comments. Then, the recorder for the group write down the explanation for their prediction(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet Students to share their PEOE worksheet containing both their predictions and the explanation for their predictions in full-class discussion

		Asks each group to present their PEOE worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the PEOE worksheet only contains highlight of the predictions and explanations for each group). After this has been done, the teacher might invite the class to discuss which predictions and reasons or explanations they now think are best.	Team leaders or selected group representatives makes their respective presentations in full class discussion (When students reconsider their reasons, some may begin to change their minds and reconstruct their thinking. Immediately prior to the experiment, it's often fun and illuminating to have a straw vote about the outcome).
Step 6 **O**bserve **(O)**	20	Instructs the students to carry out the following laboratory activities for the preparation of X (ethyne) using the action of water on calcium carbide as follows: 1. Place 2-3 pieces of calcium carbide (reagent A) in a buchner flash 2. Seal the flash with a stopper with a dropping funnel and a gas-delivery tube. The gas-delivery tube should look upwards trough water. 3. Add water from the thistle or dropping funnel, a few drops at a time, until all the calcium carbide has reacted 4. Note that during this reaction, an unknown gas will be produce. 5. Collect 3 test tube of the gas and put a stopper on each tube when it is filled.	Carry out the activities as directed by the teacher. They follow the instructions step by step and record their observation and inference and write down the chemical equation representing the preparation Spread out their individually written observations on a flat surface (desk), where it can easily be read. Have a look at each other's observations, and make quick comments. Then, the recorder for the group or whoever is assigned, write down their observation(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet

		6. When the test tubes have all been filled. 7. Test each the unknown gas collected through combustion (ignition), addition of bromine water, and addition of acidified $KMnO_4$ respectively. 8. Then, record your observation and inference	Expected laboratory set-up: 
Step 7 **E**xplaining the Observations **(E)**	10	Each member of the group is expected to write out their explanation for their observation on pieces of papers supplied them. They are to compare individual explanations and collectively brainstorm to come out with group explanations to observations. explanations to their observations are to be written down on the PEOE worksheet supplied to them by the recorder are those agreed upon by the entire group Goes round various groups to supervise the activities. (While students are writing, you might stroll around so as to prepare yourself for the discussion that will follow). Then, asks each group to present their PEOE worksheet in	Students spread out their individually written explanation to their observations on a flat surface (desk), where it can easily be read. Have a look at each other's explanations, and make quick comments. Then, the recorder for the group write down the explanation for their observation(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet. Share their PEOE worksheet containing their predictions, explanation for their predictions, observations and explanations for their observation in full-class discussion Team leaders or selected group representatives makes their respective presentations in full class discussion

		full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the PEOE worksheet contains highlights of the predictions-explanations-observations-explanations for each group). After this has been done, teacher might invite the class to discuss which observation and explanations or reasons they now think are best. At this stage, teacher then engages the students to correlate their prediction with their observation so as to reconstruct their thinking and also reconcile any conflict between their predictions and observations. Ask the students to disengage from their groupings	At this stage, students are expected to compare their prediction and observation in order to reconcile any conflict between their predictions and observations in a brief full class discussion. Students move to their respective sits
Total	**75**		

Summary: (5 minutes)

Teacher summarizes the lesson thus;

Alkynes are generally non polar molecules with little solubility in polar solvents, such as water. Solubility in non polar solvents, such as ether and acetone, is extensive. Like the alkanes and alkenes, alkynes of four or fewer carbon atoms tend to be gases. Substituted alkynes have small dipole moments due to difference in electronegativity between the triple-bonded carbon atoms, which are sp hybridized, and the single-bonded carbon atoms, which are Sp^3 hybridized. The sp-hybridized carbon atoms, which possesses more ‘s’ character than the sp3 hybridized carbon atom, is more electronegative in character.

Assignment:

Teacher gives the students take home assignment due for submission the next class

i. mention 4 uses of alkynes

ii. Draw the structure of propyne

Expected answer to assignment question:

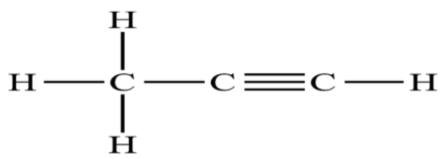
i. Alkyne is useful for artificial ripening and preservation of fruits.

ii. It is useful in acetylene lamps to generate light.

iii. Alkyne is used to prepare various organic compounds

iv. Alkyne is useful to manufacture important organic compounds like acetic acid and so on

or



<table>
<tr><td rowspan="2"></td><td>PEOE WORKSHEET FOR ALKYNE</td></tr>
<tr><td>Group_______________________ Date______________________</td></tr>
<tr><td><u>P</u>redict
(What do you think will happen?)
</td><td>1. If you place pieces of calcium carbide in a flash, then add few drop water until it react to produce an unknown gas, what do you think has happened to calcium carbide? <u>calcium carbide has undergoes hydration</u>
2. What do you think the equation for the reaction would be?
<u>$CaC_2+2H_20 \longrightarrow C_2H_2 + Ca_2(OH)_2$</u>
3. If you collect 3 test tube of the gas, then you ignite, add bromine water, add $KMnO_4$ $_r$ respectively to each of the 3 test tube containing the unknown gas, what do you think will happen?
(a) <u>the unknown gas will burn with smoky flame</u>
(b) <u>the bromine water will turn from yellowish colour to colourless</u>
(c) <u>$KMnO_4$ will likely turn from yellowish colour to colourless</u>
4. What do you think the name of the gas would be? <u>Ethyne</u></td></tr>
<tr><td><u>E</u>xplain
(Why do you think that will happen)
</td><td>Unsaturated hydrocarbons like ethyne undergoes incomplete combustion, the gas would likely burn to produce smoky flame due the presence of carbon-carbon triple bond.
The gas is likely to turn bromine water and $KMnO_4$ respectively colourless as it reacts with the triple bond</td></tr>
<tr><td><u>O</u>bserve
What actually happened?
</td><td><table>
<tr><td>Test</td><td>Observation</td><td>Inference</td></tr>
<tr><td>Unknown gas+ ignition</td><td>Burns with smoky flame</td><td>Ethyne is produced</td></tr>
<tr><td>Unknown gas + bromine water</td><td>Turn from yellowish colour to colourless</td><td>The unknown gas produced is ethyne</td></tr>
<tr><td>Unknown gas + $KMnO_4$</td><td>Turn from yellowish colour to colourless</td><td>The unknown gas produced is ethyne</td></tr>
</table></td></tr>
<tr><td><u>E</u>xplain
(Why did that happen?)
</td><td>Ethyne undergoes incomplete combustion, the gas burn to produce smoky flame due the presence of carbon-carbon triple bond.
The unknown gas turn bromine water and $KMnO_4$ respectively colourless as it reacts with the carbon-carbon triple bond</td></tr>
</table>

Fig 9: Expected PEOE worksheet for Alkyne

LESSON 4 **FOR EXPERIMENTAL GROUP 1 (PREDICT-EXPLAIN-OBSERVE-EXPLAIN)**

School:	As Applicable
Subject:	Chemistry (Organic Chemistry)
Specific Topic:	Alkanols
Class:	SS II
Number in class:	As Applicable
Average Age:	16 Years
Sex:	Mixed
Time:	80 minutes
Date:	As Applicable

Behavioural objectives: By the end of the lesson, students should be able to:

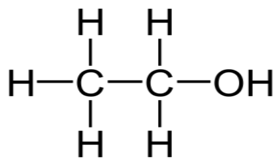
1. define the term alkanol;
2. write general formula of alkanols;
3. mention the two classes of alkanols;
4. mention at least four physical properties of some alkanols;
5. draw the structure of ethanol accurately;
6. clearly describe at least three chemical properties of ethanol;
7. carefully carryout the laboratory preparation of ethanol; and
8. mention at least four uses of alkanols.

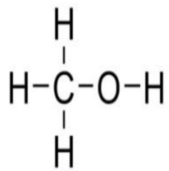
Instructional Materials: Distilled water, ethene, H_2SO_4, test-tube rack, bunsen burner, test-tube holder, beaker, PEOE worksheet

Previous knowledge: Students have studied alkynes.

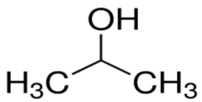
Lesson Presentation

Content Development	Time (mins)	Teacher's activities	Students' activities
Step 1 Introduction/ Checking Previous Knowledge	5	Arouses students' interest and motivates them to learn. Tell students the objectives of the lesson. Probes into students' prior knowledge through questions such as: What are alkynes? What are alkanols?	Answer the questions verbally. They are encouraged to write down their both wrong and right ideas. (Two or three students say their ideas for class to correct. They are encouraged to write down or take note of the corrected ideas) Expected answers: Alkynes an unsaturated hydrocarbon that contains at least one carbon-carbon triple bond with general molecular formula CnH_2n-_2 and functional group of C=C and it prefix is "-yne" Alkanol are characterized by one or more hydroxyl groups attached to a carbon atom of an alkyl group with general molecular formula $CnH_{2n+1}OH$ and functional group of OH and it prefix is "-nol"
		Makes known to the students the teaching technique and its demand on them Explains that the simpler members of alkanol family is methanol (CH_3OH), ethanol (C_2H_5OH) and other members are propanol (C_3 H_7OH), butanol (C_4H_9OH), Pentanol ($C_5H_{11}OH$), Hexanol ($C_6H_{13}OH$), Heptanol ($C_7H_{15}OH$).	Jot down some points as the teacher speaks. May ask questions for clarification.

Step 2 Grouping/ Elicitation of Students' ideas	15	Divides students into groups of 4-7; asks them to assume the role of captain, recorder, time-keeper and so on. Elicits ideas from the students. Asks the students to mention the sources of alkanol they know? Asks students to draw the structure of ethanol (C_2H_5OH). Asks students the mention the physical properties of ethanol they know?	Move into different groups and assume different roles as agreed by members. Give responses to the questions based on prior knowledge. Expected answers The common natural sources of alcohol are often isolated from volatile oils of plants, and in most animal tissues (and abundant in egg yolks), and also extracted from fish liver oils. Answer the question by drawing it on pieces of papers. Expected answer:  Ethanol Answer the question verbally. They are encouraged to write down the right ideas. Expected answers: i. Ethanol is flammable, colourless liquid. ii. It has a boiling point of 78.5°C and a melting point of -114.5°C iii. It has a pleasant sharp smell iv. It is highly soluble in water and organic solvents, but poor

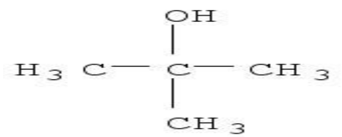
		Asks the students the uses of ethanol they know?	soluble in fat and oils. Expected answers: i. Ethanol is a constituent of alcoholic beverages such as beer, wine, whisky and other liquors. ii. A mixture of ethanol and water has much lower freezing point than that of water. This mixture is known as antifreeze and is used in radiators of vehicles in cold country iii. It is also used as solvent for resins, fats, oils, fatty acid and hydrocarbon iv. Ethanol is used to sterilize wounds and syringes v. In the manufacturing of dyes, and drugs
		Briefly explains to students the classes of alkanol as primary alkanol, secondary alkanol and tertiary alkanol as follows: i. Primary alkanol: Is an alkanol which has one alkyl group on the carbon atom carrying the OH group  Methanol	Listen to teacher's explanation and they are asked to increase their list of fact and concepts on alkanol as the lesson progresses as well as write out responses to the questions asked by the teacher. May ask questions for clarification.

ii. Secondary alkanol: Is an alkanol which has two alkyl group on the carbon atom carrying the OH group



2-propanol

iii. Tertiary alkanol: Is an alkanol which has three alkyl group on the carbon atom carrying the OH group



2-methylpropan-2-ol

Briefly further outlines the physical properties of alkanol listing the name, formula, class, boiling point, and melting point as follows:

Name	Molecular Formula	Melting point	Melting point	Solubility
Methanol	CH_3OH	-97^oC	65 ^oC	Miscible
Ethanol	C_2H_5OH	-117^oC	78^oC	Miscible
Propan-1-ol	C_3H_7OH	-127^oC	97 ^oC	Miscible
Butan-1-ol	C_4H_9OH	-90^oC	118 ^oC	8.0g
Pentan-1-ol	$C_5H_{11}OH$	-79^oC	138 ^oC	2.7g

Describe chemical properties of ethanol as follows:

i. Reaction with sodium: Alcohol are very weak acidic. Ethanol reacts with sodium metal to form sodium ethoxide and hydrogen gas

$$\underset{\text{Sodium metal}}{2Na} + \underset{\text{Ethanol}}{2C_2H_5OH} \longrightarrow \underset{\text{Sodium ethoxide}}{2C_2H_5ONa} + \underset{\text{Hydrogen}}{H_2}$$

ii. With alkanoic acid: Ethanol reacts with ethanoic acid in the presence of concentrated tetraoxosulphate (VI) acid to form ethyl ethanoate and water. This process is often referred to as esterification.

$$\underset{\text{Ethanoic acid}}{CH_3COOH(\ell)} + \underset{\text{Ethanol}}{C_2H_5OH(\ell)} \xrightarrow{\text{Conc. } H_2SO_4} \underset{\text{Ethyl Ethanoate}}{CH_3COOC_2H_5(\ell)} + H_2O(\ell)$$

iii. Dehydration: Ethanol when heated with conc. H_2SO_4 at 443K or Al_2O_3 undergoes dehydration

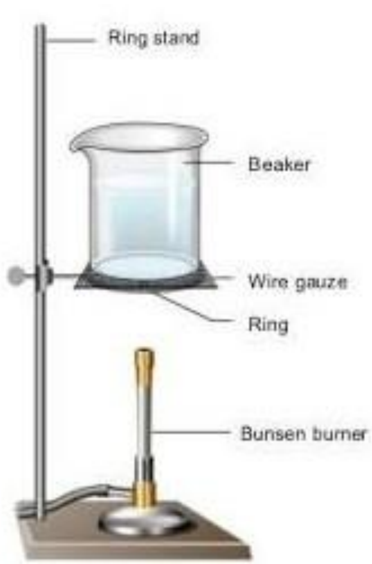
$$\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow[443\text{ K}]{H_2SO_4} \underset{\text{Ethene}}{CH_2{=}CH_2} + H_2O$$

iv. Oxidation with acidified potassium dichromate: Ethanol is oxidized to ethanoic acid with the help of acidified $K_2Cr_2O_7$

Step 3 Introducing the Experiment	5	Introduces the experiment thus; the purpose of the experiment that will be carry out later during this lesson is to prepare sample of a member alkanols by using the action of water on ethene and then to perform various tests on the product obtained to examine it properties.	Listen to the teacher and jot down some points as the teacher speaks, and asks questions for clarification.
Step 4 <u>**P**</u>redict **(P)**	10	At this step, before doing the experiment, the teacher asks the students to predict the answers to some questions based on the earlier introduced experiment (noting that the answers to the questions can be addressed through the experiment that follows in step 6). Asks students to predict answers to questions such as; 1. If you mix ethene, 10grams of water, and 2 grams of dilute sulfuric acid (H_2SO_4) together in a beaker, what do you think will happen? 2. If you slightly heat the mixture on a bunsen burner, it will react to produce an unknown liquid, what do you think has happened to ethene? 3. What do you think the equation for the reaction would be? 4. If you collect 1 test tube of the unknown liquid, then you perceive the odour, how do you think it odour	Captain directs discussion based on questions and the directives given by the teacher to guide their actions. Spread out their individually written predictions on a flat surface (desk), where it can easily be read. Have a look at each other's predictions, and make quick comments. Then, the recorder for the group or whoever is assigned, write down their prediction(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet

		would be? 5. If you collect 2 test tube of the unknown liquid, then you ignite, add potassium dichromate ($K_2Cr_2O_7$) respectively to each of the 2 test tube containing the unknown liquid, what do you think will happen? 6. What do you think the name of the unknown liquid would be? Each member of the group is expected to write out their prediction on pieces of papers supplied them. They are to compare individual answers and collectively brainstorm to come out with group ideas on all questions raised thus far. Predictions are to be written down on the PEOE worksheet supplied to them by the recorder are those agreed upon by the entire group Goes round various groups to supervise the activities.	
Step 5: **E**xplaining the Predictions **(E)**	10	Instruct each member of the group to write out their explanation for their prediction on pieces of papers supplied them. They are to compare individual explanations and collectively brainstorm to come out with group explanations to predictions. explanations to predictions are to be written down on the PEOE worksheet	Spread out their individually written explanation to their predictions on a flat surface (desk), where it can easily be read. Have a look at each other's predictions, and make quick comments. Then, the recorder for the group write down the explanation for their prediction(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet

		supplied to them by the recorder are those agreed upon by the entire group Goes round various groups to supervise the activities. (While students are writing, you might stroll around so as to prepare yourself for the discussion that will follow). Asks each group to present their PEOE worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the PEOE worksheet only contains highlight of the predictions and explanations for each group). After this has been done, the teacher might discuss with the class which predictions and reasons or explanations they now think are best.	Students to share their PEOE worksheet containing both their predictions and the explanation for their predictions in full-class discussion Team leaders or selected group representatives makes their respective presentations in full class discussion (When students reconsider their reasons, some may begin to change their minds and reconstruct their thinking. Immediately prior to the experiment, it's often fun and illuminating to have a straw vote about the outcome).
Step 6 **<u>O</u>**bserve **(O)**	20	Instructs students to carry out the laboratory activities for the preparation of X (ethanol) by hydration of ethene as follows: 1. Pour 5gram of ethene (reagent A) into a buchner beaker 2. Add 10gram of water (stream) to the beaker containing the ethene and mix thoroughly. 3. Add 2grams of dilute sulfuric acid (H_2SO_4) (reagent B) to the beaker containing mixture of ethene and water 4. Heat the mixture slightly, then record your observation	Carry out the activities as directed by the teacher. They follow the instructions step by step and record their observation and inference and write down the chemical equation representing the preparation Students spread out their individually written observations on a flat surface (desk), where it can easily be read. Have a look at each other's observations, and make quick comments. Then, the recorder for the group or whoever is assigned, write down their observation(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet

		Expected observation: "A colourless unknown liquid is formed" 5. Divide the "X" unknown liquid into three portions in test tube 6. Test the "X" liquid using odour, combustion, and potassium dichromate ($K_2Cr_2O_7$) respectively. 7. Then record your observation and inference and also write the chemical equation for the reaction	Expected Laboratory set-up: 
Step 7 **E**xplaining the Observations **(E)**	10	Each member of the group is expected to write out their explanation for their observation on pieces of papers supplied them. They are to compare individual explanations and collectively brainstorm to come out with group explanations to observations. explanations to their observations are to be written down on the PEOE worksheet supplied to them by the recorder are those agreed upon by the entire group Goes round various groups to supervise the activities. (While students are writing, you might stroll around so as	Students spread out their individually written explanation to their observations on a flat surface (desk), where it can easily be read. Have a look at each other's explanations, and make quick comments. Then, the recorder for the group write down the explanation for their observation(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet. Share their PEOE worksheet containing their predictions, explanation for their predictions, observations and explanations for their observation in full-class discussion

		to prepare yourself for the discussion that will follow). Asks each group to present their PEOE worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the PEOE worksheet contains highlights of the predictions-explanations-observations-explanations for each group). After this has been done, teacher might invite the class to discuss which observation and explanations or reasons they now think are best. At this stage, teacher then engages the students to correlate their prediction with their observation so as to reconstruct their thinking and also reconcile any conflict between their predictions and observations. Ask the students to disengage from their groupings	Team leaders or selected group representatives makes their respective presentations in full class discussion At this stage, students are expected to compare their prediction and observation in order to reconcile any conflict between their predictions and observations in a brief full class discussion Students move to their respective sits
Total	**75**		

Summary: (5 minutes)

Teacher summarizes the lesson thus;

The industrial and local production of ethanol is through fermentation process. It involves the production of ethanol by the enzymatic hydrolysis of complex molecule (polysaccharide) in the absence of air. The fermented liquor contains up of to 10% ethanol and is used in drinks.

Assignment:

Teacher gives the students take home assignment due for submission the next class

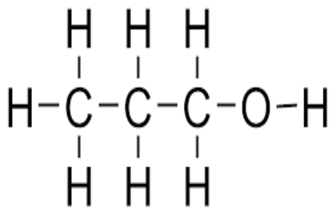
i. Mention three uses of alkanols

ii. draw the structure of propanol

Expected assignment answers:

1. It is also used as solvent for resins, fats, oils, fatty acid and hydrocarbon
2. Ethanol is used to sterilize wounds and syringes
3. In the manufacturing of dyes, drugs and detergents and so on

ii.



Propanol

	PEOE WORKSHEET FOR ALKANOL
	Group________________________ Date_______________________

Predict
(What do you think will happen?)

If you mix ethene, and 10 grams of water together in a beaker, what do you think will happen? There will be no reaction

2. If you add dilute H_2SO_4 to the mixture and slightly heat it on a bunsen burner, it will react to produce an unknown liquid, what do you think has happened to ethene? Ethene has undergoes hydration

3. What do you think the equation for the reaction would be?

$$C_2H_4\,(g) + H_2O\,(g) \xrightarrow{\text{Dilute } H_2SO_4 \text{ Catalyst}} C_2H_5OH\,(g)$$

4. If you collect 1 test tube of the unknown liquid, then you perceive the odour, how do you think it odour would be? pleasant odour

5. If you collect 2 test tube of the unknown liquid, then you ignite, add potassium dichromate ($K_2Cr_2O_7$) respectively to each of the 2 test tube containing the unknown liquid, what do you think will happen?

(a) The unknown liquid will likely burn with a blue fire

(b) Orange colour of $K_2Cr_2O_7$ will likely turn to green

6. What do you think the name of the unknown liquid would be? The liquid is likely to be ethanol

Explain
(Why do you think that will happen)

There is need for a catalyst in order to attach to very electronegative oxygen atom presence for reaction to take place.
Complete combustion produces the typical blue flame caused by exited carbon dioxide
Because oxidation would likely occur, then the orange solution containing dichromate (VI) ions is reduced to a green solution containing chromium (III) ions.

Observe
What actually happened?

Test	Observation	Inference
Unknown liquid+ odour	It has pleasant odour reminiscent of whiskey	The liquid is ethanol
Unknown liquid + ignition	The unknown liquid burn with a blue fire	The liquid is ethanol
$K_2Cr_2O_7$ + Unknown liquid	The unknown liquid change yellowish colour of $K_2Cr_2O_7$ to green	The unknown liquid is ethanol

Explain
(Why did that happen?)

Oxidation occurs, and then the orange solution containing dichromate (VI) ions is reduced to a green solution containing chromium (III) ions.

Fig 10: Expected PEOE worksheet for Alkanols

LESSON 5	**FOR EXPERIMENTAL GROUP 1 (PREDICT-EXPLAIN-OBSERVE-EXPLAIN)**
School:	As Applicable
Subject:	Chemistry (Organic Chemistry)
Specific Topic:	Alkanoic Acids (Carboxylic Acids)
Class:	SS II
Number in Class:	As Applicable
Average Age:	16 Years
Sex:	Mixed
Time:	80 minutes
Date:	As Applicable

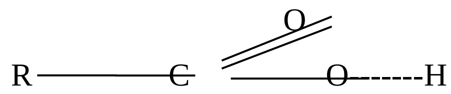
Behavioural objectives: By the end of the lesson, students should be able to;

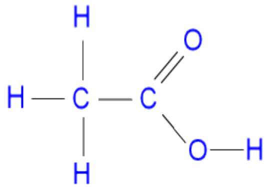
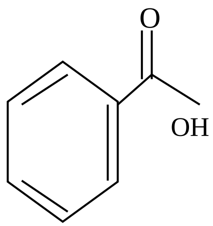
1. define the term alkanoic acids;
2. write general formula of alkanoic acids;
3. mention the classes of alkanoic acids with examples;
4. state at least three physical properties of some of the alkanoic acids;
5. draw the structure of ethanoic and phenylmethanoic (benzoic) acids accurately;
6. describe at least three chemical properties of alkanoic acid;
7. carefully carry out the laboratory preparation of ethanoic acid; and
8. mention at least four uses of alkanoic acids.

Instructional Materials: Ethanol, sodium dichromate solution, sulfuric acid, pear shaped flask hydrogen chloride, anti-bumping granules, hydrogen tetraoxosulphate (iv), water and PEOE worksheet

Previous knowledge: The students have studied alkanol.

Lesson Presentation

Content Development	Time (mins)	Teacher's activities	Students' activities
Step 1 Introduction/ Checking Previous Knowledge	5	Arouses students' interest and motivates them to learn. Tell students the objectives of the lesson. Probes into students' prior knowledge through questions such as: what are alkanol? What are alkanoic acids? Make known to the students the teaching technique and its demand on them. Explains that alkanoic acids are classified into two namely: Aliphatic carboxylic acids and aromatic carboxylic acids. Ethanoic and phenylmethanoic (benzoic) acids are examples of Aliphatic carboxylic acids and aromatic carboxylic acids respectively.	Answer the questions verbally. They are encouraged to write down their right ideas. (Two or three students say their ideas for class to correct. They are encouraged to write down or take note of the corrected ideas) Expected answers: Alkanol are characterized by one or more hydroxyl groups attached to a carbon atom of an alkyl group with general with general molecular formula $C_nH_{2n+1}OH$ Alkanoic acids also known as organic or carboxylic acids, that contain the carboxyl group, -COOH, as their functional group with general molecular formula $CnH_{2}n+COOH$.  Jot down some points as the teacher speaks. May ask questions for clarification.

Step 2 Grouping/ Elicitation of Students' ideas	15	Divides students into groups of 4-7; asks them to assume the role of captain, recorder, time-keeper and so on. Elicits ideas from the students. Ask students to draw the structure of ethanoic and phenylmethanoic (benzoic) acids as examples aliphatic and aromatic carboxylic acids respectively Asks students to mentions the uses of ethanoic acid they know?	Move into different groups and assume different roles as agreed by members. Give responses to the questions based on prior knowledge. Answer the question by drawing it on pieces of papers. Expected answers:  Ethanoic acid  Benzoic acid Expected answers: Ethanoic acid as an example of aliphatic carboxylic acid is used as follows: i. It is used as aspirin. ii. For making dyes in varnishes and iii. Used in the filter tips of cigarettes.

		Asks students to mentions the uses of benzoic acid they know?	Expected answers: Benzoic acid as an example of aromatic carboxylic acid is used as follows: i. Benzoic acid is widely used as a preservative ii. It is used in the manufacture of various cosmetics, dyes, plastics, and iii. It is also used in insect repellents. iv. Benzoic acid helps prevent infection caused by bacteria. v. It is used to season tobacco and to enhance perfume
		Briefly outlines the physical properties of the first few members of the alkanoic acids listing the molecular formula, structure, IUPAC name, common name, physical state, density, boiling and melting point and also discusses the chemical properties as follows;	Listen to teacher's explanation and they are asked to increase their list of fact and concepts on alkanoic acids as the lesson progresses as well as write out responses to the questions asked by the teacher. May ask questions for clarification.

Molecular formula	Structural formula	IUPAC name	Common name
CH_2O_2	HCOOH	Methanoic acid	Formic acid
$C_2H_4O_2$	HCOOH	Ethanoic acid	Acetic acid
$C_3H_6O_2$	CH_3COOH	Propanoic acid	Propanoic acid
$C_7H_6O_2$	C_6H_5COOH	Benzoic acid	phenylmethanoic acid

Properties		Boiling point	Melting point	Density g/cm^3
Name	Physical state			
Methanoic acid	Colourless Liquid	101^oC	8^oC	1.226
Ethanoic acid	Colourless Liquid	118^oC	17^oC	1.049
Propanoic acid	Colourless Liquid	141^oC	-22^oC	0.992
Benzoic acid	Colourless Crystallin e solid	164^oC	122^oC	1.2659

Briefly explain the chemical properties of alkanoic acid as follows:

i. Acidic property: Carboxylic acids are weak acids and their carboxylic anions are strong conjugate bases are slightly alkaline due to the hydrolysis of carboxylate anion compared to other species, the order of acidity and basicity or corresponding conjugate bases are as follows:

(a) $2CH_3COOH + CaCO_3 \rightarrow (CH_2COO)_2 + H_2O + CO_2$

(b) $2CH_3COOH + Mg \rightarrow (CH_3COO)_2 + H_2 (g)$

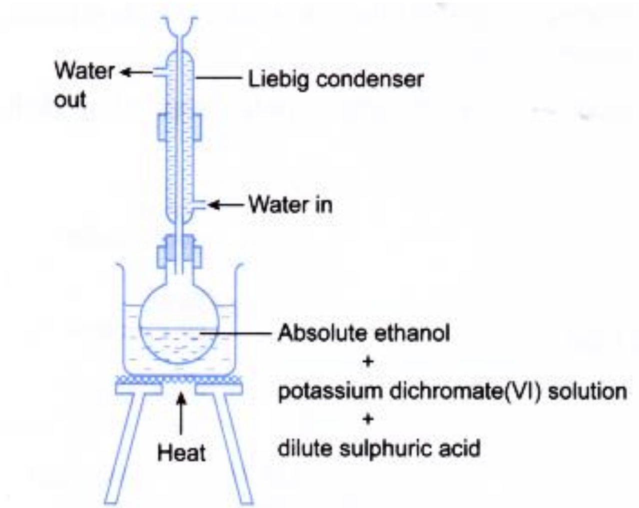
(c) CH3COOH+ NaOH $\rightarrow CH_3COONa + H_2O$

ii. Ester formation: Carboxylic acids are esterified with alcohols or phenols in the presence of a mineral acid such as concentrated H_2SO_4 or HCl gas as a catalyst

		$$RCOOH + R'OH \underset{}{\overset{H^+}{\rightleftharpoons}} RCOOR' + H_2O$$ This reaction is reversible and the same catalyst, hydrogen ion, that catalyzes the forward reaction i.e. esterification necessarily catalyzes the reverse reaction i.e. hydrolysis.	
Step 3 Introducing the Experiment	5	Introduces the experiment thus; the purpose of the experiment that will be carry out later during this lesson is to prepare sample of a member alkanoic acids by the oxidation of ethanol using sodium dichromate solution, sulfuric acid, and then to perform various tests on the product obtained to examine it properties.	Listen to the teacher and jot down some points as the teacher speaks, and asks questions for clarification.
Step 4 **P**redict **(P)**	10	At this step, before doing the experiment, the teacher asks the students to predict the answers to some questions based on the earlier introduced experiment (note that the answers to the questions can be addressed through the experiment that follows in step 6). Asks students to predict answers to questions such as; 1. If you mix 5 grams of sodium dichromate with 10cm^3 of dilute sulfuric acid and a solution of ethanol and deionised water together in a flask, what do you think will happen? 2. If you slightly heat the mixture on a bunsen burner, it will	Captain directs discussion based on questions and the directives given by the teacher to guide their actions. Spread out their individually written predictions on a flat surface (desk), where it can easily be read. Have a look at each other's predictions, and make quick comments. Then, the recorder for the group or whoever is assigned, write down their prediction(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet

		react to produce an unknown liquid, what do you think has happened to ethanol? 3. What do you think the equation for the reaction would be? 4. If you collect 1 test tube of the unknown liquid, then you perceive the odour, how do you think it odour would be? 5. If you collect 3 test tube of the unknown liquid, then you ignite, put indicator paper, magnesium, and sodium carbonate respectively to each of the 3 test tube containing the unknown liquid, what do you think will happen? 6. What do you think the name of the unknown liquid would be? Each member of the group is expected to write out their prediction on pieces of papers supplied them. They are to compare individual answers and collectively brainstorm to come out with group ideas on all questions raised thus far. Predictions are to be written down on the PEOE worksheet supplied to them by the recorder are those agreed upon by the entire group Goes round various groups to supervise the activities.	

Step 5: **<u>E</u>**xplaining the Predictions **(E)**	10	Instructs each member of the group to write out their explanation for their predictions on pieces of papers supplied to them. They are to compare individual explanations and collectively brainstorm to come out with group explanations to predictions. explanations to predictions are to be written down on the PEOE worksheet supplied to them by the recorder are those agreed upon by the entire group Goes round various groups to supervise the activities. (While students are writing, you might stroll around so as to prepare yourself for the discussion that will follow). Asks each group to present their PEOE worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the PEOE worksheet only contains highlight of the predictions and explanations for each group). After this has been done, the teacher might discuss with the class which predictions and reasons or explanations they now think are best. (When students reconsider their reasons, some may begin to change their minds and reconstruct their thinking).	Students spread out their individually written explanation to their predictions on a flat surface (desk), where it can easily be read. Have a look at each other's predictions, and make quick comments. Then, the recorder for the group write down the explanation for their prediction(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet Students to share their PEOE worksheet containing both their predictions and the explanation for their predictions in full-class discussion Team leaders or selected group representatives makes their respective presentations in full class discussion

Step 6 **<u>O</u>**bserve **(O)**	20	Instructs students to carry out the laboratory activities for the preparation of ethanoic acid by the oxidation of ethanol using sodium dichromate solution, sulfuric acid, pear shaped flask and so on as follows: 1. Put a few anti-bumping granules and $10cm^3$ of dilute sulfuric acid in the round bottomed or pear shaped flask. 2. In a fume cupboard, add in 9g of sodium dichromate and dissolve by careful swirling. 3. Use a small dry funnel to avoid crystals of dichromate being caught on the neck of the flask. 4. Slowly with swirling and cooling in an ice bath, add $6cm^3$ of concentrated sulfuric acid. 5. Mix $2cm^3$ of ethanol and $10cm^3$ of deionised water in the dropping funnel. Add the solution from the dropping funnel drop wise down the condenser, while swirling the contents of the flask and cooling it if necessary to prevent too vigorous a reaction. 6. Note: direct heating without water bath must not be used, as the boiling point of the mixture will eventually exceed 100^oC	Carry out the activities as directed by the teacher. They follow the instructions step by step and record their observation and inference and write down the chemical equation representing the preparation Students spread out their individually written observations on a flat surface (desk), where it can easily be read. Have a look at each other's observations, and make quick comments. Then, the recorder for the group or whoever is assigned, write down their observation(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet Expected laboratory set-up:  ***Figure*** *Laboratory preparation of ethanoic acid*

		7. Distill off about 15cm^3. This is aqueous unknown acid formed 8. Divide the distillate into four portions in test tubes 9. Test the aqueous unknown acid using odour, indicator paper, magnesium, sodium carbonate respectively. 10. Then record your observations and inference	
Step 7 **E**xplaining the Observation **(E)**	10	Each member of the group is expected to write out their explanation for their observation on pieces of papers supplied them. They are to compare individual explanations and collectively brainstorm to come out with group explanations to observations. explanations to their observations are to be written down on the PEOE worksheet supplied to them by the recorder are those agreed upon by the entire group Goes round various groups to supervise the activities. (While students are writing, you might stroll around so as to prepare yourself for the discussion that will follow). Teacher then, asks each group to present their PEOE worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the PEOE worksheet contains highlights of the predictions-	Students spread out their individually written explanation to their observations on a flat surface (desk), where it can easily be read. Have a look at each other's explanations, and make quick comments. Then, the recorder for the group write down the explanation for their observation(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet. Students to share their PEOE worksheet containing their predictions, explanation for their predictions, observations and explanations for their observation in full-class discussion Team leaders or selected group representatives makes their respective presentations in full class discussion

		explanations-observations-explanations for each group). After this has been done, teacher might invite the class to discuss which observation and explanations or reasons they now think are best. At this stage, teacher then engages the students to correlate their prediction with their observation so as to reconstruct their thinking and also reconcile any conflict between their predictions and observations. Ask the students to disengage from their groupings	At this stage, students are expected to compare their prediction and observation in order to reconcile any conflict between their predictions and observations in a brief full class discussion Students move to their respective sits.
Total	**75**		

Summary: (5 minutes)

Teacher summarizes the lesson thus;

Alkanoic acids or carboxylic acids are soluble in water. Carboxylic acids do not dimerise in water, but forms hydrogen bonds with water. Carboxylic acids are polar and due to the presence of the hydroxyl in the carboxyl group, they are able to form hydrogen bonds with water molecules. Smaller carboxylic acids (C1 to C5) are soluble in water, whereas larger carboxylic acids (C6 and above) are less soluble due to the increasing hydrophobic nature of the hydrocarbon chains.

Assignment:

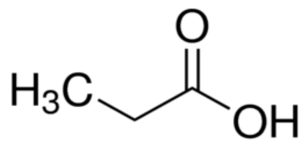
Teacher gives the students take home assignment due for submission the next class

i. Mention three uses of carboxylic acid
ii. Draw the structure of propanoic acid

Expected answers to assignment questions:

Uses of carboxylic acid among others are:

1. Carboxylic acids are used in manufacturing of soaps need higher fatty acids.
2. Carboxylic acids are used in food industry for the production of soft drinks and food products. For example, acetic acid is used in making vinegar.
3. Carboxylic acids are often used as a coagulant in the manufacturing of rubber.
4. Carboxylic acids used in making dye, perfumes and rayon.



<table>
<tr><td rowspan="2"></td><td>PEOE WORKSHEET FOR ALKANOIC ACID</td></tr>
<tr><td>Group_______________________ Date______________________</td></tr>
<tr><td>Predict
(What do you think will happen?)
</td><td>1. If you mix 5 grams of sodium dichromate with $10cm^3$ of dilute sulfuric acid and a solution of ethanol and deionised water together in a flask, what do you think will happen? There may be no reaction until heated
2. If you slightly heat the mixture on a bunsen burner, it will react to produce an unknown liquid, what do you think has happened to ethanol? Ethanol is oxidized
3. What do you think the equation for the reaction would be?
$CH_3CH_2OH(aq) + 2[O] \longrightarrow CH_3COOH(g) + H_2O$
4. If you collect 1 test tube of the unknown liquid, then you perceive the odour, how do you think it odour would be? Is likely a vinegar odour
5. If you collect 3 test tubes of the unknown liquid, then you put indicator paper, Mg, and Na_2CO_3 respectively, what do you think will happen?
(a) may turn from green to red
(b) hydrogen gas may be generated
(c) CO_2 gas may be generated
6. What do you think the name of the unknown liquid would be? It is likely to be ethanoic acid</td></tr>
<tr><td>Explain
(Why do you think that will happen)
</td><td>Because it requires heat for the water of ethanol to oxidized
The mechanism of reaction revealed that magnesium ethanoate and hydrogen gas will be liberated. Because it is considered a volatile organic compound</td></tr>
<tr><td>Observe
What actually happened?
</td><td><table>
<tr><td>Test</td><td>Observation</td><td>Inference</td></tr>
<tr><td>Unknown liquid +odour</td><td>Vinegar odour</td><td>Ethanoic acid is produced</td></tr>
<tr><td>Unknown liquid +Indicator paper</td><td>Changes colour from green to red</td><td>Ethanoic acid is the unknown liquid</td></tr>
<tr><td>Unknown liquid +Magnesium strip</td><td>Effervescence, Hydrogen gas generated</td><td>Ethanoic acid is present</td></tr>
<tr><td>Unknown liquid +sodium carbonate</td><td>Effervescence, Carbon dioxide gas generated</td><td>Ethanoic acid is produced</td></tr>
</table></td></tr>
<tr><td>Explain
(Why did that happen?)
</td><td>Sharp testing liquid with the characteristics vinegar smell is associated with ethanoic acid.
There is an immediate fizzing as carbon dioxide is produced</td></tr>
</table>

Fig 11: Expected PEOE worksheet for Alkanoic acid

LESSON 6: **EXPERIMENTAL GROUP 1 (PREDICT-EXPLAIN-OBSERVE-EXPLAIN)**

School:	As Applicable
Subject:	Chemistry (Organic Chemistry)
Specific Topic:	Alkanoates (Esters)
Class:	SS II
Number in Class:	As Applicable
Average Age:	16 Years
Sex:	Mixed
Time:	80 minutes
Date:	As Applicable

Behavioural objectives: By the end of the lesson, students should be able to;

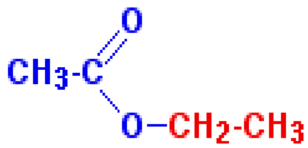
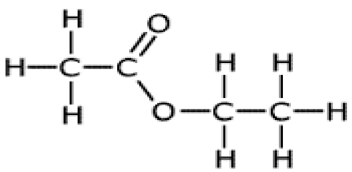
1. define the term esters;
2. clearly describe the process of esterification;
3. mention at least three physical properties of alkanoates;
4. draw the structure of ethyl ethanoate accurately;
5. clearly describe at least three chemical properties of ethyl ethanoate;
6. carefully carry out the laboratory preparation of ethyl ethanoate; and
7. mention at least four uses of esters.

Instructional Materials: Ethanol, ethanoic acid, conc H_2SO_4, test-tubes, test-tube holder, test-tubes rack, bunsen burner, and PEOE worksheet

Previous knowledge: Students have studied alkanoic acids

Lesson Presentation

Content Development	Time (mins)	Teacher's activities	Students' activities
Step 1 Introduction/ Checking Previous Knowledge	5	Arouses students' interest and motivates them to learn. Tell students the objectives of the lesson. Probes into students' prior knowledge through questions such as: what are carboxylic acids? What are esters? Makes known to the students the teaching technique and its demand on them Briefly explains to the students that alkanoates has esters as their family name and contain the -RCOOR, as their functional group have the general formula (CnH_2nO_2). The standard system for naming esters uses the suffix "-oate" to indicate that a molecule is an ester	Answer the questions verbally. They are encouraged to write down their right ideas. (Two or three students say their ideas for class to correct. They are encouraged to write down or take note of the corrected ideas) Expected answer: Carboxylic acids also known as organic or alkanoic acids, that contain the carboxyl group, -COOH, as their functional group with general molecular formula CnH_2n+COOH. Esters are the derivatives of the carboxylic acids in which the –OH part of the carboxylic group has been replaced by –OR group where, R may be alkyl or aryl group. Students jot down some points as the teacher speaks. May ask questions for clarification

Step 2 Grouping/ Elicitation of Students' ideas	15	Divides students into groups of 4-7; asks them to assume the role of captain, recorder, time-keeper and so on. Elicits ideas from the students. Asks students to mention the sources of esters they know? Asks the students to draws the structure of ethyl ethanoate or ethyl acetate ($C_4H_8O_2$) or $CH_3COOCH_2CH_3$	Move into different groups and assume different roles as agreed by members. Give responses to the questions based on prior knowledge. Expected answers Alkyl alkanoates or esters are found widely in nature. Short carbon chain simply alkyl alkanoates exist as liquids and have a characteristic pleasant odour. They occur in essential oils, many fruits and flowers and sometime called fruit essences because of their pleasant odours Answer the question by drawing it on pieces of papers. Expected answer:  ethyl ethanoate or 

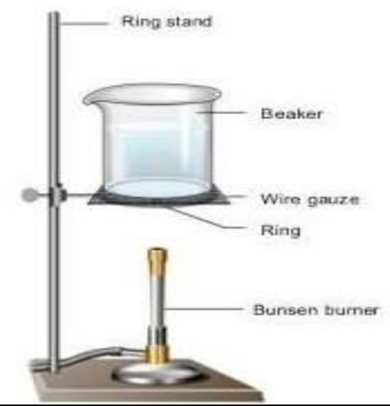
		Ask student to mention the physical properties ethyl ethanoate they know	Expected answers: i. It is colourless volatile liquid with a pleasant smell. ii. It is slightly soluble in water but dissolve readily in organic solvent such as ethanol, acetone, ethoxyethane and benzene. iii. It has a boiling point of 77.1 ^{0}C (170.8 ^{0}F) and melting point of -83.6 ^{0}C respectively. iv. It is less dense than water v. Ethyl acetate is highly flammable and the vapour mixtures can explodes
		Asks the students to mentions the uses of ethyl ethanoate acid they know?	Expected answers: i. Ethyl ethanoate is used primarily as a solvent and diluent. ii. It is commonly used to clear circuit boards and in some nail varnish removers. iii. It is also used as paints as an activator or hardener. iv. In the laboratory, mixtures containing ethyl ethanoate are commonly used in column chromatography and extractions. v. Ethyl ethanoate is the most common ester in wine, being the product of the most common volatile organic acid. vi. Ethyl ethanoate is an effective asphyxiant for use in insert collecting and study.

		Briefly describe the chemical properties of ethyl ethanoate as follows; i. Hydrolysis: ethyl ethanoate and other esters can be hydrolyzed to the corresponding carboxylic acid and ethanol. $CH_3COOC_2H_5 + H_20 \rightarrow CH_3COOH + C_2H_5OH$ ii. Reaction with ammonia $CH_3COOC_2H_5 + NH_3 \rightarrow C_2H_5OH + CH_3CONH_2$ Briefly explains that the names and structures of simple linear esters in which $R_2 = CH_3$, is known as a "-methyl group" examples are; methyl formate ($C_2H_4O_2$), methyl ethanoate ($C_3H_6O_2$), and methyl propanoate ($C_4H_8O_2$). Esters in which $R_2 = CH_2CH_3$, is ethyl group" examples are; ethyl formate ($C_3H_6O_2$), ethyl ethanoate ($C_4H_8O_2$), ethyl propanoate ($C_5H_{10}O_2$). Esters in which $R_2 = CH_2CH_2CH_3$, is known as an "-propyl group" examples are; propyl formate ($C_4H_8O_2$), propyl ethanoate ($C_5H_{10}O_2$) and propyl propanoate ($C_6H_{12}O_2$). The teacher concluded that the focus of the lesson would be ethyl ethanoate ($C_4H_8O_2$) which is one of the simpler esters.	Listen to teacher's explanation and they are asked to increase their list of fact and concepts on esters as the lesson progresses as well as write out responses to the questions asked by the teacher. May ask questions for clarification.

Step 3 Introducing the Experiment	5	Introduces the experiment thus; the purpose of the experiment that will be carry out later during this lesson is to prepare sample of a member alkanoates by using ethanoic acid, ethanol, and then to perform various tests on the product obtained to examine it properties	Listen to the teacher and jot down some points as the teacher speaks, and asks questions for clarification.
Step 4 **P**redict **(P)**	10	At this step, before doing the experiment, the teacher asks the students to predict the answers to some questions based on the earlier introduced experiment (noting that the answers to the questions can be addressed through the experiment that follows in step 6). Asks students to predict answers to questions such as; 1. If you mix 2 cm^3 of ethanol with 2cm^3 of ethanoic acid, then add few drops of conc.H_2SO_4 together in a flask, what do you think will happen if you slightly heat the mixture? 2. What do you think the equation for the reaction would be? 3. What do you think the name of the reaction would be? 4. If you divide the product of the reaction into three portions in test tubes, and then you test it using odour, water, and potassium dichromate ($K_2Cr_2O_7$) respectively,	Captain directs discussion based on questions and the directives given by the teacher to guide their actions. Spread out their individually written predictions on a flat surface (desk), where it can easily be read. Have a look at each other's predictions, and make quick comments. Then, the recorder for the group or whoever is assigned, write down their prediction(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet

		what do you think will happen? 5. What do you think the name of the unknown product would be? Each member of the group is expected to write out their prediction on pieces of papers supplied them. They are to compare individual answers and collectively brainstorm to come out with group ideas on all questions raised thus far. Predictions are to be written down on the PEOE worksheet supplied to them by the recorder are those agreed upon by the entire group Goes round various groups to supervise the activities.	
Step 5: **<u>E</u>**xplaining the Predictions **(E)**	10	Instruct each member of the group to write out their explanation for their prediction on pieces of papers supplied to them. They are to compare individual explanations and collectively brainstorm to come out with group explanations to predictions. explanations to predictions are to be written down on the PEOE worksheet supplied to them by the recorder are those agreed upon by the entire group Goes round various groups to supervise the activities. (While students are writing, you might stroll around so as	Students spread out their individually written explanation to their predictions on a flat surface (desk), where it can easily be read. Have a look at each other's predictions, and make quick comments. Then, the recorder for the group write down the explanation for their prediction(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet Students to share their PEOE worksheet containing both their predictions and the explanation for their predictions in full-class discussion

		to prepare yourself for the discussion that will follow). Asks each group to present their PEOE worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the PEOE worksheet only contains highlight of the predictions and explanations for each group). After this has been done, the teacher might invite the class to discuss which predictions and reasons or explanations they now think are best.	Team leaders or selected group representatives makes their respective presentations in full class discussion (When students reconsider their reasons, some may begin to change their minds and reconstruct their thinking.
Step 6 **<u>O</u>**bserve **(O)**	20	Instructs students to carry out the following activities to illustrate the laboratory preparation of X (ethyl ethanoate or ester) through the process called esterification using ethanoic acid, ethanol and so on. Teacher ask the students to carry out the following activities: 1. Measure $2cm^3$ of ethanol into test-tube (a) and $2cm^3$ of ethanoic acid into test-tube (b) 2. Mix the two solution in a clean/dry test-tube (c) 3. Then add few drops of conc.H_2SO_4. Reflux for few minutes. 4. Heat the mixture slightly 5. Record the observation that occur in test-tube (c) Expected observation: "A colourless unknown liquid is	Carry out the activities as directed by the teacher. They follow the instructions step by step and record their observation and inference and write down the chemical equation representing the preparation Students spread out their individually written observations on a flat surface (desk), where it can easily be read. Have a look at each other's observations, and make quick comments. Then, the recorder for the group or whoever is assigned, write down their observation(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet

		formed" 6. Divide the "X" unknown liquid into three portions in test tube 7. Test the "X" liquid using odour, water, and potassium dichromate ($K_2Cr_2O_7$) respectively. 8. Then record your observation and inference and also write the chemical equation for the reaction	Expected laboratory set-up 
Step 7 **E**xplaining the Observations **(E)**	10	Instruct each member of the group to write out their explanation for their observation on pieces of papers supplied to them. They are to compare individual explanations and collectively brainstorm to come out with group explanations to observations. explanations to their observations are to be written down on the PEOE worksheet supplied to them by the recorder are those agreed upon by the entire group Goes round various groups to supervise the activities. (While students are writing, you might stroll around so as to prepare yourself for the discussion that will follow). Asks each group to present their PEOE worksheet in full-class discussion, by placing the worksheet on a chalkboard.	Spread out their individually written explanation to their observations on a flat surface (desk), where it can easily be read. Have a look at each other's explanations, and make quick comments. Then, the recorder for the group write down the explanation for their observation(s) as agreed upon by the group and directed by the group captain on the PEOE worksheet. Students to share their PEOE worksheet containing their predictions, explanation for their predictions, observations and explanations for their observation in full-class discussion Team leaders or selected group representatives makes their respective presentations in full class discussion At this stage, students are expected to compare their prediction and observation in order to reconcile any conflict between their

		(At this stage, the PEOE worksheet contains highlights of the predictions-explanations-observations explanations for each group). After this has been done, teacher might discuss with the class which observation and explanations or reasons they now think are best. Ask the students to disengage from their groupings	predictions and observations in a brief full class discussion. (At this stage, teacher then engages the students to correlate their prediction with their observation so as to reconstruct their thinking and also reconcile any conflict between their predictions and observations) Students move to their respective sits.
Total	**75**		

Summary: (5 minutes)

Teacher summarizes the lesson thus;

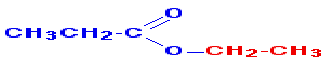
Esterification is the reaction of a carboxylic acid and alcohol in the presence of an acid catalyst to produce an ester. The main chain of an ester comes from the carboxylic acid, while the alkyl group in an ester comes from the alcohol. Teacher further explains that the reaction is extremely slow acid reversible at room temperature, and is catalyzed by a high concentration of hydrogen ions

Assignment:

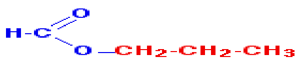
Teacher gives the students take home assignment due for submission the next class

i. Draw the structures of the following esters; ethyl propanoate, propyl methanoate, methyl butanoate, and propyl ethanoate.

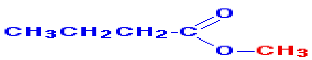
Expected answers to assignment questions:



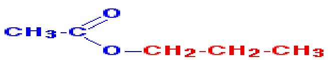
ethyl propanoate



propyl methanoate



methyl butanoate



propyl ethanoate

<table>
<tr><td></td><td>PEOE WORKSHEET FOR ALKANOATES (ESTERS)
Group________________________ Date_______________________</td></tr>
<tr><td><u>P</u>redict
(What do you think will happen?)
</td><td>1. If you mix 2 cm^3 of ethanol with 2cm^3 of ethanoic acid, then add few drops of conc.H_2SO_4 together in a flask, what do you think will happen if you slightly heat the mixture? <u>Colourless liquid is likely to be formed</u>
2. What do you think the equation for the reaction would be?
$$\underset{\text{Ethanoic acid}}{CH_3COOH(\ell)} + \underset{\text{Ethanol}}{C_2H_5OH(\ell)} \xrightarrow{\text{Conc. } H_2SO_4} \underset{\text{Ethyl Ethanoate}}{CH_3COOC_2H_5(\ell)} + H_2O(\ell)$$
3. What do you think the name of the reaction would be? <u>Esterification</u>
4. If you divide the product of the reaction into three portions in test tubes, and then you test it using odour, water, and potassium dichromate ($K_2Cr_2O_7$) respectively, what do you think will happen?
(a) <u>Fruity smell is likely to be perceived</u>
(b) <u>The unknown liquid will likely soluble in water</u>
(c) <u>Orange colour of $K_2Cr_2O_7$ will likely turn to green</u>
5. What do you think the name of the unknown product would be? <u>The liquid is likely to be ethyl ethanoate</u></td></tr>
<tr><td><u>E</u>xplain
(Why do you think that will happen)
</td><td>Because oxidation would likely occur, then the orange solution containing dichromate (VI) ions is reduced to a green solution containing chromium (III) ions.</td></tr>
<tr><td><u>O</u>bserve
What actually happened?
</td><td><table>
<tr><td>Test</td><td>Observation</td><td>Inference</td></tr>
<tr><td>Unknown liquid + odour</td><td>Sweet fruity smell was perceived</td><td>Presence of ethyl ethanoate</td></tr>
<tr><td>Unknown liquid + water</td><td>Slightly soluble in water</td><td>ethyl ethanoate is present</td></tr>
<tr><td>Unknown liquid + $K_2Cr_2O_7$</td><td>Orange colour of $K_2Cr_2O_7$ turned to green</td><td>The unknown liquid is ethyl ethanoate</td></tr>
</table></td></tr>
<tr><td><u>E</u>xplain
(Why did that happen?)
</td><td>It is slightly soluble in water because, it is less dense than water
Oxidation occurs, and then the orange solution containing dichromate (VI) ions is reduced to a green solution containing chromium (III) ions.</td></tr>
</table>

Fig 12: Expected PEOE worksheet for Alkanoates (Esters)

APPENDIX Y

LESSON PLANS

VEE HEURISTIC LESSON PLANS FOR EXPERIMENTAL GROUP 2

LESSON 1:

School:	As Applicable
Subject:	Chemistry (Organic Chemistry)
Specific Topic:	Alkanes
Class:	SS II
Number in class:	As Applicable
Average Age:	16 Years
Sex:	Mixed
Time:	80 minutes
Date:	As Applicable

Behavioural objectives: By the end of the lesson, students should be able to:

1. define the term alkanes;
2. write general formula of alkanes;
3. identify at least three sources of methane;
4. mention at least four physical properties of some alkanes;
5. draw the structure of methane accurately;

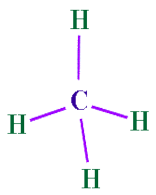
6. clearly describe the chemical properties of methane;
7. correctly carryout the laboratory preparation of methane;
8. mention at least five uses of methane; and
9. construct Vee diagram of the concept of alkanes.

Instructional Materials: Bunsen burner, beaker, soda lime, salt of fatty acid sodium acetate and sodium hydroxide reagents

Previous knowledge: Students have studied hydrocarbon.

Lesson Presentation

Content Development	Time (mins)	Teacher's activities	Students' activities
Step 1 Introduction/ establishing a learning set	5	Arouses students' interest and motivates them to learn by telling them that the best group will be given a gift. Tell students the objectives of the lesson. Probes into students' prior knowledge through questions such as: what are the two classes of hydrocarbon? What are alkanes? Makes known to the students the teaching technique and its demand on them Briefly explains that the simplest member of alkane	Answer the question verbally. They are encouraged to write down the right ideas Expected answers: The two classes of hydrocarbon are saturated and unsaturated hydrocarbon Alkanes are saturated hydrocarbons that is to say compounds of carbon and hydrogen which only have single, covalent, bonds holding the atoms together. with general molecular formula C_nH_{2n+2} and functional group of C-C and it prefix is "-ane" Jot down some points as the teacher speaks. May ask questions for clarification.

		family is methane (CH_4) and other members are ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), pentane (C_5H_{12}), and hexane (C_6H_{14}).	
Step 2 Formation of Groups/Pooling of ideas	15	Teacher share students out into groups of 4-7; ask them to assume the role of captain, recorder, time-keeper and so on. Elicits ideas from the students. Asks the students to mention the sources of alkanes they know? Asks the students to draw the structure of methane	Students move to their respective groups and assume their different roles as agreed by members Give responses to the questions based on prior knowledge Expected answers: i. Petroleum: petroleum is a complex mixture of alkanes and other hydrocarbons ii. Natural gas: methane is a major constituent of the natural gas and occur along with petroleum in the earth's sedimentary traps iii. Destructive distillation of wood and coal iv. Anaerobic decomposition of organic matter, in the presence of bacteria. Students answer the question by drawing it on pieces of papers. Expected answer: The structure of methane is as follows:  Methane

		Asks the students to mention the physical properties of methane they know	Answer the question verbally. They are encouraged to write down the right ideas. Expected answer: i. Methane is a colourless, odourless, and tasteless non poisonous gas. ii. Methane is sparingly soluble in water but dissolves readily in alcohol and ether. iii. Methane is lighter than air. iv. Methane melts at -184^{o}C and boils atomic -161.4^{o}C. v. Methane like carbon dioxide also traps infrared radiations (heat radiations) reflected by the earth. vi. it is neutral to litmus
		Asks students to mention the uses of methane they know	Answer the question verbally. They are encouraged to write down the right ideas. Expected answers: i. Methane is important for electricity generation by burning it as a fuel in a gas turbine or stream generator ii. Methane is used for the production of certain important compounds such as carbon black, hydrogen, alkynes, carbon disulphide, and hydrochloric acid. iii. Alkanes such pentane is used as a propellant for aerosol sprays, as a filling of low temperature thermometer.

Briefly outlines the physical properties of the first few members of the alkane listing the formula, boiling point, melting point and density as follows:

Name	Formula	Boiling Point	Melting point	Density
Methane	CH_4	-162^oC	-183	Gas
Ethane	C_2H_6	$-89\,^oC$	-182	Gas
Propane	C_3H_8	$-42\,^oC$	-188	Gas
Butane	C_4H_{10}	$-0.5\,^oC$	-138	Gas
Pentane	C_5H_{12}	$36\,^oC$	-130	0.626

Briefly describe the chemical properties of methane as follows:

i. With alkalis methane does not react. Chemically, methane is very stable and remains unaffected when treated with $KMnO_4$, $K_2Cr_2O_7$ etc. under normal condition.

ii. With trioxonitrate (V) acid vapour: methane is nitrated at 300^oC.

$$CH_4 + HNO_3 \rightarrow CH_3NO_2 + H_2O$$

iii. With stream: Methane is oxidized by stream in the presence of metallic Nickel catalyst to carbon (II) oxide and hydrogen.

$$CH_4 + O_2 \rightarrow CO + 3H_2$$

Listen to teacher's explanation and they are asked to increase their list of fact and concepts on alkanes as the lesson progresses as well as write out responses to the questions asked by the teacher.

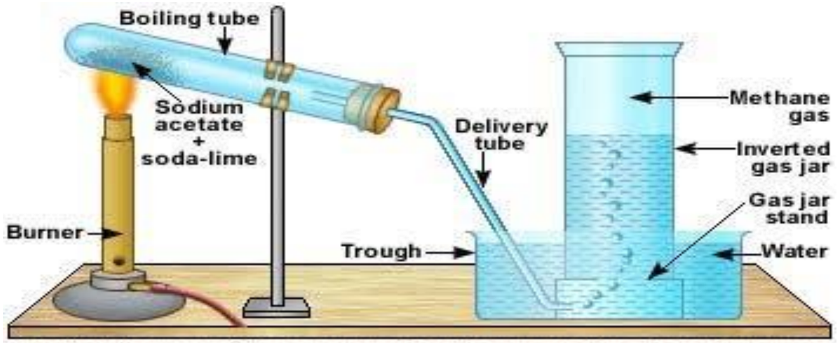
May ask questions for clarification.

		iv. Combustion: methane burns in excess of air or oxygen with a pale-blue non luminous flame to give carbon dioxide and water.	
Step 3 Group Brainstorming (Thinking Aloud)	15	Ask students to write out all facts, ideas or thought that they feel based on their prior experience on the conceptual or theoretical side (Thinking side) of V-shaped diagram under the following Vee heuristic conceptual epistemological elements; associated words, theory, principles, constructs and relevant concepts in relation to the focus question raised thus far. In this instance, the focus question is; Illustrate the laboratory preparation of methane been a simplest member of alkane They are to compare individual answers and collectively brainstorm to come out with group ideas/thought. Ideas/facts or thought to be written down on the Vee diagram by the recorder are those agreed upon by the entire group. Teacher views the ideas or thoughts written down by the respective groups	At this stage as students brainstorm they write out clearly on the small pieces of papers the various facts or ideas/ thought in relation to the focus question. All members within each group spread out their papers on a flat surface, where it can easily be read. Have a look at each other's write up and make quick comments. The recorder for the group or whoever is assigned to organizes their thoughts as agreed upon by the group embark on assembling the thoughts on the conceptual or theoretical side (thinking side) of the Vee diagram on a worksheet provided by the teacher (Cardboard). Expected Answer: They are expected to come up with a list comprising the following on the thinking side of the Vee diagram; **Associated words:** Methane (CH_4) and other members are ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), pentane (C_5H_{12}), hexane (C_6H_{14}), and so on. **Philosophy/epistemology:** Alkanes are saturated hydrocarbons that is to say compounds of

			carbon and hydrogen which only have single, covalent, bonds holding the atoms together. The sources of alkanes are petroleum, natural gas, and destructive distillation of wood. **Theory:** Methane is a flammable gas, on ignition, it will produce carbon dioxide and water and also methane is a colourless, odourless, and tasteless non poisonous gas. Methane is sparingly soluble in water but dissolves readily in alcohol and ether. Methane is lighter than air. Methane melts at -184^{o}C and boils atomic -161.4^{o}C. Methane like carbon dioxide also traps infrared radiations (heat radiations) reflected by the earth. It is neutral to litmus Properties of methane are; methane is a colourless, odourless, and tasteless non poisonous gas. Methane is sparingly soluble in water but dissolves readily in alcohol and ether. Methane is lighter than air. Methane melts at -184^{o}C and boils atomic -161.4^{o}C. Methane like carbon dioxide also traps infrared radiations (heat radiations) reflected by the earth. It is neutral to litmus Chemical properties of alkane are: i. With alkalis methane does not react. ii. $CH_4 + HNO_3 \longrightarrow CH_3NO_2 + H_2O$ iii. $CH_4 + O_2 \longrightarrow CO_2 + 3H$

			Principle: The general molecular formula for alkanes is CnH_2n_{+2} and functional group of C-C and it prefix is "-ane" **Concept:** Methane as a simplest member of alkane is important for electricity generation by burning it as a fuel in a gas turbine or stream generator; methane is used for the production of certain important compounds such as carbon black, hydrogen, alkynes, carbon disulphide, and hydrochloric acid; Alkanes such pentane is used as a propellant for aerosol sprays, as a filling of low temperature thermometer; ethane serves as a solvent in the laboratory and for fast-drying lacquers and glues
Step 4 Group Carrying out Learning Task (Doing)	20	Instructs students to carrying out learning task or laboratory activities in order to answer the focus question. They are to compare individual answers and collectively brainstorm to come out with group experimental findings. The findings of the learning task are recorded using Vee heuristic methodological epistemological elements which include; value/knowledge claims (facts), transformations and records by the recorder for the group or whoever is assigned to organizes their experimental findings as	Students engage in the learning task as directed by the teacher. They follow the instructions step by step. All members within each group spread out their papers on a flat surface, where it can easily be read. Have a look at each other's write up and make quick comments. The recorder for the group or whoever is assigned to organizes their experimental findings as agreed upon by the group embark on assembling the findings on the methodological side (doing side) of the Vee diagram on a pieces of paper or cardboard.

		agreed upon by the group on the methodological side (doing side) of the Vee diagram. Teacher views the experimental findings written down by the respective groups. Teacher then encourage students to finally come out with one well laid out Vee diagram with conceptual and methodological appropriately linked, representing the thought and experimental findings of the group on the focus question. Teacher serves as facilitator guiding the students in various groups to do the right thing In this instance, teacher asks students to carry out the following learning task or laboratory activities in order to answer the focus question (how to prepare methane) using sodium acetate and sodium hydroxide reagents as follows: 1. Measure 5grams of anhydrous sodium acetate (CH_3COONa) into a beaker. 2. Then add 2.5 grams of pulverized sodium hydroxide and mix them thoroughly in a beaker or porcelain dish. 3. Transfer the mixture into a hard glass test-tube boiling	Expected Answer: In this instance, they are expected to come up with a list comprising the following on the doing side of the Vee diagram; **Knowledge claims (facts);** Methane gas is formed $NaOH+CH_3COONa \longrightarrow CH_4 + Na_2CO_3$ **Transformations;** After a while unknown gas starts liberating. The unknown gas burn with a blue fire with colourless and odourless gas **Constructs;** The knowledge claim is based on the fact that methane is a flammable gas, on ignition, it produces carbon dioxide and water and it burn with blue frame **Records;** The unknown gas formed is methane

		tube 4. Seal the test-tube with a stopper with a gas-delivery tube. The gas-delivery tube should look upwards. 5. Fix the test-tube on the stand 6. Heat the test-tube gently with the cold part of the flame to avoid local overheating keep the flame in motions. 7. Record your observation Note that, X is a flammable gas, on ignition, it will produce carbon dioxide and water 8. Prepare an empty test-tube. Collect some gas keeping this test-tube on top of the gas delivery tube then ignite it. 9. Record your observation and inference	Expected laboratory set-up:  $NaOH + CH_3COONa \longrightarrow CH_4 + Na_2CO_3$
Step 5 Presentations of group Vee Diagram	10	Asks each group to present their Vee diagram worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the Vee diagramming worksheet contains highlight of the thinking and the experimental findings for each group) Asks the team leaders or group representatives to come out and make their presentations.	Team leaders or selected group representatives makes their respective presentations in full class discussion while member watch, listen, discuss and make contributions at the end of each presentation.

Step 6 Summary and Final Class Vee Diagram	5	After presentations of Vee diagram has been done. Invite the class to discuss which thinking and experimental finding they now think are best. (This exercise is valuable for both the students and the teacher. Having full-class discussion will helps the students to reconcile any conflict between their thinking and experimental findings) (When students correlate their thinking with their experimental findings, they reconstruct their thinking). Harmonizes the ideas from the respective diagrams posted on the board into one class diagram. Eventually a Vee diagram that depicts the understanding of the entire class is drawn. Ask the students to disengage from their groupings	Students reconcile any conflict between their groups Vee diagram with the entire class Vee diagram. At this stage, students try to reconstruct their thinking. Students move to their respective sits.
Step 7 Evaluation	5	Evaluates the lesson by asking the following questions; 1. Mention two sources of alkanes you know? 2. Mention two physical properties of methane? Encourages students to copy the final class Vee diagram and to submit a neatly drawn and beautifully arranged individual Vee diagrams the next class.	Students answer the questions asked. Students will perform all the tasks given by the teacher. May ask questions for clarification.
	75		

Summary: (5 minutes)

Teacher summarizes the lesson thus;

The alkanes can exist as gases, liquids, or solids at room temperature. The unbranched alkanes such as methane, ethane, propane and butane are gases; pentane through hexadecane is liquids; the homologues larger than hexadecane are solids. Branched alkanes normally exhibit lower boiling points than unbranched alkanes of the same carbon content.

Assignment:

Teacher gives the students take home assignment due for submission the next class

i. What is the boiling point of butane

ii. Give two reasons why soda lime is used instead of caustic soda in the preparation of methane

Expected answers to the assignment questions:

i. -0.5^0C ii. Soda lime does not attack glass apparatus unlike caustic soda; and soda lime is not deliquescent unlike caustic soda.

Conceptual (Thinking) **Focus Question** **Methodology (Doing)**

carryout the laboratory preparation of unknown "X" member of alkane?

ASSOCIATED WORDS:
Methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), pentane (C_5H_{12}) hexane (C_6H_{14}**)**

PHILOSOPHY:
Alkanes are saturated hydrocarbons that is to say compounds of carbon and hydrogen which only have single, covalent, bonds holding the atoms together. The sources of alkanes are petroleum, natural gas, and destructive distillation of wood.

THEORY:
Methane is a flammable gas, on ignition, it will produce carbon dioxide and water and also methane is a colourless, odourless, and tasteless non poisonous gas. Methane is sparingly soluble in water but dissolves readily in alcohol and ether Methane is lighter than air. Methane melts at -184°C and boils atomic -161.4°C. With alkalis methane does not react.

PRINCIPLES:
The general molecular formula for alkanes is CnH_2n_{+2} and functional group of C-C and it prefix is "-ane"

CONCEPTS:
methane for example is important for electricity generation by burning it as a fuel in a gas turbine or stream generator; methane is used for the production of certain important compounds such as carbon black, hydrogen, alkynes, and hydrochloric, aerosol sprays, as a filling of low temperature thermometer; ethane serves as a solvent in the laboratory and for fast-drying lacquers and glues

Interplay ⟷

KNOWLEDGE CLAIM:
Methane gas is formed
$NaOH + CH_3COONa \longrightarrow CH_4 + Na_2CO_3$

TRANSFORMATIONS:

Test	Observation
CH_3COONa+ NaOH + Heat	After a while unknown gas starts liberating
Unknown gas + ignition	The unknown gas burn with a blue fire with colourless and odourless gas

CONSTRUCTS:
The knowledge clam is based on the fact that methane is a flammable gas, on ignition, it produces carbon and water and it burn with blue flame

RECORDS:
The unknown gas formed is methane

EVENTS AND/OR OBJECTS

(a) Measure 5grams of anhydrous sodium acetate (CH_3COONa) into a beaker. (b) Then add 2.5 grams of pulverized sodium hydroxide and mix them thoroughly in a beaker or porcelain dish. (c) Transfer the mixture into a hard glass test-tube boiling tube (d) Seal the test-tube with a stopper with a gas-delivery tube. The gas-delivery tube should look upwards. (e) Fix the test-tube on the stand (f) Heat the test-tube gently with the cold part of the flame to avoid local overheating keep the flame in motions. (g) Record your observation. **Objects:** Bunsen burner, beaker, soda lime, salt of fatty acid sodium acetate and sodium hydroxide reagents

Fig 13: End Product of Vee Diagramming for Alkane

LESSON 2: **FOR EXPERIMENTAL GROUP 2 (VEE HEURISTIC STRATEGY)**

School:	As Applicable
Subject:	Chemistry
Specific Topic:	Alkenes
Class:	SS II
Number in class:	As Applicable
Average Age:	16 Years
Sex:	Mixed
Time:	80 minutes
Date:	As Applicable

Behavioural objectives: By the end of the lesson students should be able to:

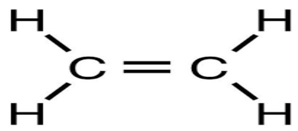
1. define the term alkenes;
2. write general formula of alkenes;
3. identify the at least two sources of alkenes;
4. mention at least four physical properties of some alkenes;
5. draw the structure of ethene accurately;
6. clearly describe the chemical properties of ethene;
7. correctly carryout the laboratory preparation of ethene;
8. mention at least four uses of ethene; and
9. construct Vee diagram of the concept of alkenes

Instructional Materials: Beakers, measuring cylinder, ethyne, ethanol (C_2H_5OH), conc.H_2SO_4, and nickel catalyst.

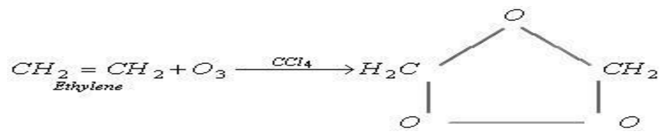
Previous knowledge: Students have studied alkane

Lesson Presentation

Content Development	Time (mins)	Teacher's activities	Students' activities
Step 1 Introduction/ establishing a learning set	5	Arouses students' interest and motivates them to learn. Tell students the objectives of the lesson. Probes into students' prior knowledge through questions such as: what are alkanes? What are alkenes? Makes known to the students the teaching technique and its demand on them Briefly explains that the simpler member of alkene family is ethene (C_2H_4) and other members are propene (C_3H_6), butene (C_4H_8), pentene (C_5H_{10}), hexene (C_6H_{12}), heptene (C_7H_{14}), and so on.	Answer the question verbally. They are encouraged to write down the right ideas Expected answers: Alkanes are saturated hydrocarbons that is to say compounds of carbon and hydrogen which only have single, covalent, bonds holding the atoms together. With general molecular formula CnH_2n_{+2} and functional group of C-C. Alkenes are unsaturated hydrocarbon that contains at least one carbon-carbon double bond with general molecular formula CnH_2n and functional group of C=C and it prefix is "-ene" Jot down some points as the teacher speaks. May ask questions for clarification

Step 2 Formation of Groups/Pooling of ideas	15	Teacher share students out into groups of 4-7; ask them to assume the role of captain, recorder, time-keeper and so on Elicits ideas from the students. Asks students to mention the sources of alkenes they know? Asks the students to draw the structure of ethene Asks the students to mention the physical properties of ethene they known Asks the students to mention some uses of alkenes they know	Students move to their respective groups and assume their different roles as agreed by members Give responses to the questions based on prior knowledge Expected answers: i. Terpene: Is the main source of natural alkene. ii. Fruits: It is found in fruits such as raw apricots Students answer the question by drawing it on pieces of papers. Expected answer: The structure of ethene is as follows:  Expected answers; i. Ethene is a colourless gas with a faint sweetish smell. ii. It has a melting of -169^{0}C and boiling points of 104^{0}C iii. It is slightly less dense than air iv. It is insoluble in water but soluble in alcohol and ether. v. It is neutral to litmus paper Answer the question verbally. They are encouraged to write down the right ideas.

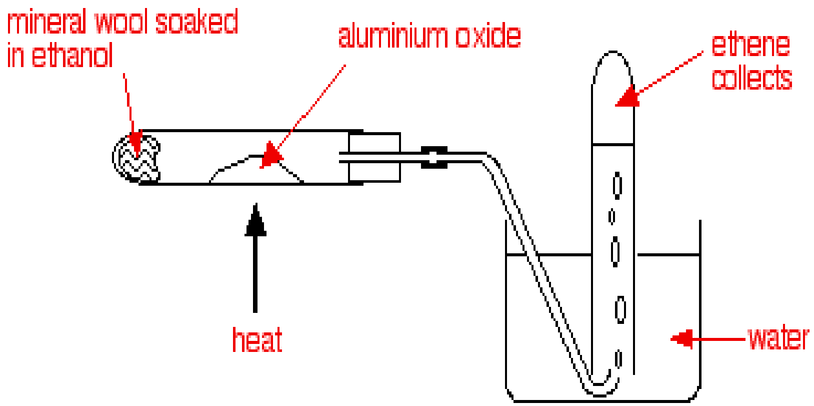
			Expected answers: i. Ethene is extremely important in the manufacture of plastic. All plastics are in some way related to alkenes ii. Ethene is used as fuel and illuminant. iii. Ethene is used in the manufacture of glycerol and detergent. iv. For the manufacturing of a wide variety of polymers e.g., polyethene, polyvinylchloride (PVC) and teflon and so on. v. As raw materials for the manufacture of industrial chemicals such as alcohols, aldehydes, and so on. vi. Ethene is used for artificial ripening of fruits, as a general anesthetic, for making poisonous mustard gas and ethylene-oxygen flame. vii. It is used for the production of synthetic rubber.
		Briefly explains that ethene undergo ionic addition reaction and further describe the chemical properties of ethene as follows: i. Hydrogenation: Ethene is converted to ethane by the addition of 1 mole of hydrogen gas in the presence of nickel catalyst at suitable temperature and pressure $C_2H_4 + H_2 \longrightarrow C_2H_6$ ii. With halo water: At room temperature, the double	Listen to teacher's explanation and they are asked to increase their list of fact and concepts on alkenes as the lesson progresses as well as write out responses to the questions asked by the teacher. May ask questions for clarification.

		bond in ethene is converted to single bond when halowater is added. (c) $C_2H_4+Cl_2H_2O \longrightarrow C_2H_4HOCl$ (d) $C_2H_4+Br_2H_2O \longrightarrow C_2H_4HOBr$ iii. With Ozone: Ozone is passed into the solution of ethene in trichloromethane (chloroform) to give ethene ozonide.  iv. With Conc. Tetraoxosulphate (vi) acids: ethene is passed into a concentrated tetraoxosulphate (vi) acid to give ethyl hydrogen sulphate at 170^oC $C_2H_2 + H_2SO_4 \longrightarrow CH_3\text{-}CH_2\text{-}SO_4\text{-}H$ ethyl hydrogen sulphate	
Step 3 Group Brainstorming (Thinking Aloud)	15	Asks students to write out all facts, ideas or thought that they feel based on their prior experience on the conceptual or theoretical side (Thinking side) of V-shaped diagram under the following Vee heuristic conceptual epistemological elements; associated words, theory, principles, constructs and relevant concepts in	At this stage as students brainstorm they write out clearly on the small pieces of papers the various facts or ideas/ thought in relation to the focus question. All members within each group spread out their papers on a flat surface, where it can easily be read. Have a look at each other's write up and make quick comments. The recorder for the group or

		relation to the focus question(s) raised thus far. In this instance, the focus question is; Illustrate the laboratory preparation of ethene been a simplest member of alkene They are to compare individual answers and collectively brainstorm to come out with group ideas/thought. Ideas/facts or thought to be written down on the Vee diagram by the recorder are those agreed upon by the entire group. Teacher views the ideas or thoughts written down by the respective groups	whoever is assigned to organizes their thoughts as agreed upon by the group embark on assembling the thoughts on the conceptual or theoretical side (thinking side) of the Vee diagram on a Vee diagramming worksheet provided by the teacher (Cardboard). Expected Answer: In this instance, the focus question is; they are expected to come up with a list comprising the following on the thinking side of the Vee diagram; **Associated words:** Ethene (C_2H_4) and other members are propene (C_3H_6), butene (C_4H_8), pentene (C_5H_{10}), hexene (C_6H_{12}), heptene (C_7H_{14}), and so on. **Philosophy/epistemology:** Alkenes are unsaturated hydrocarbon that contains at least one carbon-carbon double bond. Sources of alkenes are; Terpene: Is the main source of natural alkene. and Fruits: It is found in fruits such as raw apricots **Theory:** Ethene is a colourless gas with a faint sweetish smell; It has a melting of -169^{0}C and boiling points of 104^{0}C; It is slightly less dense than air; It is insoluble in water but soluble in alcohol and ether; It is neutral to litmus paper.

			Ethene undergoes hydrogenation: $C_2H_4+H_2 \longrightarrow C_2H_6$ Ethene reacts with halo water: At room temperature, the double bond in ethene is converted to single bond when halowater is added. $C_2H_4+Cl_2H_2O \longrightarrow C_2H_4HOCl$ $C_2H_4+Br_2H_2O \longrightarrow C_2H_4HOBr$ **Principle:** The general molecular formula for alkenes is CnH_2n and functional group of C=C and it prefix is "-ene" **Concept:** Ethene is extremely important in the manufacture of plastic. All plastics are in some way related to alkenes; Ethene is used as fuel and illuminant; Ethene is used in the manufacture of glycerol and detergent; For the manufacturing of a wide variety of polymers e.g., polyethene, polyvinylchloride (PVC) and teflon and so on; As raw materials for the manufacture of industrial chemicals such as alcohols, aldehydes, and so on; Ethene is used for artificial ripening of fruits, as a general anesthetic, for making poisonous mustard gas and ethylene-oxygen flame; It is used for the production of synthetic rubber such as styrene-butadiene rubber.

Step 4 Group Carrying out Learning Task (Doing)	20	Asks the students to carrying out learning task or laboratory activities in order to answer the focus question. They are to compare individual answers and collectively brainstorm to come out with group experimental findings. The findings of the learning task are recorded using Vee heuristic methodological epistemological elements which include; value claims, knowledge claims (facts), transformations and records by the recorder for the group or whoever is assigned to organizes their experimental findings as agreed upon by the group on the methodological side (doing side) of the Vee diagram. Teacher views the experimental findings written down by the respective groups. Teacher then encourage students to finally come out with one well laid out Vee diagram with conceptual and methodological appropriately linked, representing the thought and experimental findings of the group on the focus question(s). Teacher serves as facilitator guiding the students in various groups to do the right thing In this instance, teacher asks students to carry out the	Students engage in the learning task as directed by the teacher. They follow the instructions step by step. All members within each group spread out their papers on a flat surface, where it can easily be read. Have a look at each other's write up and make quick comments. The recorder for the group or whoever is assigned to organizes their experimental findings as agreed upon by the group embark on assembling the findings on the methodological side (doing side) of the Vee diagram on a pieces of paper or cardboard. Expected Answer: In this instance, they are expected to come up with a list comprising the following on the doing side of the Vee diagram; **Knowledge claims;** Ethene gas is formed $CH_3CH_2OH \xrightarrow{Al_2O_3} CH_2{=}CH_2 + H_2O$ **Transformations;** The gas burned with a luminous flame and limewater turned milky and carbon dioxide was also formed The yellow/red colour of the bromine water turned to colourless The purple colour of the permanganate solution turned to colourless (the presence of the carbon-carbon double bond)

		following learning task or laboratory activities in order to answer the focus question (preparation of ethene) using sodium acetate and sodium hydroxide reagents as follows: Instructs students to carry out the laboratory activities for the preparation of X (ethene)by dehydrating ethanol using it as a dehydrating agent and catalyst sodium as follows: 1. Pour some ethanol into the boiling tube to a 2-3cm depth. 2. Add some glass wool to soak up the ethanol, using a glass rod to push the wool down the tube. 3. Clamp the boiling tube in a horizontal position using a retort stand. 4. Put a small amount of aluminum oxide about half way along the boiling tube. 5. Light the bunsen burner, adjust it to a blue flame and heat the aluminum oxide (make sure the test tube is filled with water when you start to collect the gas produced) 6. As the aluminum oxide gets hot the heat reaches the ethanol at the end of the tube. The ethanol then change	**Constructs;** The knowledge claim is based on the fact that the gas is insoluble which produce a milky white precipitate. Similarly, gas turns brown bromine water colourless as it reacts with the double bond. **Records;** The unknown gas formed is ethene Expected laboratory set-up: 

		to vapour passes over the hot aluminum oxide and it is dehydrated to produce an unknown gas. 7. Let the bubbles produced escape for a short time (these are mainly bubbles of displaced air). Collect 5 test tube of the gas and put a stopper on each tube when it is filled. 8. When the test tube have all been filled, loosen the resort stand and raise the apparatus so that the delivery tube no longer dips into the water. Then turn off the bunsen burner. 9. Test each gas collected through addition of lime water, bromine, and addition of acidified $KMnO_4$ respectively. Then, record your observation and inference	
Step 5 Presentations of group Vee Diagram	10	Teacher asks each group to present their Vee diagram worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the Vee diagramming worksheet contains highlight of the thinking and experimental finds	Team leaders or selected group representatives makes their respective presentations in full class discussion while member watch, listen, discuss and make contributions at the end of each presentation.
Step 6 Summary and Final Class Vee	5	After presentations of Vee diagram has been done. Teacher then invite the class to discuss which thinking and experimental finding they now think are best. (This	Students reconcile any conflict between their groups Vee diagram with the entire class Vee diagram. At this stage, students try to reconstruct their thinking.

Diagram		exercise is valuable for both the students and the teacher. Having full-class discussion will helps the students to reconcile any conflict between their thinking and experimental findings) (When students correlate their thinking with their experimental findings, they reconstruct their thinking). Harmonizes the ideas from the respective diagrams posted on the board into one class diagram. Eventually a Vee diagram that depicts the understanding of the entire class is drawn. Ask the students to disengage from their groupings	 Students then move to their respective sits
Step 7 Evaluation	5	Teacher evaluates the lesson by asking the following questions; 1. draw the structure of ethene 2. write the chemical equation for the preparation of ethene Encourages students to copy the final class Vee diagram and to submit a neatly drawn and beautifully arranged individual Vee diagrams the next class.	Students answer the questions asked. Students will perform all the tasks given by the teacher and May ask questions for clarification.
	75		

Summary: (5 minutes)

Teacher summarizes the lesson thus;

Ethene can also be prepared by the cracking of petroleum (ethene is a bye product of petroleum). Teacher emphasize that ethene is extremely important in the manufacture of plastic. All plastics are in some way related to alkenes and it is also used as fuel and illuminant.

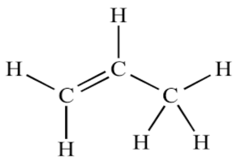
Assignment:

Teacher gives the students take home assignment due for submission the next class

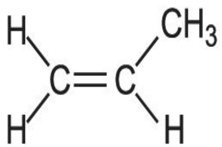
1. What is the melting and boiling points of tran-but-2-ene?
2. Draw the structure of propene

Expected answer to assignment questions:

1. Tran-but-2-ene has a melting and boiling points -139^{0}C and 1^{0}C respectively
2.



Or



Conceptual (Thinking) **Focus Question** **Methodology (Doing)**

ASSOCIATED WORDS:
Ethene (C_2H_4), propene (C_3H_6), butene (C_4H_8), pentene (C_5H_{10}), hexene (C_6H_{12}) heptene (C_7H_{14})

PHILOSOPHY:
Alkenes are unsaturated hydrocarbons that contains at least one carbon-carbon double bond . Terpene is the main natural source of alkene and it is also found in fruits such as raw apricots

THEORY:
Ethene is a colourless gas with a faint sweetish smell; it is slightly less dense than air; it is insoluble un water but soluble in alcohol and ester; it is neutral to litmus paper; It has a melting of -169^{0}C and boiling points of 104^{0}C

PRINCIPLES:
The general molecular formula for alkenes is C_nH_{2n} and functional group of C=C and it prefix is "-ene"

CONCEPTS:
Ethene is extremely important in the manufacture of plastics; Ethene is used as fuel and illuminant; Is used in manufacture of glycerol and detergent; it is used for artificial ripening of fruits; It is used for the production of synthetic rubber such as styrene-butadiene; As raw materials for the manufacture of industrial chemicals

CONSTRUCTS:

carryout the laboratory preparation of unknown "X" member of alkene?

Interplay

KNOWLEDGE CLAIM:
Ethene gas is formed
$CH_3CH_2OH \xrightarrow{Al_2O_3} CH_2{=}CH_2 + H_2O$

TRANSFORMATIONS:

Test	Observation
Unknown gas + lime water + Heat (combustion)	The gas burned with a luminous flame and limewater turned milky and carbon dioxide was also formed
Unknown gas + bromine	The yellow/red colour of the bromine water turned to colourless
Addition of $KMnO_4$ to the unknown gas	The purple colour of the permanganate solution turned to colourless (the presence of the carbon-carbon double bond)

The knowledge claim is based on the fact that the gas is insoluble which produce a milky white precipitate.

RECORDS:
The unknown gas produced is ethene

EVENTS AND/OR OBJECTS

(a) Pour some ethanol into the boiling tube to a 2-3cm depth. (b) Add some glass wool to soak up the ethanol, using a glass rod to push the wool down the tube (c) Clamp the boiling tube in a horizontal position using a retort stand (d) Put a small amount of aluminum oxide about half way along the boiling tube (e) Light the bunsen burner, adjust it to a blue flame and heat the aluminum oxide (f) As the aluminum oxide gets hot the heat reaches the ethanol at the end of the tube. The ethanol then change to vapour passes over the hot aluminum oxide and it is dehydrated to produce an unknown gas (g) Let the bubbles produced escape for a short time (these are mainly bubbles of displaced air). Collect 5 test tube of the gas and put a stopper on each tube when it is filled (h) When the test tube have all been filled, loosen the resort stand and raise the apparatus so that the delivery tube no longer dips into the water (i) Then turn off the bunsen burner (j) Test each gas collected through addition of lime water, bromine, and addition of acidified $KMnO_4$ respectively. Then, record your observation and inference. **Objects:** beakers, measuring cylinder, ethyne, ethanol (C_2H_5OH), H_2SO_4, nickel catalyst

Fig 14: End Product of Vee Diagramming for Alkene

LESSON 3: **FOR EXPERIMENTAL GROUP 2 (VEE HEURISTIC STRATEGY)**

School:	As Applicable
Subject:	Chemistry (Organic Chemistry)
Specific Topic:	Alkynes
Class:	SS II
Number in class:	As Applicable
Average Age:	16 Years
Sex:	Mixed
Time:	80 minutes
Date:	As Applicable

Behavioural objectives: By the end of the lesson, students should be able to:

1. define the term alkynes;
2. write general formula of alkynes;
3. identify at least two sources of alkynes;
4. mention at least four physical properties of some alkynes;
5. draw the structure of ethyne accurately;
6. clearly describe the chemical properties of ethyne;
7. correctly carryout the laboratory preparation of ethyne;
8. mention at least five uses of ethyne; and
9. construct Vee diagram of the concept of alkynes

Instructional Materials: Bunsen burner, beaker, soda lime, salt of fatty acid sodium acetate and sodium hydroxide reagents

Previous knowledge: Students have studied alkenes.

Lesson Presentation

Content Development	Time (mins)	Teacher's activities	Students' activities
Step 1 Introduction/ establishing a learning set	5	Arouses students' interest and motivates them to learn. Tell students the objectives of the lesson. Probes into students' prior knowledge through questions such as: what are alkenes? What are alkynes? Makes known to the students the teaching technique and its demand on them Explains that the simplest member of alkynes family is ethyne (C_2H_2) and other members are propyne (C_3H_4), butyne (C_4H_6), pentyne (C_5H_8), hexyne (C_6H_{10}), heptyne (C_7H_{12}), and so on.	Answer the question verbally. They are encouraged to write down the right ideas Expected answers: Alkenes an unsaturated hydrocarbon that contains at least one carbon-carbon double bond with general molecular formula CnH_2n and functional group of C=C and it prefix is "-ene" Alkynes an unsaturated hydrocarbon that contains at least one carbon-carbon triple bond with general molecular formula CnH_2n_{-2} and functional group of C=C and it prefix is "-yne" Jot down some points as the teacher speaks. May ask questions for clarification

Step 2 Formation of Groups/Pooling of ideas	15	Teacher share students out into groups of 4-7; ask them to assume the role of captain, recorder, time-keeper and so on. Elicits ideas from the students. Asks the students to mention the sources of alkynes they know? Asks students to draw the structure of ethyne Asks students to mention some physical properties of ethyne they know?	Students move to their respective groups and assume their different roles as agreed by members Give responses to the questions based on prior knowledge Expected answers: i. Crude oil and natural gas: small amount of alkynes are in crude oil and natural gas ii. Alkynes are also found in nature in plants and in some animals possess physiological functions Answer the question by drawing it on pieces of papers. Expected answer: The structure of ethyne is as follows: H ---C $\equiv$C---H Expected answers: i. Ethyne is a colourless gas with a characteristic sweet smell when pure. ii. It is lighter than air iii. Ethyne has faint garlic odour iv. Ethyne is slightly soluble in water v. Ethyne is completely soluble in organic solvents.

			vi. It has a melting point of -81°C and a boiling point of -84°C. vii. It is unstable and may explode on compression to a liquid.
		Asks students to mention some uses of ethyne they know	Expected answers: i. Ethyne is useful for artificial ripening and preservation of fruits. ii. It is useful in acetylene lamps to generate light. iii. Ethyne is used to prepare various organic compounds iv. It is useful to manufacture important organic compounds like acetic acid, acetaldehyde, ethyl alcohol and polymers like PVC. v. it is useful to produce an oxyacetylene flame vi. Ethyne is used in welding to produce oxy-acetylene flame of temperature about 3000°C
		Briefly outlines the physical properties of the first few members of the alkynes listing the formula, boiling point, melting point and density as follows:	Listen to teacher's explanation and they are asked to increase their list of fact and concepts on alkynes as the lesson progresses as well as write out responses to the questions asked by the teacher. May ask questions for clarification.

Name	Formula	Boiling Point	Melting point	Density
Ethyne	C_2H_2	-83°C	-183	Gas
Propyne	C_3H_4	-23 °C	-182	Gas

Butyne	C_4H_6	9 °C	-188	Gas
Pentyne	C_5H_8	27 °C	-138	Gas
Hexyne	C_6H_{10}	40 °C	-130	0.626

Describe the chemical properties of ethyne as follows:

i. Combustion: Ethyne burns in air with sooty flame and gives carbon dioxide, water and heat.

$$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O + heat$$

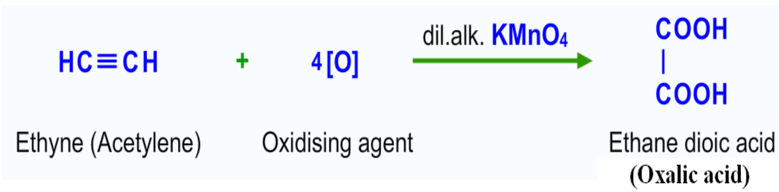
ii. Addition of hydrogen: Ethyne on addition with hydrogen forms initially ethene and finally forms ethane.

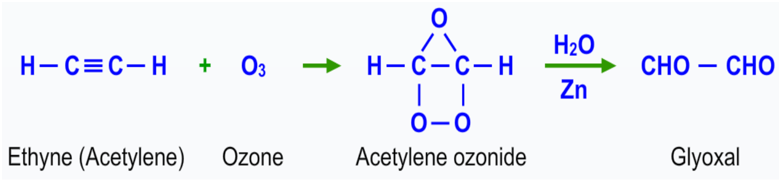
$$CH{\equiv}CH + H_2 \rightarrow CH_2{=}CH_2 + H_2 \rightarrow CH_3{-}CH_3$$

iii. Reaction with halogens: Ethyne reacts with halogen acids to form 1,2-Tetra haloethanes.

$$CH{\equiv}CH + 2X_2 \rightarrow CHX_2{-}CHX_2$$

vi. Oxidation of ethyne: Ethyne undergoes oxidation or combustion reactions. Ethyne is oxidized to form Oxalic acid in the presence of dilute $KMnO_4$

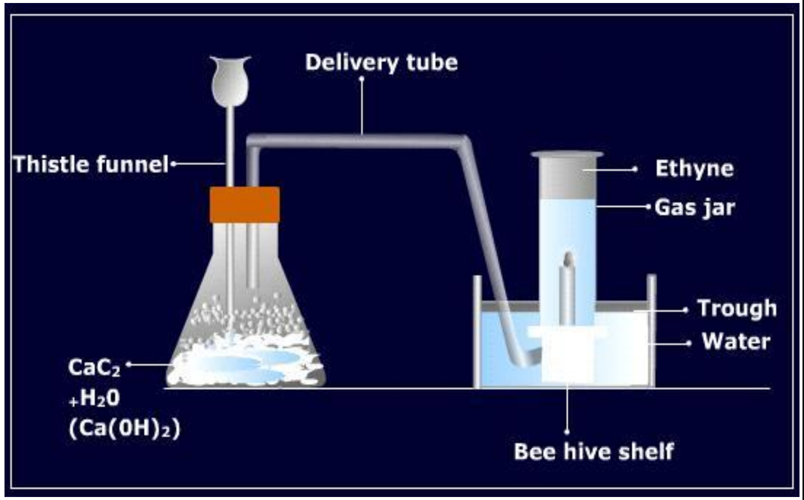


		v. Ozonolysis: Ethyne reacts with ozone to produce acetylene ozonide which further hydrolysed in presence of Zinc to form Glyoxal 	
Step 3 Group Brainstorming (Thinking Aloud)	15	Asks students to write out all facts, ideas or thought that they feel based on their prior experience on the conceptual or theoretical side (Thinking side) of V-shaped diagram under the following Vee heuristic conceptual epistemological elements; associated words, theory, principles, constructs and relevant concepts in relation to the focus question(s) raised thus far. In this instance, the focus question is; Illustrate the laboratory preparation of ethyne been a simplest member of alkyne They are to compare individual answers and collectively brainstorm to come out with group ideas/thought. Ideas/facts or thought to be written down on the Vee diagram by the recorder are those agreed upon by the entire group.	At this stage as students brainstorm they write out clearly on the small pieces of papers the various facts or ideas/ thought in relation to the focus question. All members within each group spread out their papers on a flat surface, where it can easily be read. Have a look at each other's write up and make quick comments. The recorder for the group or whoever is assigned to organizes their thoughts as agreed upon by the group embark on assembling the thoughts on the conceptual or theoretical side (thinking side) of the Vee diagram on a Vee diagramming worksheet provided by the teacher (Cardboard). Expected Answer: They are expected to come up with a list comprising the following on the thinking side of the Vee diagram;

		Teacher views the ideas or thoughts written down by the respective groups	**Associated words:** Ethyne (C_2H_2) and other members are propyne (C_3H_4), butyne (C_4H_6), pentyne (C_5H_8), hexyne (C_6H_{10}), heptyne (C_7H_{12}), and so on. **Philosophy/epistemology:** Alkynes an unsaturated hydrocarbon that contains at least one carbon-carbon triple bond. Sources of alkynes are crude oil and natural gas. Alkynes are also found in nature in plants and in some animals possess physiological functions **Theory:** Ethyne as the simplest member of alkynes is a colourless gas with a characteristic sweet smell when pure; It is lighter than air; Ethyne has faint garlic odour; Ethyne is slightly soluble in water; Ethyne is completely soluble in organic solvents; It has a melting point of -81^oC and a boiling point of -84^oC; It is unstable and may explode on compression to a liquid. Ethyne burns in air with sooty flame and gives carbon dioxide, water and heat. $2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O + heat$ Ethyne on addition with hydrogen forms initially ethene and finally forms ethane. $CH{\equiv}CH + H_2 \rightarrow CH_2{=}CH_2 + H_2 \rightarrow CH_3CH_3$

			Ethyne reacts with halogen acids to form 1,2-Tetra halo ethanes. $CH \equiv CH + 2X_2 \rightarrow CHX_2\text{-}CHX_2$ **Principle:** The general molecular formula for alkynes is C_nH_{2n-2} and functional group of $C \equiv C$ and it prefix is "-yne" **Concept:** Ethyne as a simplest member of alkyne is useful for artificial ripening and preservation of fruits; It is useful in acetylene lamps to generate light; Ethyne is used to prepare various organic compounds**;** It is useful to manufacture important organic compounds like acetic acid, acetaldehyde, ethyl alcohol and polymers like PVC; it is useful to produce an oxyacetylene flame; Ethyne is used in welding to produce oxy-acetylene flame of temperature about 3000^oC
Step 4 Group Carrying out Learning Task (Doing)	20	Asks the students to carrying out learning task or laboratory activities in order to answer the focus question. They are to compare individual answers and collectively brainstorm to come out with group experimental findings. The findings of the learning task are recorded using Vee heuristic methodological epistemological elements which include;	Students engage in the learning task as directed by the teacher. They follow the instructions step by step. All members within each group spread out their papers on a flat surface, where it can easily be read. Have a look at each other's write up and make quick comments. The recorder for the group or whoever is assigned to organizes their

		value claims, knowledge claims (facts), transformations and records by the recorder for the group or whoever is assigned to organizes their experimental findings as agreed upon by the group on the methodological side (doing side) of the Vee diagram. Teacher views the experimental findings written down by the respective groups. Teacher then encourage students to finally come out with one well laid out Vee diagram with conceptual and methodological appropriately linked, representing the thought and experimental findings of the group on the focus question(s). Teacher serves as facilitator guiding the students in various groups to do the right thing In this instance, teacher asks students to carry out the following learning task or laboratory activities in order to answer the focus question (preparation of methane) using sodium acetate and sodium hydroxide reagents as follows: Teacher asks the students to carry out the following laboratory activities for the preparation of X (ethyne) using the action of water on calcium carbide as follows: 1. Place 2-3 pieces of calcium carbide in a buchner flash	experimental findings as agreed upon by the group embark on assembling the findings on the methodological side (doing side) of the Vee diagram on a pieces of paper or cardboard. Expected Answer: In this instance, they are expected to come up with a list comprising the following on the doing side of the Vee diagram; **Knowledge claims;** Ethyne gas is formed $CaC_2 + 2H_20 \longrightarrow C_2H_2 + Ca_2(OH)_2$ **Transformations;** The unknown gas burns with smoky flame The unknown gas turns the reddish colour of bromine to colourless The unknown gas turns the yellowish colour of $KMnO_4$ to colourless **Constructs:** The knowledge claim is based on the fact that the ethyne gas undergoes incomplete combustion, the gas burn to produce smoky flame due the presence of carbon-carbon triple bond.

		2. Seal the flash with a stopper with a dropping funnel and a gas-delivery tube. The gas-delivery tube should look upwards trough water. 3. Add water from the thistle or dropping funnel, a few drops at a time, until all the calcium carbide has reacted 4. Note that during this reaction, an unknown gas will be produce. 5. Collect 3 test tube of the gas and put a stopper on each tube when it is filled. 6. When the test tubes have all been filled. 7. Test each the unknown gas collected through combustion (ignition), addition of bromine water, and addition of acidified $KMnO_4$ respectively. 8. Then, record your observation and inference	**Records;** The unknown gas formed is ethyne Expected laboratory set-up: 
Step 5 Presentations of group Vee Diagram	10	Teacher asks each group to present their Vee diagram worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the Vee diagramming worksheet contains highlight of the thinking and the experimental findings for each group) Teacher then asks the term leaders or appointed group representatives to come out and make their presentations.	Term leaders or selected group representatives makes their respective presentations in full class discussion while member watch, listen, discuss and make contributions at the end of each presentation.

Step 6 Summary and Final Class Vee Diagram	5	After presentations of Vee diagram has been done. Teacher then invite the class to discuss which thinking and experimental finding they now think are best. (This exercise is valuable for both the students and the teacher. Having full-class discussion will helps the students to reconcile any conflict between their thinking and experimental findings) (When students correlate their thinking with their experimental findings, they reconstruct their thinking). Teacher then harmonizes the ideas from the respective diagrams posted on the board into one class diagram. Eventually a Vee diagram that depicts the understanding of the entire class is drawn. Teacher ask the students to disengage from their groupings	Students reconcile any conflict between their groups Vee diagram with the entire class Vee diagram. At this stage, students try to reconstruct their thinking. Students then move to their respective sits
Step 7 Evaluation	5	Evaluates the lesson by asking the following questions; 1. mention the sources of alkynes you know 2. mention some physical properties of some alkynes Encourages students to copy the final class Vee diagram and to submit a neatly drawn and beautifully arranged individual Vee diagrams the next class.	Students answer the questions asked. Students will perform all the tasks given by the teacher and they are also allowed to ask questions
	75		

Summary: (5 minutes)

Teacher summarizes the lesson thus;

Alkynes are generally non polar molecules with little solubility in polar solvents, such as water. Solubility in non polar solvents, such as ether and acetone, is extensive. Like the alkanes and alkenes, alkynes of four or fewer carbon atoms tend to be gases. Substituted alkynes have small dipole moments due to difference in electronegativity between the triple-bonded carbon atoms, which are sp hybridized, and the single-bonded carbon atoms, which are Sp^3 hybridized. The sp-hybridized carbon atoms, which possesses more “s” character than the sp3 hybridized carbon atom, is more electronegative in character.

Assignment:

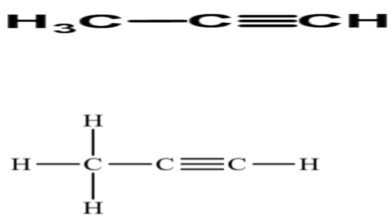
Teacher gives the students take home assignment due for submission the next class

1. mention 4 uses of alkynes
2. Draw the structure of propyne

Expected answer to assignment question:

1. Alkyne is useful for artificial ripening and preservation of fruits.
2. It is useful in acetylene lamps to generate light.
3. Alkyne is used to prepare various organic compounds
4. Alkyne is useful to manufacture important organic compounds like acetic acid and so on

Structure of propyne



Conceptual (Thinking) | **Focus Question** | **Methodology (Doing)**

Focus Question: carryout the laboratory preparation of unknown "X" member of alkynes?

ASSOCIATED WORDS:
Ethyne (C_2H_2), propyne (C_3H_4), butyne (C_4H_6), pentyne (C_5H_8), hexyne (C_6H_{10}), heptyne (C_7H_{12}), and so on

PHILOSOPHY:
Alkynes are unsaturated hydrocarbon that at least one carbon-carbon triple bond
Sources of alkynes are crude oil and natural gas
Alkynes are also found in nature in plants and in
TRANSFORMATIONS:
and in some animals possess physiological functions.

THEORY:
Ethyne as the simplest member of alkynes is a colourless gas with a characteristic sweet smell when pure; It is lighter than air; It faint garlic odour; It is slightly soluble in water; Ethyne is completely soluble in organic solvents; It has a melting point of -81°C and a boiling point of -84°C; It is unstable and may explode on compression to a liquid. Ethyne burns in air with sooty flame and gives carbon dioxide, water and heat. $2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$ + heat
Ethyne on addition with hydrogen forms initially ethene and finally forms ethane. Ethyne reacts with halogen acids to form 1,2-Tetra halo ethanes.

PRINCIPLES:
The general molecular formula for alkynes is C_nH_{2n-2} and functional group of $C \equiv C$ and it prefix is -yne"

CONCEPTS:
Ethyne as a simplest member of alkyne is useful for artificial ripening and preservation of fruits; It is useful in acetylene lamps to generate light; Ethyne is used to prepare various organic compounds**;** It is useful to manufacture important organic compounds like acetic acid and polymers like PVC; it is useful to produce an oxyacetylene flame;

Interplay

KNOWLEDGE CLAIM:

Ethyne gas is formed
$CaC_2 + 2H_2O \longrightarrow C_2H_2 + Ca_2(OH)_2$ contains

Test	Observation
Unknown gas+ ignition	Burns with smoky flame
Unknown gas + bromine water	The unknown gas turns the reddish colour of bromine to colourless
Unknown gas + $KMnO_4$	The unknown gas turns the yellowish colour of $KMnO_4$ to colourless

CONSTRUCTS:
The knowledge claim is based on fact that the ethyne gas undergoes incomplete combustion, the gas burn to produce smoky flame due to the presence of C-C triple bond

RECORDS:
The unknown gas produced is ethyne

EVENTS AND/OR OBJECTS

(a) Place 2-3 pieces of calcium carbide in a buchner flash (b) seal the flash with a stopper with a dropping funnel and a gas-delivery tube. The gas-delivery tube should look upwards trough water.(c) add water from the thistle or dropping funnel, a few drops at a time, until all the calcium carbide has reacted (d) note that during this reaction, an unknown gas will be produce (e) collect 3 test tube of the gas and put a stopper on each tube when it is filled (f) when the test tubes have all been filled (g) test each the unknown gas collected through combustion (ignition), addition of bromine water, and addition of acidified $KMnO_4$ respectively (h)Then, record your observation and inference. **Objects:** Bunsen burner, beaker, soda lime, salt of fatty acid sodium acetate and sodium hydroxide reagents

Fig 15: End Product of Vee Diagramming for Alkyne

LESSON 4:	**FOR EXPERIMENTAL GROUP 2 (VEE HEURISTIC STRATEGY)**
School:	As Applicable
Subject:	Chemistry (Organic Chemistry)
Specific Topic:	Alkanols
Class:	SS II
Number in class:	As Applicable
Average Age:	16 Years
Sex:	Mixed
Time:	80 minutes
Date:	As Applicable

Behavioural objectives: By the end of the lesson, students should be able to:

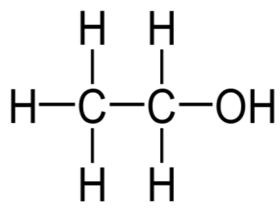
1. define the term alkanol;
2. write general formula of alkanols;
3. mention the two classes of alkanols;
4. mention at least four physical properties of some alkanols;
5. draw the structure of ethanol accurately;
6. clearly describe at least three chemical properties of ethanol;
7. carefully carryout the laboratory preparation of ethanol;
8. mention at least four uses of alkanols; and
9. construct Vee diagram of the concept of alkanols.

Instructional Materials: Distilled water, ethene, H_2SO_4, beaker, bunsen burner

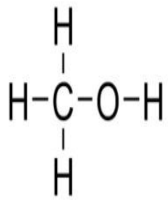
Previous knowledge: Students have studied alkynes.

Lesson Presentation

Content Development	Time (mins)	Teacher's activities	Students' activities
Step 1 Introduction/ establishing a learning set	5	Arouses students' interest and motivates them to learn. Tell students the objectives of the lesson. Probes into students' prior knowledge through questions such as: What are alkynes? What are alkanols?	Answer the question verbally. They are encouraged to write down the right ideas Expected answers: Alkynes an unsaturated hydrocarbon that contains at least one carbon-carbon triple bond with general molecular formula $CnH_2n\text{-}_2$ and functional group of C=C and it prefix is "-yne" Alkanol are characterized by one or more hydroxyl groups attached to a carbon atom of an alkyl group with general molecular formula $CnH_{2n+1}OH$ and functional group of OH and it prefix is "-nol"
		Makes known to the students the teaching technique and its demand on them Briefly explains that the simpler members of alkanol family is methanol (CH_3OH), ethanol (C_2H_5OH) and other members are propanol (C_3 H_7OH), butanol (C_4H_9OH), Pentanol ($C_5H_{11}OH$), Hexanol ($C_6H_{13}OH$), Heptanol.	Jot down some points as the teacher speaks. May ask questions for clarification

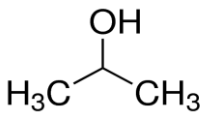
Step 2 Formation of Groups/Pooling of ideas	15	Teacher share students out into groups of 4-7; ask them to assume the role of captain, recorder, time-keeper and so on. Elicits ideas from the students. Asks the students to mention the sources of alkanol they know? Asks the students to draw the structure of ethanol (C_2H_5OH). Asks the students the mention the physical properties of ethanol they know?	Students move to their respective groups and assume their different roles as agreed by members Give responses to the questions based on prior knowledge Students answer the question verbally. They are encouraged to write down the right ideas Expected answers The common natural sources of alcohol are often isolated from volatile oils of plants, and in most animal tissues (and abundant in egg yolks), and also extracted from fish liver oils. Students answer the question by drawing it on pieces of papers. Expected answer:  Ethanol Expected answer: i. Ethanol is flammable, colourless liquid.

		Asks the students the uses of ethanol they know?	ii. It has a boiling point of 78.5ºC and a melting point of -114.5ºC iii. It has a pleasant sharp smell iv. It is highly soluble in water and organic solvents, but poor soluble in fat and oils. Expected answers: i. Ethanol is a constituent of alcoholic beverages such as beer, wine, whisky and other liquors. ii. A mixture of ethanol and water has much lower freezing point than that of water. This mixture is known as antifreeze and is used in radiators of vehicles in cold country iii. It is also used as solvent for resins, fats, oils, fatty acid and hydrocarbon iv. Ethanol is used to sterilize wounds and syringes v. In the manufacturing of dyes, drugs and detergents
		Briefly explains to students the classes of alkanol as primary alkanol, secondary alkanol and tertiary alkanol as follows: i. Primary alkanol: Is an alkanol which has one alkyl group on the carbon atom carrying the OH group	Listen to teacher's explanation and they are asked to increase their list of fact and concepts on alkynes as the lesson progresses as well as write out responses to the questions asked by the teacher. May ask questions for clarification



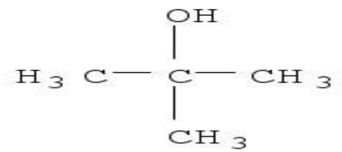
Methanol

ii. Secondary alkanol: Is an alkanol which has two alkyl group on the carbon atom carrying the OH group



2-propanol

iii. Tertiary alkanol: Is an alkanol which has three alkyl group on the carbon atom carrying the OH group



2-methylpropan-2-ol

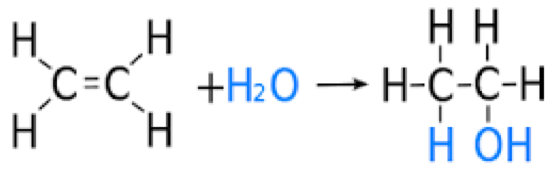
Describe chemical properties of ethanol as follows:

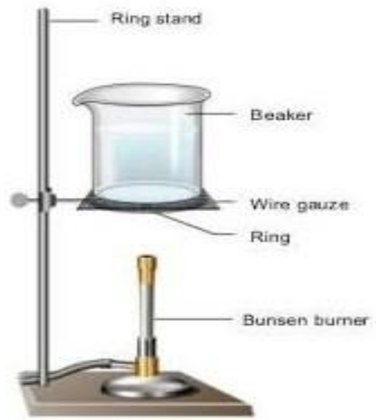
i. With alkanoic acid: Ethanol reacts with ethanoic acid in the presence of concentrated tetraoxosulphate (VI) acid to form ethyl ethanoate and water. This process is often referred to as esterification.

		$$\underset{\text{Ethanoic acid}}{CH_3COOH(\ell)} + \underset{\text{Ethanol}}{C_2H_5OH(\ell)} \xrightarrow{\text{Conc. } H_2SO_4} \underset{\text{Ethyl Ethanoate}}{CH_3COOC_2H_5(\ell)} + H_2O(\ell)$$ ii. Dehydration: Ethanol when heated with conc. H_2SO_4 at 443K or Al_2O_3 undergoes dehydration $$\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow[443\ K]{H_2SO_4} \underset{\text{Ethene}}{CH_2{=}CH_2} + H_2O$$ iii. Oxidation with acidified potassium dichromate: Ethanol is oxidized to ethanoic acid with the help of acidified $K_2Cr_2O_7$ $$\underset{\text{Ethanol}}{CH_3CH_2OH+2[O]} \xrightarrow{K_2Cr_2/H_2SO_4\ (\text{Conc.})} \underset{\text{Ethanoic acid}}{CH_3COOH} + H_20$$	
Step 3 Group Brainstorming (Thinking Aloud)	15	Ask students to write out all facts, ideas or thought that they feel based on their prior experience on the conceptual or theoretical side (Thinking side) of V-shaped diagram under the following Vee heuristic conceptual epistemological elements; associated words, theory, principles, constructs and relevant concepts in relation to the focus question(s) raised thus far.	At this stage as students brainstorm they write out clearly on the small pieces of papers the various facts or ideas/ thought in relation to the focus question. All members within each group spread out their papers on a flat surface, where it can easily be read. Have a look at each other's write up and make quick comments. The recorder for the group or whoever is assigned to organizes their thoughts as

		In this instance, the focus question is; Illustrate the laboratory preparation of ethanol been a simplest member of alkanols They are to compare individual answers and collectively brainstorm to come out with group ideas/thought. Ideas/facts or thought to be written down on the Vee diagram by the recorder are those agreed upon by the entire group. Teacher views the ideas or thoughts written down by the respective groups	agreed upon by the group embark on assembling the thoughts on the conceptual or theoretical side (thinking side) of the Vee diagram on a Vee diagramming worksheet provided by the teacher (Cardboard). Expected Answer: They are expected to come up with a list comprising the following on the thinking side of the Vee diagram; **Associated words:** Ethanol (C_2H_5OH) and other members are propanol ($C_3 H_7OH$), butanol (C_4H_9OH), Pentanol ($C_5H_{11}OH$), Hexanol ($C_6H_{13}OH$), Heptanol ($C_7H_{15}OH$), Octanol ($C_8H_{17}OH$) and so on. **Philosophy/epistemology:** Alkanol are characterized by one or more hydroxyl groups attached to a carbon atom of an alkyl group. The common natural sources of alcohol are often isolated from volatile oils of plants, and in most animal tissues (and abundant in egg yolks), and also extracted from fish liver oils **Theory:** Ethanol as the member of alkanol is flammable, colourless liquid; It has a boiling point of 78.5^oC and a melting point of -114.5^oC; It has a pleasant sharp smell; It is highly soluble in

			water and organic solvents, but poor soluble in fat and oils. Ethanol reacts with sodium to form sodium ethoxide and hydrogen gas; ethanol reacts with ethanoic acid in the presence of concentrated tetraoxosulphate (VI) acid to form ethyl ethanoate and water; Ethanol is oxidized to ethanoic acid with the help of acidified $K_2Cr_2O_7$ **Principle:** The general molecular formula for alkanol is $CnH_{2n+1}OH$ and functional group of OH and it prefix is "-nol" **Concept:** Classes of alkanol as primary alkanol, secondary alkanol and tertiary alkanol. Ethanol as a member of alkanol family is a constituent of alcoholic beverages such as beer, wine, whisky and other liquors; A mixture of ethanol and water has much lower freezing point than that of water. This mixture is known as antifreeze and is used in radiators of vehicles in cold country; It is also used as solvent for resins, fats, oils, fatty acid and hydrocarbon; Ethanol is used to sterilize wounds and syringes; In the manufacturing of dyes, drugs and detergents; As a petrol substitute ethanol can be mixed with petrol to the extent of 25% and used as fuel in internal combustion engines; Ethanol is used in preparation of large number organic

			compounds such as chloroform, iodoform, ethanoic acid, ethanol and so on
Step 4 Group Carrying out Learning Task (Doing)	20	Teacher asks the students to carrying out learning task or laboratory activities in order to answer the focus question. They are to compare individual answers and collectively brainstorm to come out with group experimental findings. The findings of the learning task are recorded using Vee heuristic methodological epistemological elements which include; value claims, knowledge claims (facts), transformations and records by the recorder for the group or whoever is assigned to organizes their experimental findings as agreed upon by the group on the methodological side (doing side) of the Vee diagram. Teacher views the experimental findings written down by the respective groups. Teacher then encourage students to finally come out with one well laid out Vee diagram with conceptual and methodological appropriately linked, representing the thought and experimental findings of the group on the focus question(s).	Students engage in the learning task as directed by the teacher. They follow the instructions step by step. All members within each group spread out their papers on a flat surface, where it can easily be read. Have a look at each other's write up and make quick comments. The recorder for the group or whoever is assigned to organizes their experimental findings as agreed upon by the group embark on assembling the findings on the methodological side (doing side) of the Vee diagram on a pieces of paper or cardboard. Expected Answer: In this instance, they are expected to come up with a list comprising the following on the doing side of the Vee diagram; **Knowledge claims;** Ethanol is formed or 

		In this instance, teacher asks students to carry out the following learning task or laboratory activities in order to answer the focus question (preparation of methane) using sodium acetate and sodium hydroxide reagents as follows: Teacher asks the students to carry out the laboratory activities for the preparation of X (ethanol) by hydration of ethene as follows: 1. Pour 5gram of ethene into a buchner beaker 2. Add 10gram of water to the beaker containing the ethene and mix thoroughly. 3. Add 2grams of dilute sulfuric acid (H_2SO_4) to the beaker containing mixture of ethene and water 4. Heat the mixture slightly, then record your observation Expected observation: "A colourless unknown liquid is formed" 5. Divide the "X" unknown liquid into three portions in test tube 6. Test the "X" liquid using odour, combustion, and potassium dichromate ($K_2Cr_2O_7$) respectively. 7. Then record your observation and inference and also write the chemical equation for the reaction	**Transformations;** Pleasant odour reminiscent of whiskey The unknown liquid burn with a blue fire The unknown liquid change yellowish colour of $K_2Cr_2O_7$ to green **Constructs:** The knowledge claim is based on the fact that oxidation occurs, and then the orange solution containing dichromate (VI) ions is reduced to a green solution containing chromium (III) ions. **Records;** The unknown liquid formed is ethanol Expected Laboratory set-up: 

Step 5 Presentations of group Vee Diagram	10	Teacher asks each group to present their Vee diagram worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the Vee diagramming worksheet contains highlight of the thinking and the experimental findings for each group) Teacher then asks the term leaders or appointed group representatives to come out and make their presentations.	Term leaders or selected group representatives makes their respective presentations in full class discussion while member watch, listen, discuss and make contributions at the end of each presentation.
Step 6 Summary and Final Class Vee Diagram	5	After presentations of Vee diagram has been done. Teacher then invite the class to discuss which thinking and experimental finding they now think are best. (This exercise is valuable for both the students and the teacher. Having full-class discussion will helps the students to reconcile any conflict between their thinking and experimental findings) Teacher then harmonizes the ideas from the respective diagrams posted on the board into one class diagram. Eventually a Vee diagram that depicts the understanding of the entire class is drawn. Teacher ask the students to disengage from their groupings	Students reconcile any conflict between their groups Vee diagram with the entire class Vee diagram. At this stage, students try to reconstruct their thinking. (When students correlate their thinking with their experimental findings, they reconstruct their thinking). Students then move to their respective sits

Step 7 Evaluation	5	Evaluates the lesson by asking the following questions; 1. mention the classes of alkanols 2. mention some physical properties of some alkanols Encourages students to copy the final class Vee diagram and to submit a neatly drawn and beautifully arranged individual Vee diagrams.	Students answer the questions asked. Students will perform all the tasks given by the teacher and they are also allowed to ask questions
	75		

Summary: (5 minutes)

Teacher summarized the lesson thus;

The industrial and local production of ethanol is through fermentation process. It involves the production of ethanol by the enzymatic hydrolysis of complex molecule (polysaccharide) in the absence of air. The fermented liquor contains up of to 10% ethanol and is used in drinks.

Assignment:

Teacher gives the students take home assignment due for submission the next class

i. Mention three uses of alkanols

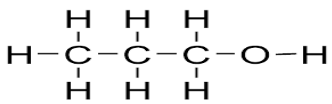
ii. Draw the structure of propanol

Expected assignment answers:

i. It is also used as solvent for resins, fats, oils, fatty acid and hydrocarbon

ii. Ethanol is used to sterilize wounds and syringes

iii. In the manufacturing of dyes, drugs and detergents and so on



Propanol

Conceptual (Thinking) **Focus Question** **Methodology (Doing)**

carryout the laboratory preparation of unknown "X" member of alkanol?

ASSOCIATED WORDS:
Ethanol (C_2H_5OH), propanol (C_3H_7OH), butanol (C_4H_9OH), Pentanol ($C_5H_{11}OH$), Hexanol ($C_6H_{13}OH$), Heptanol ($C_7H_{15}OH$)

PHILOSOPHY:
Alkanol are characterized by one or more hydroxyl groups attached to a carbon atom of an alkyl group. The common natural sources of alcohol are often isolated from volatile oils of plants, and in most animal tissues (and abundant in egg yolks), and also extracted from fish liver oils

THEORY:
Ethanol as the member of alkanol is flammable, colourless liquid; It has a boiling point of 78.5^oC and a melting point of -114.5^oC; It has a pleasant sharp smell; It is highly soluble in water and organic solvents, but poor soluble in fat and oils. Ethanol reacts with sodium to form sodium ethoxide and hydrogen gas; ethanol reacts with ethanoic acid in the presence of concentrated tetraoxosulphate (VI) acid to form ethyl ethanoate and water; Ethanol is oxidized to ethanoic acid with the help of acidified $K_2Cr_2O_7$

PRINCIPLES:
The general molecular formula for alkanol is $C_nH_{2n+1}OH$ and functional group of OH and it prefix is "-nol"

CONCEPTS:
Classes of alkanol are primary alkanol, secondary alkanol and tertiary alkanol. Ethanol as a member of alkanol family is a constituent of alcoholic beverages such as beer, wine, whisky and other liquors; This mixture is known as antifreeze and is used in radiators of vehicles in cold country; It is also used as solvent for resins, fats, oils, fatty acid and hydrocarbon; Ethanol is used to sterilize wounds and syringes; it is used in manufacturing of dyes, drugs and detergents.

Interplay

KNOWLEDGE CLAIM:

Ethanol is formed

$$C_2H_4 + H_2O \xrightarrow{\text{dil.}H_2SO_4\text{Catalyst}} C_2H_5OH$$

TRANFORMATIONS:

Test	Observation
Unknown liquid+ odour	It has pleasant odour reminiscent of whiskey
Unknown liquid + ignition	The unknown liquid burn with a blue fire
$K_2Cr_2O_7$ + Unknown liquid	The unknown liquid change yellowish colour of $K_2Cr_2O_7$ to green

CONSTRUCTS:
The knowledge claim is based on the fact that oxidation occurs, and the orange solution containing di-chromate (VI) ions is reduced to a green solution containing chromium (III) ions.

RECORDS:
The unknown liquid is ethanol

EVENTS AND/OR OBJECTS

(a) Pour 5gram of ethene into a buchner beaker (b) add 10gram of water to the beaker containing the ethene and mix thoroughly.(c) add 2grams of dilute sulfuric acid (H_2SO_4) to the beaker containing mixture of ethene and water (d) heat the mixture slightly, then record your observation (e) expected observation: "A colourless unknown liquid is formed" (f) Divide the "X" unknown liquid into three portions in test tube (g) test the "X" liquid using odour, combustion, and potassium dichromate ($K_2Cr_2O_7$) respectively. (h) then record your observation and inference and also write the chemical equation for the reaction. **Objects:** Distilled water, ethene, H_2SO_4, beaker and bunsen burner.

Fig 16: End Product of Vee Diagramming for Alkanol

LESSON 5	**FOR EXPERIMENTAL GROUP 2 (VEE HEURISTIC STRATEGY)**
School:	As Applicable
Subject:	Chemistry
Specific Topic:	Alkanoic Acids (Carboxylic Acids)
Class:	SS II
Number in Class:	As Applicable
Average Age:	16 Years
Sex:	Mixed
Time:	80 minutes
Date:	As Applicable

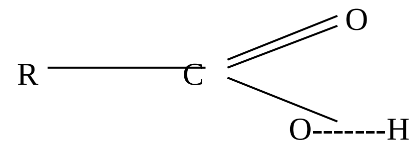
Behavioural objectives: By the end of the lesson, students should be able to;

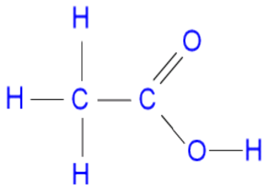
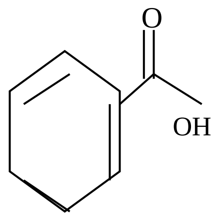
1. define the term alkanoic acids;
2. write general formula of alkanoic acids;
3. mention the classes of alkanoic acids with examples;
4. state at least three physical properties of some of the alkanoic acids;
5. draw the structure of ethanoic and phenylmethanoic (benzoic) acids accurately;
6. describe at least three chemical properties of alkanoic acid;
7. carefully carry out the laboratory preparation of ethanoic acid;
8. mention at least four uses of alkanoic acids; and
9. construct Vee diagram of the concept of alkanoic acids.

Instructional Materials: Ethanoic acid, hydrogen chloride, hydrogen tetraoxosulphate (iv)

Previous knowledge: Students have studied alkanols

Lesson Presentation

Content Development	Time (mins)	Teacher's activities	Students' activities
Step 1 Introduction/ establishing a learning set	5	Teacher arouses students' interest and motivates them to learn. Tell students the objectives of the lesson. Probes into students' prior knowledge through questions such as: what are alkanol? What are alkanoic acids? Makes known to the students the teaching technique and its demand on them Briefly explains that alkanoic acids are classified into two namely: Aliphatic carboxylic acids and aromatic carboxylic acids. Ethanoic and phenylmethanoic (benzoic) acids are examples of Aliphatic carboxylic acids and aromatic carboxylic acids respectively	Students answer the question verbally. They are encouraged to write down the right ideas Expected answers: Alkanol are characterized by one or more hydroxyl groups attached to a carbon atom of an alkyl group with general with general molecular formula $C_nH_{2n+1}OH$ Alkanoic acids also known as organic or carboxylic acids, that contain the carboxyl group, -COOH, as their functional group with general molecular formula $CnH_2n+COOH$  Jot down some points as the teacher speaks. May ask questions for clarification

Step 2 Formation of Groups/Pooling of ideas	15	Teacher share students out into groups of 4-7; ask them to assume the role of captain, recorder, time-keeper and so on. Elicits ideas from the students. Ask the students to draw the structure of ethanoic and phenylmethanoic (benzoic) acids as examples aliphatic and aromatic carboxylic acids respectively Asks students to mentions the uses of ethanoic acid and benzoic acid they know?	Students move to their respective groups and assume their different roles as agreed by members Give responses to the questions based on prior knowledge Answer the question by drawing it on pieces of papers. Expected answers:  Ethanoic acid  Benzoic acid Expected answers: Ethanoic acid as an example of aliphatic carboxylic acid is used as follows: i. It is used as aspirin. ii. For making dyes in varnishes and iii. Used in the filter tips of cigarettes.

<table>
<tr>
<td></td>
<td></td>
<td>
Asks students to mentions the uses of benzoic acid they know
Briefly outlines the physical properties of the first few members of the alkanoic acids listing the molecular formula, structure, IUPAC name, common name, physical state, density, boiling and melting point and also discusses the chemical properties as follows:
<table>
<tr><th>Molecular formula</th><th>Structural formula</th><th>IUPAC name</th><th>Common name</th></tr>
<tr><td>CH_2O_2</td><td>HCOOH</td><td>Methanoic acid</td><td>Formic acid</td></tr>
<tr><td>$C_2H_4O_2$</td><td>HCOOH</td><td>Ethanoic acid</td><td>Acetic acid</td></tr>
<tr><td>$C_3H_6O_2$</td><td>CH_3COOH</td><td>Propanoic acid</td><td>Propanoic acid</td></tr>
<tr><td>$C_7H_6O_2$</td><td>C_6H_5COOH</td><td>Benzoic acid</td><td>phenylmethanoic acid</td></tr>
</table>
<table>
<tr><th colspan="2">Properties</th><th rowspan="2">Boiling point</th><th rowspan="2">Melting point</th><th rowspan="2">Density g/cm^3</th></tr>
<tr><th>Name</th><th>Physical state</th></tr>
<tr><td>Methanoic acid</td><td>Colourless Liquid</td><td>101^oC</td><td>8^oC</td><td>1.226</td></tr>
<tr><td>Ethanoic acid</td><td>Colourless Liquid</td><td>118^oC</td><td>17^oC</td><td>1.049</td></tr>
</table>
</td>
<td>
Expected answers:
i. Benzoic acid is widely used as a preservative
ii. It is used in the manufacture of various cosmetics, dyes, plastics, and
iii. It is also used in insect repellents.
Listen to the teacher explanation and they are asked to increase their list of ideas, fact, and thought on alkanoic acids as the lesson progresses as well as write out responses to the questions asked by the teacher.
May asks questions for clarifications
</td>
</tr>
</table>

Propanoic acid	Colourless Liquid	141ºC	-22ºC	0.992
Benzoic acid	Colourless Crystalline solid	164ºC	122ºC	1.2659

Explain the chemical properties of alkanoic acid as follows:

i. Acidic property: Carboxylic acids are weak acids and their carboxylic anions are strong conjugate bases are slightly alkaline due to the hydrolysis of carboxylate anion compared to other species, the order of acidity and basicity or corresponding conjugate bases are as follows:

(a) $2CH_3COOH + CaCO_3 \rightarrow (CH_2COO)_2 + H_2O + CO_2$

(b) $2CH_3COOH + Mg \rightarrow (CH_3COO)_2 + H_2 (g)$

(c) CH3COOH+ NaOH $\rightarrow CH_3COONa + H_2O$

ii. Ester formation: Carboxylic acids are esterified with alcohols or phenols in the presence of a mineral acid such as concentrated H_2SO_4 or HCl gas as a catalyst

$$RCOOH + R'OH \xrightleftharpoons{H^+} RCOOR' + H_2O$$

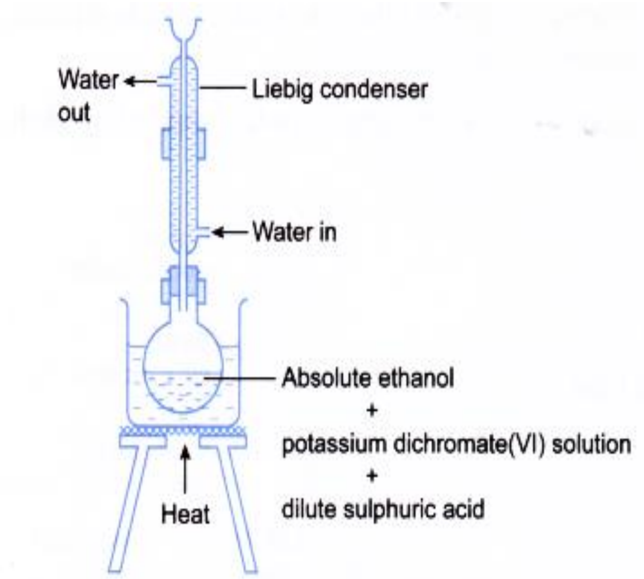
This reaction is reversible and the same catalyst, hydrogen ion, that catalyzes the forward reaction i.e. esterification necessarily catalyzes the reverse reaction i.e. hydrolysis.

Step 3 Group Brainstorming (Thinking Aloud)	15	Instructs students to write out all facts, ideas or thought that they feel based on their prior experience on the conceptual or theoretical side (Thinking side) of V-shaped diagram under the following Vee heuristic conceptual epistemological elements; associated words, theory, principles, constructs and relevant concepts in relation to the focus question(s) raised thus far. In this instance, the focus question is; Illustrate the laboratory preparation of ethanoic acid as a simplest member of aliphatic carboxylic acids? They are to compare individual answers and collectively brainstorm to come out with group ideas/thought. Ideas/facts or thought to be written down on the Vee diagram by the recorder are those agreed upon by the entire group. Teacher views the ideas or thoughts written down by the respective groups	At this stage as students brainstorm they write out clearly on the small pieces of papers the various facts or ideas/ thought in relation to the focus question. All members within each group spread out their papers on a flat surface, where it can easily be read. Have a look at each other's write up and make quick comments. The recorder for the group or whoever is assigned to organizes their thoughts as agreed upon by the group embark on assembling the thoughts on the conceptual or theoretical side (thinking side) of the Vee diagram on a Vee diagramming worksheet provided by the teacher (Cardboard). Expected Answer: In this instance, the focus question is; they are expected to come up with a list comprising the following on the thinking side of the Vee diagram; **Associated words:** Aliphatic carboxylic acids and aromatic carboxylic acids. Ethanoic and phenylmethanoic (benzoic) acids are examples of Aliphatic carboxylic acids and aromatic carboxylic acids respectively

			Philosophy/epistemology: Alkanoic acids also known as organic or carboxylic acids, that contain the carboxyl group, -COOH, **Theory:** Carboxylic acids are weak acids and their carboxylic anions are strong conjugate bases are slightly alkaline due to the hydrolysis of carboxylate anion compared to other species, the order of acidity and basicity or corresponding conjugate bases Carboxylic acids are esterified with alcohols or phenols in the presence of a mineral acid such as concentrated H_2SO_4 or HCl gas as a catalyst **Principle:** The general molecular formula for alkanoic acids is $CnH_2n+COOH$ and functional group of -COOH, and it prefix is "-noic" **Concept:** Ethanoic acid as an example of aliphatic carboxylic acid is used as aspirin; For making dyes in varnishes and also used in the filter tips of cigarettes.

Step 4 Group Carrying out Learning Task (Doing)	20	Teacher asks the students to carrying out learning task or laboratory activities in order to answer the focus question. They are to compare individual answers and collectively brainstorm to come out with group experimental findings. The findings of the learning task are recorded using Vee heuristic methodological epistemological elements which include; value claims, knowledge claims (facts), transformations and records by the recorder for the group or whoever is assigned to organizes their experimental findings as agreed upon by the group on the methodological side (doing side) of the Vee diagram. Teacher views the experimental findings written down by the respective groups. Teacher then encourage students to finally come out with one well laid out Vee diagram with conceptual and methodological appropriately linked, representing the thought and experimental findings of the group on the focus question(s). Teacher serves as facilitator guiding the students in various groups to do the right thing In this instance, teacher asks students to carry out the following learning task or laboratory activities in order to	Students engage in the learning task as directed by the teacher. They follow the instructions step by step. All members within each group spread out their papers on a flat surface, where it can easily be read. Have a look at each other's write up and make quick comments. The recorder for the group or whoever is assigned to organizes their experimental findings as agreed upon by the group embark on assembling the findings on the methodological side (doing side) of the Vee diagram on a pieces of paper or cardboard. Expected Answer: In this instance, they are expected to come up with a list comprising the following on the doing side of the Vee diagram; **Knowledge claims;** Ethanoic acid is formed $CH_3CH_2OH(aq) + 2[O] \longrightarrow CH_3COOH(g) + H_2O$ **Transformations;** The unknown gas has a vinegar odour. The unknown gas Changes colour from green to red Effervescence, Hydrogen gas generated Effervescence, carbon dioxide gas generated

		answer the focus question (preparation of methane) using sodium acetate and sodium hydroxide reagents as follows: Teacher asks the students to carry out the laboratory activities for the preparation of ethanoic acid by the oxidation of ethanol using sodium dichromate solution, sulfuric acid, pear shaped flask and so on as follows: 1. Put a few anti-bumping granules and $10cm^3$ of dilute sulfuric acid in the round bottomed or pear shaped flask. 2. In a fume cupboard, add in 9g of sodium dichromate and dissolve by careful swirling. 3. Use a small dry funnel to avoid crystals of dichromate being caught on the neck of the flask. 4. Slowly with swirling and cooling in an ice bath, add 6cm3 of concentrated sulfuric acid. 5. Mix $2cm^3$ of ethanol and $10cm^3$ of deionised water in the dropping funnel. Add the solution from the dropping funnel drop wise down the condenser, while swirling the contents of the flask and cooling it if necessary to prevent too vigorous a reaction. 6. Direct heating without water bath must be used, as the boiling point of the mixture will eventually exceed	**Constructs:** The knowledge claim is based on the fact that the sharp tasting liquid with the characteristics vinegar smell is associated with ethanoic acid. **Records;** The unknown gas formed is ethanoic acid

		100°C 7. Distill off about 15cm^3. This is aqueous "X" acid 8. Divide the distillate into three portions in test tube 9. Test the aqueous "X" acid using odour, indicator paper magnesium, sodium carbonate respectively. 10. Then record your observation and inference and also write the chemical equation for the reaction.	Expected laboratory set-up:  ***Figure*** *Laboratory preparation of ethanoic acid*
Step 5 Presentations of group Vee Diagram	10	Asks each group to present their Vee diagram worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the Vee diagramming worksheet contains highlight of the thinking and the experimental findings for each group) Asks the team leaders or appointed group representatives to come out and make their presentations.	Team leaders or selected group representatives makes their respective presentations in full class discussion while member watch, listen, discuss and make contributions at the end of each presentation.

Step 6 Summary and Final Class Vee Diagram	5	After presentations of Vee diagram has been done. Teacher then invite the class to discuss which thinking and experimental finding they now think are best. (This exercise is valuable for both the students and the teacher. Having full-class discussion will helps the students to reconcile any conflict between their thinking and experimental findings) (When students correlate their thinking with their experimental findings). Teacher then harmonizes the ideas from the respective diagrams posted on the board into one class diagram. Eventually a Vee diagram that depicts the understanding of the entire class is drawn. Teacher ask the students to disengage from their groupings	Students reconcile any conflict between their groups Vee diagram with the entire class Vee diagram. At this stage, students try to reconstruct their thinking. Students then move to their respective sits
Step 7 Evaluation	5	Teacher evaluates the lesson by asking the following questions; 1. mention the classes of alkanoic acids with examples 2. state the physical properties of the alkanoic acids Teacher then encourages students to copy the final class Vee diagram and to submit a neatly drawn and beautifully arranged individual Vee diagrams the next class.	Students answer the questions asked. Students will perform all the tasks given by the teacher and they are also allowed to ask questions
	75		

Summary: (5 minutes)

Teacher summarizes the lesson thus;

Alkanoic acids or carboxylic acids are soluble in water. Carboxylic acids do not dimerise in water, but forms hydrogen bonds with water. Carboxylic acids are polar and due to the presence of the hydroxyl in the carboxyl group, they are able to form hydrogen bonds with water molecules. Smaller carboxylic acids (C1 to C5) are soluble in water, whereas larger carboxylic acids (C6 and above) are less soluble due to the increasing hydrophobic nature of the hydrocarbon chains.

Assignment:

Teacher gives the students take home assignment due for submission the next class

i. Mention three uses of carboxylic acid
ii. Draw the structure of propanoic acid

Expected answers to assignment questions:

1. Carboxylic acids make up a series of fatty acids which are extremely good for human health.
2. Carboxylic acids are used in manufacturing of soaps need higher fatty acids.
3. Carboxylic acids are used in food industry for the production of soft drinks and food products. For example, acetic acid is used in making vinegar

Conceptual (Thinking) **Focus Question** **Methodology (Doing)**

ASSOCIATED WORDS:
Aliphatic carboxylic acids and aromatic carboxylic acids. Ethanoic and benzoic acids are examples of Aliphatic carboxylic acids and aromatic carboxylic acids

PHILOSOPHY:
Alkanoic acids also known as organic or carboxylic acids, that contain the carboxyl group, -COOH,

THEORY:
Carboxylic acids are weak acids and their carboxylic anions are strong conjugate bases are slightly alkaline due to the hydrolysis of carboxy -late anion compared to other species, the order of acidity/basicity or corresponding conjugate bases
Carboxylic acids are esterified with alcohols or phenols in the presence of a mineral acid such as concentrated H_2SO_4 or HCl gas as a catalyst

PRINCIPLES:
The general molecular formula for alkanoic acids is CnH_2n+COOH and functional group of -COOH, and it prefix is "-noic"

CONCEPTS:
Ethanoic acid as an example of aliphatic carboxylic acid is used as aspirin; For making dyes in varnishes and also used in the filter tips of cigarettes. Carboxylic acids do not dimerise in water, but forms hydrogen bonds with water. Carboxylic acids are polar and due to the presence of the hydroxyl in the carboxyl group, they are able to form hydrogen bonds with water molecules.

carryout the laboratory preparation of unknown "X" member of aliphatic carboxylic acid?

Interplay

KNOWLEDGE CLAIM
Ethanoic acid is formed

$$CH_3CH_2OH(aq) + 2[O] \longrightarrow CH_3COOH(g) + H_2O$$

TRANSFORMATIONS:

Test	Observation
Unknown liquid +odour	Vinegar odour
Unknown liquid +Indicator paper	Changes colour from green to red
Unknown liquid +Magnesium strip	Effervescence, Hydrogen gas generated
Unknown liquid +sodium carbonate	Effervescence, Carbon dioxide gas generated

CONSTRUCT:
The knowledge claim is based on the fact that the sharp tasting liquid with the characteristics vinegar smell is associated with ethanoic

RECORDS:
The unknown acid is ethanoic acid

EVENTS AND/OR OBJECTS

(a) put a few anti-bumping granules and $10cm^3$ of dilute sulfuric acid in the round bottomed or pear shaped flask (b) in a fume cupboard, add in 9g of sodium dichromate and dissolve by careful swirling (c) use a small dry funnel to avoid crystals of dichromate being caught on the neck of the flask (d) Slowly with swirling and cooling in an ice bath, add 6cm3 of concentrated sulfuric acid (e) mix $2cm^3$ of ethanol and $10cm^3$ of deionised water in the dropping funnel. Add the solution from the dropping funnel drop wise down the condenser, while swirling the contents of the flask and cooling it if necessary to prevent too vigorous a reaction (f) direct heating without water bath must be used, as the boiling point of the mixture will eventually exceed 100^oC (g) distill off about $15cm^3$. This is aqueous "X" acid (h) divide the distillate into three portions in test tube (i) test the aqueous "X" acid using odour, indicator paper magnesium, sodium carbonate respectively (j) then record your observation and inference and also write the chemical equation for the reaction

Fig 17: End Product of Vee Diagramming for Alkanoic acid

LESSON 6: **EXPERIMENTAL GROUP 2 (VEE HEURISTIC STRATEGY)**

School: As Applicable

Subject: Chemistry (Organic Chemistry)

Specific Topic: Alkanoates (Esters)

Class: SS II

Number in Class: As Applicable

Average Age: 16 Years

Sex: Mixed

Time: 80 minutes

Date: As Applicable

Behavioural objectives: By the end of the lesson, students should be able to;

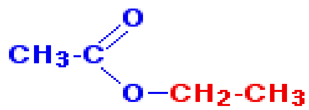
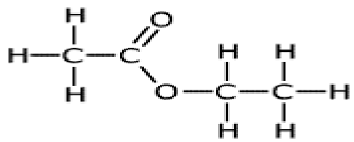
1. define the term esters;
2. clearly describe the process of esterification;
3. mention at least three physical properties of alkanoates;
4. draw the structure of ethyl ethanoate accurately;
5. clearly describe at least three chemical properties of ethyl ethanoate;
6. carefully carry out the laboratory preparation of ethyl ethanoate;
7. mention at least four uses of esters; and
8. construct Vee diagram of the concept of alkanoates (Esters)

Instructional Materials: ethanoic acid, test-tubes, 13-x 100-mm, beaker, 400ml, bunsen burner, ring and wire gauze.

Previous knowledge: Students have studied alkanoic acids

Lesson Presentation

Content Development	Time (mins)	Teacher's activities	Students' activities
Step 1 Introduction/ establishing a learning set	5	Arouses students' interest and motivates them to learn. Tell students the objectives of the lesson. Probes into students' prior knowledge through questions such as: what are carboxylic acids? What are esters? Makes known to the students the teaching technique and its demand on them Explains to the students that alkanoates has esters as their family name and contain the -RCOOR, as their functional group have the general formula (CnH_2nO_2). The standard system for naming esters uses the suffix "-oate" to indicate that a molecule is an ester.	Answer the question verbally. They are encouraged to write down the right ideas Expected answer: Carboxylic acids also known as organic or alkanoic acids, that contain the carboxyl group, -COOH, as their functional group with general molecular formula CnH_2n+COOH. Esters are the derivatives of the carboxylic acids in which the –OH part of the carboxylic group has been replaced by –OR group where, R may be alkyl or aryl group. Jot down some points as the teacher speaks. May ask questions for clarification

Step 2 Formation of Groups/Pooling of ideas	15	Teacher share students out into groups of 4-7; ask them to assume the role of captain, recorder, time-keeper and so on. Asks students to mention the sources of esters they know Asks students to draws the structure of ethyl ethanoate or ethyl acetate ($C_4H_8O_2$) or $CH_3COOCH_2CH_3$	Students move to their respective groups and assume their different roles as agreed by members Give responses to the questions based on prior knowledge Students answer the question verbally. They are encouraged to write down the right ideas. Expected answers Alkyl alkanoates or esters are found widely in nature. Short carbon chain simply alkyl alkanoates exist as liquids and have a characteristic pleasant odour. They occur in essential oils, many fruits and flowers and sometime called fruit essences because of their pleasant odours. Answer the question by drawing it on pieces of papers. Expected answer:  ethyl ethanoate or 

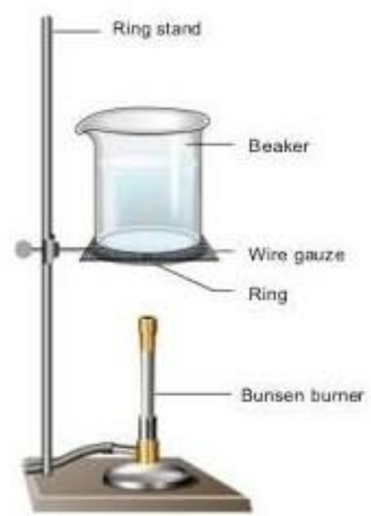
		Ask student to mention the physical properties ethyl ethanoate they know	Expected answers: i. It is colourless volatile liquid with a pleasant smell ii. It is slightly soluble in water but dissolve readily in organic solvent such as ethanol, acetone, ethoxyethane and benzene iii. It has a boiling point of 77.1 ^{0}C (170.8 ^{0}F) and melting point of -83.6 ^{0}C respectively. iv. It is less dense than water v. Ethyl acetate is highly flammable and the vapour mixtures can explodes
		Asks students to mentions the uses of ethyl ethanoate acid they know	Expected answers: i. Ethyl ethanoate is used primarily as a solvent and diluent. ii. It is commonly used to clear circuit boards and in some nail varnish removers. iii. It is also used as paints as an activator or hardener. iv. In the laboratory, mixtures containing ethyl ethanoate are commonly used in column chromatography and extractions. v. Ethyl ethanoate is the most common ester in wine, being the product of the most common volatile organic acid. vi. Ethyl ethanoate is an effective asphyxiant for use in insert collecting and study.

		Briefly describe the chemical properties of ethyl ethanoate as follows; i. Hydrolysis: ethyl ethanoate and other esters can be hydrolyzed to the corresponding carboxylic acid and ethanol. $CH_3COOC_2H_5 + H_20 \rightarrow CH_3COOH + C_2H_5OH$ ii. Reaction with ammonia $CH_3COOC_2H_5 + NH_3 \rightarrow C_2H_5OH + CH_3CONH_2$	Listen to the teacher explanation and they are asked to increase their list of ideas, fact, and thought on esters as the lesson progresses as well as write out responses to the questions asked by the teacher. May asks questions for clarifications
Step 3 Group Brainstorming (Thinking Aloud)	15	Teacher ask students to write out all facts, ideas or thought that they feel based on their prior experience on the conceptual or theoretical side (Thinking side) of V-shaped diagram under the following Vee heuristic conceptual epistemological elements; associated words, theory, principles, constructs and relevant concepts in relation to the focus question(s) raised thus far. They are to compare individual answers and collectively brainstorm to come out with group ideas/thought. Ideas/facts or thought to be written down on the Vee diagram by the recorder are those agreed upon by the entire group.	At this stage as students brainstorm they write out clearly on the small pieces of papers the various facts or ideas/ thought in relation to the focus question. All members within each group spread out their papers on a flat surface, where it can easily be read. Have a look at each other's write up and make quick comments. The recorder for the group or whoever is assigned to organizes their thoughts as agreed upon by the group embark on assembling the thoughts on the conceptual or theoretical side (thinking side) of the Vee diagram on a Vee diagramming worksheet provided by the teacher (Cardboard).

		Teacher views the ideas or thoughts written down by the respective groups	Expected Answer: In this instance, the focus question is; they are expected to come up with a list comprising the following on the thinking side of the Vee diagram; **Associated words:** Ethyl formate ($C_3H_6O_2$), ethyl ethanoate ($C_4H_8O_2$), ethyl propanoate ($C_5H_{10}O_2$). Esters in which $R_2 = CH_2CH_2CH_3$, is known as an "-propyl group" examples are; propyl formate ($C_4H_8O_2$), propyl ethanoate ($C_5H_{10}O_2$) and propyl propanoate ($C_6H_{12}O_2$). **Philosophy/epistemology:** Esters are the derivatives of the carboxylic acids in which the –OH part of the carboxylic group has been replaced by –OR group where, R may be alkyl or aryl group. Alkyl alkanoates or esters are found widely in nature. Short carbon chain simply alkyl alkanoates exist as liquids and have a characteristic pleasant odour. They occur in essential oils, many fruits and flowers and sometime called fruit essences because of their pleasant odours **Theory:** Ethyl ethanoate as a simplest ester is colourless volatile liquid with a pleasant smell; slightly soluble in water but dissolve

			readily in organic solvent such as ethanol, acetone, ethoxyethane and benzene; It has a boiling point of 77.1 ^{0}C (170.8 ^{0}F) and melting point of -83.6 ^{0}C respectively; It is less dense than water; Ethyl acetate is highly flammable and the vapour mixtures can explodes. Ethyl ethanoate and other esters can be hydrolyzed to the corresponding carboxylic acid and ethanol. Ethyl ethanoate reacts with ammonia to form ethanol **Principle:** The general molecular formula for alkanol is CnH_2nO_2 and functional group of RCOOR, and it suffix is "-oate" to indicate that $\bar{a}$ molecule is an ester. **Concept:** Ethyl ethanoate as a simplest form of ester is used primarily as a solvent and diluent; It is commonly used to clear circuit boards and in some nail varnish removers; It is also used as paints as an activator or hardener; In the laboratory, mixtures containing ethyl ethanoate are commonly used in column chromatography and extractions; ethyl ethanoate is the most common ester in wine, being the product of the most common volatile organic acid; ethyl ethanoate is an effective asphyxiant for use in insert collecting and study.

Step 4 Group Carrying out Learning Task (Doing)	20	Teacher asks the students to carrying out learning task or laboratory activities in order to answer the focus question. They are to compare individual answers and collectively brainstorm to come out with group experimental findings. The findings of the learning task are recorded using Vee heuristic methodological epistemological elements which include; value claims, knowledge claims (facts), transformations and records by the recorder for the group or whoever is assigned to organizes their experimental findings as agreed upon by the group on the methodological side (doing side) of the Vee diagram. Teacher views the experimental findings written down by the respective groups. Teacher then encourage students to finally come out with one well laid out Vee diagram with conceptual and methodological appropriately linked, representing the thought and experimental findings of the group on the focus question(s). Teacher serves as facilitator guiding the students in various groups to do the right thing In this instance, teacher asks students to carry out the following learning task or laboratory activities in order to	Students engage in the learning task as directed by the teacher. They follow the instructions step by step. All members within each group spread out their papers on a flat surface, where it can easily be read. Have a look at each other's write up and make quick comments. The recorder for the group or whoever is assigned to organizes their experimental findings as agreed upon by the group embark on assembling the findings on the methodological side (doing side) of the Vee diagram on a pieces of paper or cardboard. Expected Answer: In this instance, they are expected to come up with a list comprising the following on the doing side of the Vee diagram; **Knowledge claims;** Ethyl ethanoate acid is formed $\underset{\text{Ethanoic acid}}{CH_3COOH(\ell)} + \underset{\text{Ethanol}}{C_2H_5OH(\ell)} \xrightarrow{\text{Conc. } H_2SO_4}$ $\underset{\text{Ethyl Ethanoate}}{CH_3COOC_2H_5(\ell)} + H_2O(\ell)$ Or $CH_3COOH(aq)+CH_3CH_2OH \rightleftharpoons CH_3COOCH_2CH_3 + H_2O(L)$ Ethanoic acid+Ethanol→ Ethyl ethanoate+ Water

		answer the focus question (preparation of methane) using sodium acetate and sodium hydroxide reagents as follows: Teacher instructs students to carry out the following activities to illustrate the laboratory preparation of X (ethyl ethanoate or ester) through the process called esterification using ethanoic acid, ethanol and so on. Teacher ask the students to carry out the following activities: 1. Measure 2cm^3 of ethanol into test-tube (a) and 2cm^3 of ethanoic acid into test-tube (b) 2. Mix the two solution in a clean/dry test-tube (c) 3. Then add few drops of conc.H_2SO_4. Reflux for few minutes. 4. Heat the mixture slightly 5. Record the observation that occur in test-tube (c) Expected observation: "A colourless unknown liquid is formed" 6. Divide the "X" unknown liquid into three portions in test tube 7. Test the "X" liquid using odour, water, and potassium dichromate ($K_2Cr_2O_7$) respectively. 8. Then record your observation and inference and also write the chemical equation for the reaction	**Transformations;** The unknown liquid has a sweet fruity smell The unknown liquid is slightly soluble in water The unknown gas turns the orange colour of $K_2Cr_2O_7$ to green **Constructs:** The knowledge claim is based on the fact that ethylethanoate is slightly soluble in water because, it is less dense than water **Records;** The unknown liquid is ethylethanoate Expected laboratory set-up: 

Step 5 Presentations of group Vee Diagram	10	Teacher asks each group to present their Vee diagram worksheet in full-class discussion, by placing the worksheet on a chalkboard. (At this stage, the Vee diagramming worksheet contains highlight of the thinking and the experimental findings for each group) Teacher then asks the term leaders or appointed group representatives to come out and make their presentations.	Term leaders or selected group representatives makes their respective presentations in full class discussion while member watch, listen, discuss and make contributions at the end of each presentation.
Step 6 Summary and Final Class Vee Diagram	5	After presentations of Vee diagram has been done. Teacher then invite the class to discuss which thinking and experimental finding they now think are best. (This exercise is valuable for both the students and the teacher. Having full-class discussion will helps the students to reconcile any conflict between their thinking and experimental findings) (When students correlate their thinking with their experimental findings, they reconstruct their thinking). Teacher then harmonizes the ideas from the respective diagrams posted on the board into one class diagram. Eventually a Vee diagram that depicts the understanding of the entire class is drawn. Teacher ask the students to disengage from their groupings	Students reconcile any conflict between their groups Vee diagram with the entire class Vee diagram. At this stage, students try to reconstruct their thinking. Students then move to their respective sits

Step 7 Evaluation	5	Evaluates the lesson by asking the following questions; 1. describe the process of esterification; 2. mention two each of physical properties of alkanoates Encourages students to copy the final class Vee diagram and to submit a neatly drawn and beautifully arranged individual Vee diagrams the next class.	Students answer the questions asked. Students will perform all the tasks given by the teacher and they are also allowed to ask questions
	75		

Summary: (5 minutes)

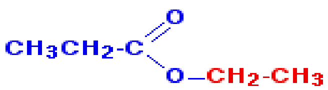
Teacher explains that esterification is the reaction of a carboxylic acid and alcohol in the presence of an acid catalyst to produce an ester. The main chain of an ester comes from the carboxylic acid, while the alkyl group in an ester comes from the alcohol. Teacher further explains that the reaction is extremely slow acid reversible at room temperature, and is catalyzed by a high concentration of hydrogen ions

Assignment:

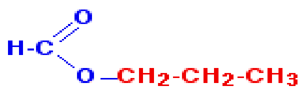
Teacher gives the students take home assignment due for submission the next class

Draw the structures of the following esters; ethyl propanoate, propyl methanoate, methyl butanoate, and propyl ethanoate.

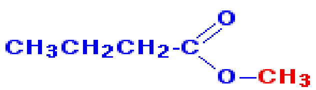
Expected answers to assignment questions:



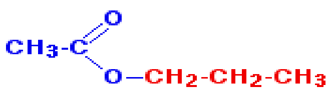
ethyl propanoate



propyl methanoate



methyl butanoate



propyl ethanoate

Conceptual (Thinking) | **Focus Question** | **Methodology (Doing)**

ASSOCIATED WORDS:
Ethyl ethanoate ($C_4H_8O_2$), ethyl propanoate ($C_5H_{10}O_2$), Propyl formate ($C_4H_8O_2$), propyl ethanoate ($C_5H_{10}O_2$) and propyl propanoate ($C_6H_{12}O_2$).

PHILOSOPHY:
Esters are the derivatives of the carboxylic acids in which the –OH part of the carboxylic group has been replaced by –OR group where, R may be alkyl or aryl group. Alkyl alkanoates or esters are found widely in nature. Short carbon chain simply alkyl alkanoates exist as liquids and have a characteristic pleasant odour. They occur in essential oils, many fruits and flowers.

THEORY:
Ethyl ethanoate as a simplest ester is colourless volatile liquid with a pleasant smell; slightly soluble in water but dissolve readily in organic solvent such as ethanol, acetone, ethoxyethane and benzene; It has a boiling point of 77.1 ^{0}C (170.8 ^{0}F) and melting point of -83.6 ^{0}C respectively; It is less dense than water; Ethyl acetate is highly flammable and the vapour mixtures can explodes. Esters can be hydrolyzed to the corresponding carboxylic acid and ethanol.
Ethyl ethanoate reacts with ammonia to form ethanol

PRINCIPLES:
The general molecular formula for alkanoates (ester) is CnH_2nO_2 and functional group of RCOOR, and it suffix is "-oate" to indicate that a molecule is an ester

CONCEPTS:
Ethyl ethanoate as a simplest form of ester is used primarily as a solvent and diluent; It is commonly used to clear circuit boards and in some nail varnish removers; It is also used as paints as an activator or hardener; In the laboratory, mixtures containing ethyl ethanoate are commonly used in column chromatography and extractions;

Focus Question: carryout the laboratory preparation of unknown "X" member of alkanoates?

Interplay ⟷

KNOWLEDGE CLAIM:
Ethyl ethanoate is formed
$CH_3COOH(aq) + CH_3CH_2OH \rightleftharpoons CH_3COOCH_2CH_3 + H_2O$

TRANSFORMATION:

Test	Observation
Unknown liquid + odour	The Sweet fruity smell was perceived
Unknown liquid + water	Slightly soluble in water
Unknown liquid + $K_2Cr_2O_7$	Orange colour of $K_2Cr_2O_7$ turned to green

CONSTRUCTS:
The knowledge claim is based on the fact that ethylethanoate is slightly soluble in water because, it is less dense than water

RECORDS:
The unknown liquid is ethylethanoate

EVENTS AND/OR OBJECTS

Measure 2cm^3 of ethanol into test-tube (a) and 2cm^3 of ethanoic acid into test-tube (b) Mix the two solution in a clean/dry test-tube 'c' (c) Then add few drops of conc.H_2SO_4. Reflux for few minutes (d) heat the mixture slightly (f) record the observation that occur in test-tube 'c' (g) divide the "X" unknown liquid into three portions in test tube (h) test the "X" liquid using odour, water, and potassium dichromate ($K_2Cr_2O_7$) respectively (i) then record your observation and inference and also write the chemical equation for the reaction. **Objects:** Ethanoic acid, test-tubes, 13-x 100-mm, beaker, 400ml, bunsen burner, ring and wire gauze

Fig 18: End Product of Vee Diagramming for Ester

APPENDIX Z

DISCUSSION LESSON PLANS FOR CONTROL GROUP

LESSON 1:

School:	As Applicable
Subject:	Chemistry
Specific Topic:	Alkanes
Class:	SS II
Number in class:	As Applicable
Average Age:	16 Years
Sex:	Mixed
Time:	80 minutes
Date:	As Applicable

Behavioural objectives: By the end of the lesson, students should be able to:

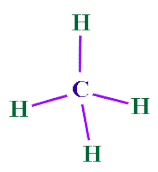
1. define the term alkanes;
2. write general formula of alkanes;
3. identify at least three sources of methane;
4. mention at least four physical properties of some alkanes;
5. draw the structure of methane accurately;
6. clearly describe the chemical properties of methane;
7. correctly carryout the laboratory preparation of methane; and
8. mention at least five uses of methane.

Instructional Materials: Bunsen burner, beaker, soda lime, salt of fatty acid

Previous knowledge: Students have studied hydrocarbon

Instructional Procedure/Presentation

Content Development	Time (mins)	Teacher's activities	Students' activities
Step 1 Introduction	5	Teacher probes into students' prior knowledge through questions such as: what are the two classes of hydrocarbon? Explains that alkanes are saturated hydrocarbons that is to say compounds of carbon and hydrogen which only have single,	Students answer the questions asked by the teacher. Expected answers: The two classes of hydrocarbon are saturated and unsaturated hydrocarbon

<table>
<tr><td></td><td></td><td>covalent, bonds holding the atoms together. with general molecular formula C_nH_{2n+2} and functional group of C-C and it prefix is "-ane"
Teacher further explain to students that sources of alkanes are:
i. Petroleum: petroleum is a complex mixture of alkanes and other hydrocarbons
ii. Natural gas: methane is a major constituent of the natural gas and occur along with petroleum in the earth's sedimentary traps
iii. Destructive distillation of wood and coal</td><td></td></tr>
<tr><td>Step 2
Physical Properties of Alkanes</td><td>15</td><td>Teacher briefly outlines the physical properties of the first few members of the alkane listing the formula, boiling point, melting point and density as follows:
<table>
<tr><td>Name</td><td>Formula</td><td>Boiling Point</td><td>Melting point</td><td>Density</td></tr>
<tr><td>Methane</td><td>CH_4</td><td>-162°C</td><td>-183</td><td>Gas</td></tr>
<tr><td>Ethane</td><td>C_2H_6</td><td>-89 °C</td><td>-182</td><td>Gas</td></tr>
<tr><td>Propane</td><td>C_3H_8</td><td>-42 °C</td><td>-188</td><td>Gas</td></tr>
<tr><td>Butane</td><td>C_4H_{10}</td><td>-0.5 °C</td><td>-138</td><td>Gas</td></tr>
<tr><td>Pentane</td><td>C_5H_{12}</td><td>36 °C</td><td>-130</td><td>0.626</td></tr>
</table></td><td></td></tr>
<tr><td>Step 3
Structure of Methane</td><td>10</td><td>Teacher asks the students to draw the structure of methane</td><td>Expected answer:
The structure of methane is as follows:


Methane</td></tr>
<tr><td>Step 4
Physical Properties of Methane</td><td>10</td><td>Briefly describe the physical properties of methane as follows;
i. Methane is a colourless, odourless, and tasteless non poisonous gas.
ii. Methane is sparingly soluble in water but</td><td></td></tr>
</table>

		dissolves readily in alcohol and ether. iii. Methane is lighter than air. iv. Methane melts at -184°C and boils atomic -161.4°C. Methane like carbon dioxide also traps infrared radiations (heat radiations) reflected by the earth.	
Step 5 Chemical Properties of Methane	10	Briefly describe the chemical properties of methane as follows: i. With alkalis methane does not react. ii. With trioxonitrate (V) acid vapour: methane is nitrated at 300°C. $CH_4 + HNO_3 \rightarrow CH_3NO_2 + H_2O$ iii. With stream: Methane is oxidized by stream in the presence of metallic Nickel catalyst to carbon (II) oxide and hydrogen. $CH_4 + O_2 \rightarrow CO_2 + 3H_2$	
Step 6 Laboratory Preparation of Methane	15	Teacher illustrate the laboratory preparation of methane using Bunsen burner, beaker, soda lime, salt of fatty acid as follows: i. Decarboxylation of fatty acids: methane is prepared by heating salt of fatty acid with soda lime. $CH_3COO^- + OH^- \rightarrow CO_3^{2-} + CH_4$ ii. Hydrogenation of carbon (II) oxide: Methane can also be obtained when carbon (II) oxide is hydrogenated over a suitable nickel catalyst supported on kieselguhr and promoted by traces of thoria $CO + 3H_2 \rightarrow CH_4 + H_2O$ $2CO + 2H_2 \rightarrow CH_4 + CO_2$	

Step 7 Uses of Alkanes	10	Teacher asks the students to write down the uses of alkanes they know	Expected answers: i. The largest amount of alkanes such as methane and ethane produced are used for heating fuel purposes ii. Alkanes such as propane and butane are important raw material (feedstock) in petrochemistry industry. iii. Alkanes such pentane is used as a propellant for aerosol sprays, as a filling of low temperature thermometer
	75		

Summary: (5 minutes)

Teacher summarizes the lesson thus;

The alkanes can exist as gases, liquids, or solids at room temperature. The unbranched alkanes such as methane, ethane, propane and butane are gases; pentane through hexadecane is liquids; the homologues larger than hexadecane are solids. Branched alkanes normally exhibit lower boiling points than unbranched alkanes of the same carbon content. This occurs because of the greater van der Waals forces that exist between molecules of the unbranched alkanes.

Assignment:

Teacher gives the students take home assignment due for submission the next class

i. What is the boiling point of butane
ii. Give two reasons why soda lime is used instead of caustic soda in the preparation of methane

Expected answers to the assignment questions:

i. -0.5^0C
ii. Soda lime does not attack glass apparatus unlike caustic soda; and soda lime is not deliquescent unlike caustic soda

LESSON 2: **FOR CONTROL GROUP (DISCUSSION METHOD)**

School:	As Applicable
Subject:	Chemistry
Specific Topic:	Alkenes
Class:	SS II
Number in class:	As Applicable
Average Age:	16 Years
Sex:	Mixed
Time:	80 minutes
Date:	As Applicable

Behavioural objectives: By the end of the lesson students should be able to:

1. define the term alkenes;
2. write general formula of alkenes;
3. identify the at least two sources of alkenes;
4. mention at least four physical properties of some alkenes;
5. draw the structure of ethene accurately;
6. clearly describe the chemical properties of ethene;
7. correctly carryout the laboratory preparation of ethene; and
8. mention at least four uses of ethene.

Instructional Materials: beakers, measuring cylinder, ethyne, ethanol (C_2H_5OH), conc.H_2SO_4, nickel catalyst

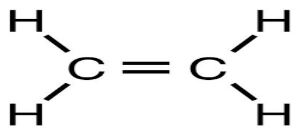
Previous knowledge: Students have studied alkanes

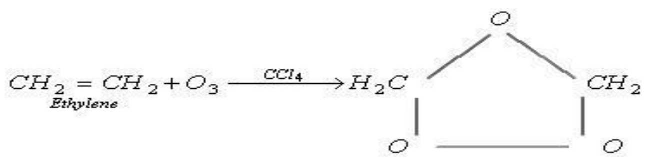
Instructional Procedure/Presentation

Content Development	Time (mins)	Teacher's activities	Students' activities
Step 1 Introduction	7	Probes into students' prior knowledge through questions such as; what are alkanes? Briefly explain that an alkene is an unsaturated hydrocarbon that contains at least one carbon-carbon double bond with general molecular formula C_nH_{2n} and functional group of C=C and it prefix is	Students answer the questions asked by the teacher Expected answers: Alkanes are saturated hydrocarbons that is to say compounds of carbon and

<table>
<tr><td></td><td></td><td>“-ene”

Briefly explain the sources of alkanes are;
i. Terpene: Is the main source of natural alkene.
ii. Fruits: It is found in fruits such as raw apricots.</td><td>hydrogen which only have single, covalent, bonds holding the atoms together. With general molecular formula C_nH_{2n+2} and functional group of C-C.</td></tr>
<tr><td>Step 2
Physical Properties of some Alkenes</td><td>10</td><td>Teacher briefly outline the physical properties of some alkenes under the following headings: formula, boiling point and melting points as follows:

<table>
<tr><th>LUPAC Name</th><th>Formula</th><th>Boiling Point</th><th>Melting point</th></tr>
<tr><td>Ethene</td><td>$H_2C=CH_2$</td><td>-102°C</td><td>-169 °C</td></tr>
<tr><td>Propene</td><td>CH_3-CH= CH_2</td><td>-48 °C</td><td>-185 °C</td></tr>
<tr><td>But-1-ene</td><td>CH_3-CH_2-CH=CH_2</td><td>-6.5 °C</td><td>-175 °C</td></tr>
<tr><td>E-But-2-ene</td><td>CH_3-CH=CH-CH_3</td><td>1°C</td><td>-159 °C</td></tr>
<tr><td>Z-But-2-ene</td><td>$(CH_3)_2C=CH_2$</td><td>-6.5 °C</td><td>-135 °C</td></tr>
<tr><td>Pent-1-ene</td><td>C_3H_7-CH=CH_2</td><td>30 °C</td><td>-181 °C</td></tr>
<tr><td>Hex-1-ene</td><td>C_4H_9-CH=CH_2</td><td>63 °C</td><td>-135 °C</td></tr>
</table></td><td></td></tr>
<tr><td>Step 3
Structure of Ethene</td><td>8</td><td>Teacher asks the students to draw the structure of ethene</td><td>Expected answers
The structure of ethene is as follows:
</td></tr>
<tr><td>Step 4
Chemical Properties of Ethene</td><td>5</td><td>Briefly explain the physical properties of ethene as follows;
1. Ethene is a colourless gas with a faint sweetish smell.
2. It has a melting of -169^{0}C and boiling points of 104^{0}C
3. It is slightly less dense than air
4. It is insoluble in water but soluble in alcohol and ether.</td><td></td></tr>
</table>

Step 5 Chemical Properties of Ethene	15	Teacher explains that ethene undergo ionic addition reaction and further describe the chemical properties of ethene as follows: i. Hydrogenation: Ethene is converted to ethane by the addition of 1 mole of hydrogen gas in the presence of nickel catalyst at suitable temperature and pressure $C_2H_4 + H_2 \longrightarrow C_2H_6$ ii. With halo water: At room temperature, the double bond in ethene is converted to single bond when halowater is added. (a) $C_2H_4 + Cl_2H_2O \longrightarrow C_2H_4HOCl$ (b) $C_2H_4 + Br_2H_2O \longrightarrow C_2H_4HOBr$ iii. With Ozone: Ozone is passed into the solution of ethene in trichloromethane (chloroform) to give ethene ozonide. 	
Step 6 Laboratory Preparation of Ethene	20	Teacher illustrate the laboratory preparation of ethene using ethanol, conc. H_2SO_4, one mole of hydrogen, ethyne, nickel catalyst as follows: i. Dehydration of ethanol: ethanol (C_2H_5OH) is dehydrated by the addition of conc. tetraoxosulphate (VI) acid to C_2H_5OH at 170°C to give ethyl hydrogen sulphate $C_2H_5OH + H_2SO_4 \xrightarrow[\text{decomposes } 170^oC]{} C_2H_2 + H_2SO_4$ ii. Partial hydrogenation of ethyne: ethene can be prepared by the addition of one mole of hydrogen to the ethyne in the presence of nickel as a catalyst at suitable temperature and pressure. The nickel	

		catalyst has a large surface area and the hydrogenation take place on the surface of the nickel catalyst. $$H\text{-}C{=}C\text{-}H + H_2 \xrightarrow[70^0C]{\text{Ni catalyst}} CH2 === CH2$$	
Step 7 Uses of Ethene	10	Teacher asks the students to mention some uses of alkenes they know?	Expected answers: i. Ethene is extremely important in the manufacture of plastic. All plastics are in some way related to alkenes ii. Ethene is used as fuel and illuminant. iii. Ethene is used in the manufacture of glycerol and detergent.
	75		

Summary: (5 minutes)

Teacher summarizes the lesson thus;

Ethene can also be prepared by the cracking of petroleum (ethene is a bye product of petroleum). He also emphasize that ethene is extremely important in the manufacture of plastic. All plastics are in some way related to alkenes and it is also used as fuel and illuminant.

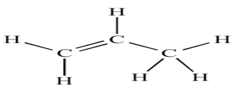
Assignment:

Teacher gives the students take home assignment due for submission the next class

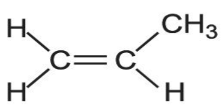
1. What is the melting and boiling points of tran-but-2-ene?
2. Draw the structure of propene

Expected answer to assignment question:

1. Tran-but-2-ene has a melting and boiling points -139^{0}C and 1^{0}C respectively
2.



Or



LESSON 3:	**FOR CONTROL GROUP (DISCUSSION METHOD)**
School:	As Applicable
Subject:	Chemistry
Specific Topic:	Alkynes
Class:	SS II
Number in class:	As Applicable
Average Age:	16 Years
Sex:	Mixed
Time:	80 minutes
Date:	As Applicable

Behavioural objectives: By the end of the lesson students should be able to:

1. define the term alkynes;
2. write general formula and functional group of alkynes;
3. identify at least two sources of alkynes;
4. mention at least four physical properties of some alkynes;
5. draw the structure of ethyne accurately;
6. clearly describe the chemical properties of ethyne;
7. correctly carryout the laboratory preparation of ethyne; and
8. mention at least five uses of ethyne.

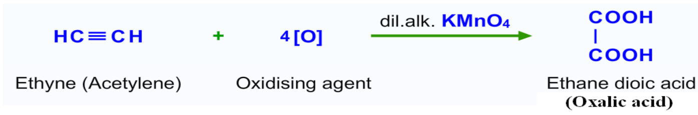
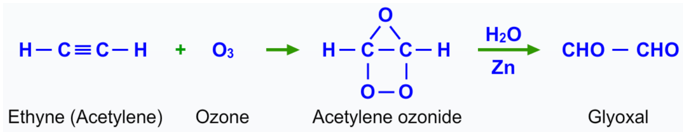
Instructional Materials: Calcium dicarbide, calcium oxide, bunsen burner, beaker

Previous knowledge: Students have studied alkenes.

Instructional Procedure/Presentation

Content Development	Time (mins)	Teacher's activities	Students' activities
Step 1 Introduction	10	Teacher probes into students' prior knowledge through questions such as; What are alkenes? What are alkynes? Alkynes an unsaturated hydrocarbon that contains at least one carbon-carbon triple bond with general molecular formula $CnH_2n\text{-}_2$ and functional group of C=C and it prefix is "-yne" Briefly explain the sources of alkynes as follows; crude oil and natural gas: small amount of alkynes	Students answer the questions asked by the teacher Expected answers: An alkene is an unsaturated hydrocarbon that contains at least one carbon-carbon double bond with general

		are in crude oil and natural gas	molecular formula CnH$_2$n and functional group of C=C and it prefix is "-ene"
Step 2 Structure of Ethyne	10	Teacher then asks the students to draw the structure of ethyne	Expected answer: The structure of ethyne is as follows: H ---C≡C---H
Step 3 Physical properties of ethyne	10	Briefly explain the physical properties of ethyne as follows; (a) Ethyne is a colourless gas with a characteristic sweet smell when pure (b) It is lighter than air (c) Ethyne has faint garlic odour (d) Ethyne is slightly soluble in water (e) Ethyne is completely soluble in organic solvents. (f) It has a melting point of -81^{o}C and a boiling point of -84^{o}C. (g) It is unstable and may explode on compression to a liquid.	
Step 4 Chemical Properties of Ethyne	15	Describe the chemical properties of ethyne as follows: (i). Combustion: Ethyne burns in air with sooty flame and gives carbon dioxide, water and heat. $2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$ + heat (ii) Addition of hydrogen: Ethyne on addition with hydrogen forms initially ethene and finally forms ethane. $CH \equiv CH + H_2 \rightarrow CH_2{=}CH_2 + H_2 \rightarrow CH_3\text{-}CH_3$ (iv) Reaction with halogens: Ethyne reacts with halogen acids to form 1,2-Tetra halo ethanes. $CH \equiv CH + 2X_2 \rightarrow CHX_2\text{-}CHX_2$	

		(v) Oxidation of ethyne: Ethyne undergoes oxidation or combustion reactions. Ethyne is oxidized to form Oxalic acid in the presence of dilute $KMnO_4$  2. Ozonolysis: Ethyne reacts with ozone to produce acetylene ozonide which further hydrolysed in presence of Zinc to form Glyoxal  	
Step 5 Illustrate the Laboratory Preparation of Ethyne	15	Teacher explains that ethyne is prepared in the laboratory by the action of water on calcium carbide. A few small pieces of calcium carbide (CaC_2) are placed inside a conical flask; water is then added to the flask with the help of a thistle funnel. Teacher further explain that ethyne gas produced during the reaction is collected by the downward displacement of water. $CaC_2 + 2H_20 \longrightarrow C_2H_2 + Ca_2(OH)_2$	
Step 6 Uses of Ethyne	15	Teacher asks the students to mention some uses of ethyne they know?	Expected answers: i. Ethyne is useful for artificial ripening and preservation of fruits. ii. It is useful in acetylene lamps to generate light. iii. Ethyne is used to prepare various organic compounds iv. It is useful to manufacture important

			organic compounds like acetic acid, acetaldehyde, ethyl alcohol and polymers like PVC. v.it is useful to produce an oxyacetylene flame
	75		

Summary: (5 minutes)

Teacher summarizes the lesson thus;

Alkynes are generally non polar molecules with little solubility in polar solvents, such as water. Solubility in non polar solvents, such as ether and acetone, is extensive. Like the alkanes and alkenes, alkynes of four or fewer carbon atoms tend to be gases. Substituted alkynes have small dipole moments due to difference in electronegativity between the triple-bonded carbon atoms, which are sp hybridized, and the single-bonded carbon atoms, which are Sp^3 hybridized. The sp-hybridized carbon atoms, which possesses more "s" character than the sp3 hybridized carbon atom, is more electronegative in character.

Assignment:

Teacher gives the students take home assignment due for submission the next class

1. Mention 4 uses of alkynes
2. Draw the structure of propyne

LESSON 4:	**FOR CONTROL GROUP (DISCUSSION METHOD)**
School:	As Applicable
Subject:	Chemistry
Specific Topic:	Alkanols
Class:	SS II
Number in class:	As Applicable
Average Age:	16 Years
Sex:	Mixed
Time:	80 minutes
Date:	As Applicable

Behavioural objectives: By the end of the lesson students should be able to:

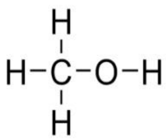
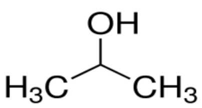
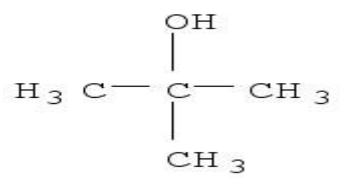
1. define the term alkanol;
2. write general formula of alkanols;
3. mention the two classes of alkanols;
4. mention at least four physical properties of some alkanols;
5. draw the structure of ethanol accurately;
6. clearly describe at least three chemical properties of ethanol;
7. carefully carryout the laboratory preparation of ethanol; and
8. mention at least four uses of alkanols.

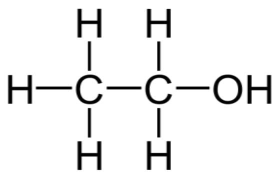
Instructional Materials: Distilled water, ethene, H_2SO_4, beaker

Previous knowledge: Students have studied alkynes.

Instructional Procedure/Presentation

Content Development	Time (mins)	Teacher's activities	Students' activities
Step 1 Introduction	5	Teacher probes into students' prior knowledge through questions such as; What are alkyne? Briefly explain that alkanol are characterized by one or more hydroxyl groups attached to a carbon atom of an alkyl group with general molecular formula $CnH_{2n+1}OH$ The teacher then further explains that the simpler members of alkanol family is methanol (CH_3OH),	Students answer the questions asked by the teacher Expected answers: Alkynes an unsaturated hydrocarbon that contains at least one carbon-carbon triple

		ethanol (C_2H_5OH) and other members are propanol (C_3H_7OH), butanol (C_4H_9OH), Pentanol ($C_5H_{11}OH$), Hexanol ($C_6H_{13}OH$), Heptanol ($C_7H_{15}OH$)	bond with general molecular formula $CnH_2n\text{-}_2$ and functional group of C=C and it prefix is "-yne"
Step 2 Classification of Alkanol	15	Teacher briefly explains to students the classes of alkanol as primary alkanol, secondary alkanol and tertiary alkanol as follows: i. Primary alkanol: Is an alkanol which has one alkyl group on the carbon atom carrying the OH group  Methanol ii. Secondary alkanol: Is an alkanol which has two alkyl group on the carbon atom carrying the OH group  2-propanol iii. Tertiary alkanol: Is an alkanol which has three alkyl group on the carbon atom carrying the OH group  2-methylpropan-2-ol	
Step 3 Physical Properties of	10	Teacher briefly outlines the physical properties of alkanol listing the name, formula, class, boiling point, and melting point as follows:	

<table>
<tr>
<td>some Alkanol</td>
<td></td>
<td>
<table>
<tr><th>Name</th><th>Molecular Formula</th><th>Melting point</th><th>Meltin g point</th><th>Solubil ity</th></tr>
<tr><td>Methanol</td><td>CH_3OH</td><td>-97°C</td><td>65 °C</td><td>Miscible</td></tr>
<tr><td>Ethanol</td><td>C_2H_5OH</td><td>-117°C</td><td>78°C</td><td>Miscible</td></tr>
<tr><td>Propan-1-ol</td><td>C_3H_7OH</td><td>-127°C</td><td>97 °C</td><td>Miscible</td></tr>
<tr><td>Butan-1-ol</td><td>C_4H_9OH</td><td>-90°C</td><td>118 °C</td><td>8.0g</td></tr>
<tr><td>Pentan-1-ol</td><td>$C_5H_{11}OH$</td><td>-79°C</td><td>138 °C</td><td>2.7g</td></tr>
</table>
</td>
<td></td>
</tr>
<tr>
<td>Step 4
Draw the Structure of Ethanol</td>
<td>10</td>
<td>Teacher asks the students to draw the structure of ethanol (C_2H_5OH)</td>
<td>Expected answer:

Ethanol</td>
</tr>
<tr>
<td>Step 5
Chemical Properties of Ethanol</td>
<td>15</td>
<td>Teacher describe chemical properties of ethanol as follows:
i. Reaction with sodium: Alcohol are very weak acidic. Ethanol reacts with sodium metal to form sodium ethoxide and hydrogen gas
$$\underset{\text{Sodium metal}}{2Na} + \underset{\text{Ethanol}}{2C_2H_5OH} \longrightarrow \underset{\text{Sodium ethoxide}}{2C_2H_5ONa} + \underset{\text{Hydrogen}}{H_2}$$
ii. With alkanoic acid: Ethanol reacts with ethanoic acid in the presence of concentrated tetraoxosulphate (VI) acid to form ethyl ethanoate and water. This process is often referred to as esterification.
$$\underset{\text{Ethanoic acid}}{CH_3COOH(\ell)} + \underset{\text{Ethanol}}{C_2H_5OH(\ell)} \xrightarrow{\text{Conc. } H_2SO_4} \underset{\text{Ethyl Ethanoate}}{CH_3COOC_2H_5(\ell)} + H_2O(\ell)$$
iii. Dehydration: Ethanol when heated with conc. H_2SO_4 at 443K or Al_2O_3 undergoes dehydration
$$\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow[443\text{ K}]{H_2SO_4} \underset{\text{Ethene}}{CH_2{=}CH_2} + H_2O$$</td>
<td></td>
</tr>
</table>

		iv. Oxidation with acidified potassium dichromate: Ethanol is oxidized to ethanoic acid with the help of acidified $K_2Cr_2O_7$ $CH_3CH_2OH+2[O] \xrightarrow{K_2Cr_2/H_2SO_4\,(Conc.)} CH_3COOH + H_20$ Ethanol Ethanoic acid	
Step 6 Chemical Properties of Ethanol	5	Teacher asks the students the mention the physical properties of ethanol they know?	Expected answers; 1. Ethanol is flammable, colourless liquid. 2. It has a boiling point of 78.5°C and a melting point of -114.5°C 3. It has a pleasant sharp smell
Step 7 Illustrate the Laboratory Preparation of Ethanol	10	Teacher carry out the following activities the illustrate the laboratory preparation of ethanol using distilled water, beaker, ethene, H_2SO_4 as follows: i. Ethyl hydrogen sulphate is diluted with water and warmed to give ethanol $CH_3{-}{-}{-}CH_2{-}{-}{-}O{-}{-}{-}SO_2 \longrightarrow CH_3CH_2OH + H_2SO_4$ ii. Hydration of ethene: it is achieved by passing the mixture of ethene and steamed over a solid acid catalyst (tetraoxophosphate (V) acid on silica) at 300°c and a pressure of 70 atmospheres $CH_3{=}{=}CH_2 + H_2O \longrightarrow CH_3CH_2OH$ The teacher further explains the industrial and local production of ethanol through fermentation process. It involves the production of ethanol by the enzymatic hydrolysis of complex molecule (polysaccharide) in the absence of air.	

Step 8 Uses of Alkanol	5	Briefly explain the uses of alkanol as follows: i. Alkanol is a constituent of alcoholic beverages such as beer, wine, whisky and other liquors. ii. A mixture of ethanol and water has much lower freezing point than that of water. This mixture is known as antifreeze and is used in radiators of vehicles in cold country iii. It is also used as solvent for resins, fats, oils, fatty acid and hydrocarbon iv. Ethanol is used to sterilize wounds and syringes	
	75		

Summary: (5 minutes)

Teacher summarized the lesson thus;

The industrial and local production of ethanol is through fermentation process. It involves the production of ethanol by the enzymatic hydrolysis of complex molecule (polysaccharide) in the absence of air. The fermented liquor contains up of to 10% ethanol and is used in drinks.

Assignment:

Teacher gives the students take home assignment due for submission the next class

1. Mention three uses of alkanols
2. draw the structure of propanol

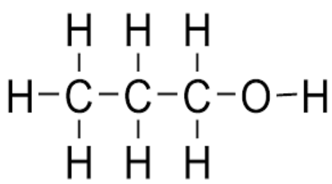
Expected assignment answers:

i. It is also used as solvent for resins, fats, oils, fatty acid and hydrocarbon

ii. Ethanol is used to sterilize wounds and syringes

iii. In the manufacturing of dyes, drugs and detergents and so on

2.



Propanol

LESSON 5 **FOR CONTROL GROUP (DISCUSSION METHOD)**

School: As Applicable

Subject: Chemistry

Specific Topic: Alkanoic Acids (Carboxylic Acids)

Class: SS II

Number in Class: As Applicable

Average Age: 16 Years

Sex: Mixed

Time: 80 minutes

Date: As Applicable

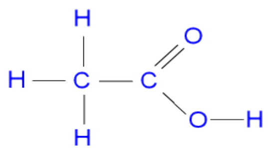
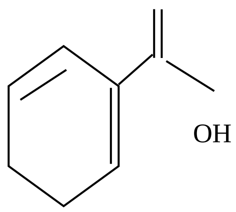
Behavioural objectives: By the end of the lesson, students should be able to;

1. define the term alkanoic acids;
2. write general formula of alkanoic acids;
3. mention the classes of alkanoic acids with examples;
4. state at least three physical properties of some of the alkanoic acids;
5. draw the structure of ethanoic and phenylmethanoic (benzoic) acids accurately;
6. describe at least three chemical properties of alkanoic acid;
7. carefully carry out the laboratory preparation of ethanoic acid; and
8. mention at least four uses of alkanoic acids.

Instructional Materials: ethanoic acid, hydrogen chloride, hydrogen tetraoxosulphate (iv)

Previous knowledge: Students have studied alkanol

Content Development	Time mins	Teacher's activities	Students' activities
Step 1 Introduction	10	Teacher probes into students' prior knowledge through questions such as: what are alkanol? Briefly explain that alkanoic acids also known as organic or carboxylic acids, that contain the carboxyl group, -COOH, as their functional group with general molecular formula $C_nH_{2n}+COOH$ Explains that alkanoic acids are classified into two namely: Aliphatic and aromatic carboxylic acids.	Students answer the questions asked by the teacher Expected answers: Alkanol are characterized by one or more hydroxyl groups attached to a carbon atom of an

<table>
<tr>
<td></td>
<td></td>
<td>Ethanoic and phenylmethanoic (benzoic) acids are examples of Aliphatic carboxylic acids and aromatic carboxylic acids respectively.</td>
<td>alkyl group with general with general molecular formula $CnH_{2n+1}OH$</td>
</tr>
<tr>
<td>Step 2
Physical Properties of Alkanoic Acids</td>
<td>15</td>
<td>The teacher further outlines the physical properties of the first few members of the alkanoic acids listing the molecular formula, structure, IUPAC name, common name, physical state, density, boiling and melting point and also discusses the chemical properties as follows:
<table>
<tr><th>Molecular formula</th><th>Structural formula</th><th>IUPAC name</th><th>Common name</th></tr>
<tr><td>CH_2O_2</td><td>HCOOH</td><td>Methanoic acid</td><td>Formic acid</td></tr>
<tr><td>$C_2H_4O_2$</td><td>HCOOH</td><td>Ethanoic acid</td><td>Acetic acid</td></tr>
<tr><td>$C_3H_6O_2$</td><td>CH_3COOH</td><td>Propanoic acid</td><td>Propanoic acid</td></tr>
<tr><td>$C_7H_6O_2$</td><td>C_6H_5COOH</td><td>Benzoic acid</td><td>phenylmethanoic acid</td></tr>
</table>
<table>
<tr><th colspan="2">Properties</th><th rowspan="2">Boiling point</th><th rowspan="2">Melting point</th><th rowspan="2">Density g/cm^3</th></tr>
<tr><th>Name</th><th>Physical state</th></tr>
<tr><td>Methanoic acid</td><td>Colourless Liquid</td><td>101°C</td><td>8°C</td><td>1.226</td></tr>
<tr><td>Ethanoic acid</td><td>Colourless Liquid</td><td>118°C</td><td>17°C</td><td>1.049</td></tr>
<tr><td>Propanoic acid</td><td>Colourless Liquid</td><td>141°C</td><td>-22°C</td><td>0.992</td></tr>
<tr><td>Benzoic acid</td><td>Colourless Crystalline solid</td><td>164°C</td><td>122°C</td><td>1.2659</td></tr>
</table>
</td>
<td></td>
</tr>
<tr>
<td>Step 3
Structure of Ethanoic and Benzoic Acids</td>
<td>10</td>
<td>Ask the students to draw the structure of ethanoic and phenylmethanoic (benzoic) acids as examples aliphatic and aromatic carboxylic acids respectively</td>
<td>Expected answers:

</td>
</tr>
</table>

Step 4 Chemical Properties of Alkanoic Acid	15	Teacher explain the chemical properties of alkanoic acid as follows: i. Acidic property: Carboxylic acids are weak acids and their carboxylic anions are strong conjugate bases are slightly alkaline due to the hydrolysis of carboxylate anion compared to other species, the order of acidity and basicity or corresponding conjugate bases are as follows: (a) $2CH_3COOH + CaCO_3 \rightarrow (CH_2COO)_2 + H_2O + CO_2$ (b) $2CH_3COOH + Mg \rightarrow (CH_3COO)_2 + H_2(g)$ (c) CH3COOH+ NaOH $\rightarrow CH_3COONa + H_2O$ ii. Ester formation: Carboxylic acids are esterified with alcohols or phenols in the presence of a mineral acid such as concentrated H_2SO_4 or HCl gas as a catalyst $RCOOH + R'OH \xrightleftharpoons{H^+} RCOOR' + H_2O$ This reaction is reversible and the same catalyst, hydrogen ion, that catalyzes the forward reaction i.e. esterification necessarily catalyzes the reverse reaction i.e. hydrolysis.	
Step 5 Laboratory preparation of ethanoic acid	15	Teacher illustrates how ethanoic acid can be prepared in the laboratory With the following equation: $CH_3CH_2OH(aq) + 2[O] \rightarrow CH_3COOH(g) + H_2O(l)$, The teacher also explains to the students another means by which ethanoic acid can be prepared using the following equation: $CH_3COONa(s) + H_2SO_4(aq) \rightarrow CH_3COOH(g) + NAHSO_4(aq)$ $CH_3CN(aq) + HCl(aq) + 2H_2O_4 \rightarrow CH_3COOH(g) + NH_4CL(aq)$	
Step 6 Uses of Alkanoic Acid	10	Teacher asks the students to mentions the uses of alkanoic acid they know?	Expected answers: Ethanoic acid as an example of aliphatic carboxylic acid is used

		Explain that Benzoic acid as an example of aromatic carboxylic acid is used as follows: i. Benzoic acid is widely used as a preservative ii. It is used in the manufacture of various cosmetics, dyes, plastics.	as follows: i. It is used as aspirin. ii. For making dyes in varnishes and iii. Used in the filter tips of cigarettes.
	75		

Summary: (5 minutes)

Teacher summarizes the lesson thus;

Alkanoic acids or carboxylic acids are soluble in water. Carboxylic acids do not dimerise in water, but forms hydrogen bonds with water. Carboxylic acids are polar and due to the presence of the hydroxyl in the carboxyl group, they are able to form hydrogen bonds with water molecules.

Assignment:

Teacher gives the students take home assignment due for submission the next class

1. Mention three uses of carboxylic acids
2. Draw the structure of propanoic acid

LESSON 6: **FOR CONTROL GROUP (DISCUSSION METHOD)**

School: As Applicable

Subject: Chemistry

Specific Topic: Alkanoates (Esters)

Class: SS II

Number in Class: As Applicable

Average Age: 16 Years

Sex: Mixed

Time: 80 minutes

Date: As Applicable

Behavioural objectives: By the end of the lesson, students should be able to;

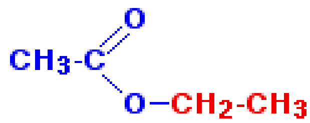
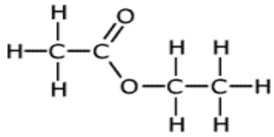
1. define the term esters;
2. clearly describe the process of esterification;
3. mention at least three physical properties of alkanoates;
4. draw the structure of ethyl ethanoate accurately;
5. clearly describe at least three chemical properties of ethyl ethanoate;
6. carefully carry out the laboratory preparation of ethyl ethanoate; and
7. mention at least four uses of esters.

Instructional Materials: Ethanol, ethanoic acid, conc H_2SO_4,

Previous knowledge: Students have studied alkanoic acids

Instructional Procedure/Presentation

Content Development	Time (mins)	Teacher's activities	Students' activities
Step 1 Introduction	10	Teacher probes into students' prior knowledge through questions such as; what are carboxylic acids? What are esters? Briefly explain that esters are the derivatives of the carboxylic acids in which the –OH part of the carboxylic group has been replaced by –OR group where, R may be alkyl or aryl group. Teacher further explain to the students that alkanoates has esters as their family name and	Students answer the questions asked by the teacher Expected answer: Carboxylic acids also known as organic or alkanoic acids, that contain the carboxyl group, -COOH, as their functional group

		contain the -RCOOR, as their functional group have the general formula ($C_nH_{2n}O_2$). Alkyl alkanoates are found widely in nature. Short carbon chain simply alkyl alkanoates exist as liquids and have a characteristic pleasant odour. They occur in essential oils, many fruits and flowers and sometime called fruit essences because of their pleasant odours	with general molecular formula C_nH_{2n}+COOH.
Step 2 Structure of Ethyl Ethanoate	10	Teacher asks the students to draws the structure of ethyl ethanoate or ethyl acetate ($C_4H_8O_2$) or $CH_3COOCH_2CH_3$	Expected answer:  ethyl ethanoate 
Step 3 Physical Properties Ethyl Ethanoate	10	Teacher ask the student to mention the physical properties ethyl ethanoate they know	Expected answers: i. It is colourless volatile liquid with a pleasant smell ii. It is slightly soluble in water but dissolve readily in organic solvent such as ethanol, acetone, ethoxyethane and benzene iii. It has a boiling point of 77.1 ^{0}C (170.8 ^{0}F) and melting point of -83.6 ^{0}C respectively.
Step 4 Chemical Properties of Ethyl Ethanoate	10	Teacher briefly describe the chemical properties of ethyl ethanoate as follows; i. Hydrolysis: ethyl ethanoate and other esters can be hydrolyzed to the corresponding carboxylic acid and ethanol.	

		$CH_3COOC_2H_5 + H_20 \rightarrow CH_3COOH + C_2H_5OH$ ii. Reaction with ammonia $CH_3COOC_2H_5 + NH_3 \rightarrow C_2H_5OH + CH_3CONH_2$	
Step 5 Laboratory Preparation of Ethyl Ethanoate through esterification	20	Teacher explains that esterification is the reaction of a carboxylic acid and alcohol in the presence of an acid catalyst to produce an ester. The main chain of an ester comes from the carboxylic acid, while the alkyl group in an ester comes from the alcohol. Alkanol + acid $\underset{\text{hydrolysis}}{\overset{\text{Esterification}}{\rightleftarrows}}$ ester + water. Teacher further explains that the reaction is extremely slow acid reversible at room temperature, and is catalyzed by a high concentration of hydrogen ions The reaction of ethanoic acid with methyl to produce an ester called ethyl ethanoate, responsible for the smell of pears. $C_2H_5OH(aq) + CH_3 \rightleftharpoons CH_3COOC_2H_5(L) + H_2O(L)$	
Step 6 Uses of Ethyl Ethanoate	15	Briefly explain the uses of ethyl ethanoate acid as follows: i. Ethyl ethanoate is used primarily as a solvent and diluent. ii. It is commonly used to clear circuit boards and in some nail varnish removers. iii. It is also used as paints as an activator or hardener. iv. In the laboratory, mixtures containing ethyl ethanoate are commonly used in column chromatography and extractions. v. Ethyl ethanoate is the most common ester in wine, being the product of the most common	

		volatile organic acid vi. Ethyl ethanoate is an effective asphyxiant for use in insert collecting and study.	
	75		

Summary: (5 minutes)

Teacher summarizes the lesson thus;

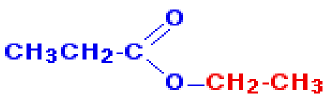
Esterification is the reaction of a carboxylic acid and alcohol in the presence of an acid catalyst to produce an ester. The main chain of an ester comes from the carboxylic acid, while the alkyl group in an ester comes from the alcohol. Teacher further explains that the reaction is extremely slow acid reversible at room temperature, and is catalyzed by a high concentration of hydrogen ions

Assignment:

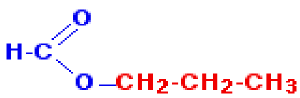
Teacher gives the students take home assignment due for submission the next class

Draw the structures of the following esters; ethyl propanoate, propyl methanoate, methyl butanoate, and propyl ethanoate.

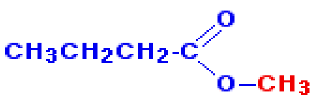
Expected answers to assignment questions:



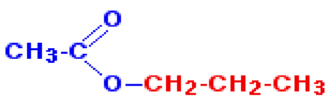
ethyl propanoate



propyl methanoate



methyl butanoate



propyl ethanoate

MAIN STUDY DATA ANALYSIS

```
[DataSet1] C:\Users\VICTOR\Documents\Victor Ajayi_Data analysis.sav
```

Univariate analysis of variance of OCAT, MAI and OCSEB

Between-Subject Factors

		Value Label	N
Group	1	Experimental 1	104
	2	Experimental 2	101
	3	Control	103
Sex	1	Male	174
	2	Female	134

Between-Subject Factors

Group	Sex	N
Experimental 1	Male	61
	Female	43
	Total	104
Experimental 2	Male	56
	Female	45
	Total	101
Control	Male	57
	Female	46
	Total	103
Total	Male	174
	Female	134
	Total	308

DEMOGRAPHIC DATA

Strategy

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	PEOE Strategy	104	33.8	33.8	33.8
	VH Strategy	101	32.8	32.8	66.6
	Discussion Method	103	33.4	33.4	100.0
	Total	308	100.0	100.0	

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	174	56.5	56.5	56.5
	Female	134	43.5	43.5	100.0
	Total	308	100.0	100.0	

```
DESCRIPTIVES VARIABLES=VAR00001 VAR00002 VAR00003 VAR00004 VAR00005 VAR00006
VAR00007 VAR00008 VAR00009 VAR00010 VAR00011 VAR00012 VAR00013
VAR00014/STATISTICS=MEAN SUM STDDEV VARIANCE RANGE MIN MAX SEMEAN KURTOSIS
SKEWNESS.
```

Descriptives

[DataSet1] C:\Users\VICTOR\Documents\Victor Ajayi_Data analysis.sav

Descriptive Statistics

	GROUP		Statistic	Std. Error
TprOCAT	**(PEOE Strategy) 1**	N	104	
Valid N (listwise)	104	Range	16.00	
		Minimum	1.00	
		Maximum	17.00	
		Sum	1058.00	
		Mean	10.1731	.31648
		Std. Deviation	3.22744	
		Variance	10.416	
		Skewness	-.606	.237
		Kurtosis	.322	.469
TprOCAT	**(VH Strategy) 2**	N	101	
Valid N (listwise)	101	Range	15.00	
		Minimum	1.00	
		Maximum	16.00	
		Sum	1026.00	
		Mean	10.1584	.32081
		Std. Deviation	3.22407	
		Variance	10.395	
		Skewness	-.719	.240
		Kurtosis	.423	.476

	GROUP		Statistic	Std. Error
TprOCAT	**Control group (DM)**	N	103	
Valid N (listwise)	103	Range	14.00	
		Minimum	2.00	
		Maximum	16.00	
		Sum	1045.00	
		Mean	10.1453	.30523
		Std. Deviation	3.09778	
		Variance	9.596	
		Skewness	-.579	.238
		Kurtosis	.309	.472

Descriptives

	GROUP		Statistic	Std. Error
TpoOCAT	**(PEOE Strategy) 1**	N	104	
Valid N (listwise)	104	Range	24.00	
		Minimum	16.00	
		Maximum	40.00	
		Sum	3049.00	
		Mean	29.3173	.52625
		Std. Deviation	5.36668	
		Variance	28.801	
		Skewness	-.446	.237
		Kurtosis	.265	.469
TpoOCAT	**(VH Strategy) 2**	N	101	
Valid N (listwise)	101	Range	24.00	
		Minimum	15.00	
		Maximum	39.00	

		Sum	2819.00	
		Mean	27.9109	.51108
		Std. Deviation	5.13634	
		Variance	26.382	
		Skewness	-.467	.240
		Kurtosis	.254	.476

	GROUP		Statistic	Std. Error
TpoOCAT	**Control group (DM)**	N	103	
Valid N (listwise)	103	Range	15.00	
		Minimum	10.00	
		Maximum	25.00	
		Sum	1603.00	
		Mean	15.5631	.38772
		Std. Deviation	3.93494	
		Variance	15.484	
		Skewness	.569	.238
		Kurtosis	.713	.472

GENDER

Descriptive

	GENDER		Statistic	Std. Error
TprOCAT (PEOE Strategy)	**Male**	N	61	
		Range	15.00	
		Minimum	1.00	
		Maximum	16.00	
		Sum	624.00	
		Mean	10.2295	.43632
		Std. Deviation	3.40780	

			Statistic	Std. Error
		Variance	11.613	
		Skewness	-.652	.306
		Kurtosis	.162	.604
	Female	N	43	
		Range	13.00	
		Minimum	2.00	
		Maximum	15.00	
		Sum	439.00	
		Mean	10.2093	.45331
		Std. Deviation	2.97258	
		Variance	8.836	
		Skewness	-.750	.361
		Kurtosis	.708	.709

	GENDER		Statistic	Std. Error
TpoOCAT (PEOE Strategy)	**Male**	N	61	
		Range	24.00	
		Minimum	16.00	
		Maximum	40.00	
		Sum	1810.00	
		Mean	29.6721	.67416
		Std. Deviation	5.26536	
		Variance	27.724	
		Skewness	-.640	.306
		Kurtosis	.123	.604
	Female	N	43	

		Range	22.00	
		Minimum	18.00	
		Maximum	40.00	
		Sum	1239.00	
		Mean	28.8140	.84335
		Std. Deviation	5.53025	
		Variance	30.584	
		Skewness	-.204	.361
		Kurtosis	-.509	.709

	GENDER		Statistic	Std. Error
TprOCAT (VH Strategy)	**Male**	N	56	
		Range	15.00	
		Minimum	1.00	
		Maximum	16.00	
		Sum	573.00	
		Mean	10.2321	.48617
		Std. Deviation	3.63814	
		Variance	13.236	
		Skewness	-.814	.319
		Kurtosis	.263	.628
	Female	N	45	
		Range	11.00	
		Minimum	4.00	
		Maximum	15.00	
		Sum	453.00	
		Mean	10.0667	.31619

	Std. Deviation	2.65775	
	Variance	7.064	
	Skewness	-.455	.354
	Kurtosis	.200	.695

	GENDER		Statistic	Std. Error
TpoOCAT (VH Strategy)	**Male**	N	56	
		Range	22.00	
		Minimum	15.00	
		Maximum	37.00	
		Sum	1580.00	
		Mean	28.2143	.70191
		Std. Deviation	5.25258	
		Variance	27.590	
		Skewness	-.778	.319
		Kurtosis	.005	.628
	Female	N	45	
		Range	21.00	
		Minimum	18.00	
		Maximum	39.00	
		Sum	1239.00	
		Mean	27.5333	.74847
		Std. Deviation	5.02087	
		Variance	25.209	
		Skewness	-.064	.354
		Kurtosis	-.272	.695

```
DESCRIPTIVES VARIABLES=VAR00019 VAR00020 VAR00021 VAR00022 VAR00023 VAR00024
VAR00025 VAR00026 VAR00027 VAR00028 VAR00029 VAR00030 VAR00031
VAR00014/STATISTICS=MEAN SUM STDDEV VARIANCE RANGE MIN MAX SEMEAN KURTOSIS
SKEWNESS.
```

Descriptives

[DataSet1] C:\Users\VICTOR\Documents\Victor Ajayi_Data analysis.sav

Descriptive Statistics

	GROUP		Statistic	Std. Error
TprMAI	**(PEOE Strategy) 1**	N	104	
Valid N (listwise)	104	Range	.89	
		Minimum	1.00	
		Maximum	1.89	
		Sum	143.03	
		Mean	1.3753	.02112
		Std. Deviation	.21537	
		Variance	.046	
		Skewness	.295	.237
		Kurtosis	.080	.469
TprMAI	**(VH Strategy) 2**	N	101	
Valid N (listwise)	101	Range	.87	
		Minimum	1.00	
		Maximum	1.87	
		Sum	137.50	
		Mean	1.3614	.01715
		Std. Deviation	.17237	
		Variance	.030	
		Skewness	.131	.240
		Kurtosis	.721	.476

	GROUP		Statistic	Std. Error
TprMAI	**Control group (DM)**	N	103	
Valid N (listwise)	103	Range	.87	
		Minimum	1.00	
		Maximum	1.87	
		Sum	136.86	
		Mean	1.3287	.01943
		Std. Deviation	.19719	
		Variance	.039	
		Skewness	.131	.238
		Kurtosis	.020	.472

Descriptives

	GROUP		Statistic	Std. Error
TpoMAI	**(PEOE Strategy) 1**	N	104	
Valid N (listwise)	104	Range	.66	
		Minimum	3.34	
		Maximum	4.00	
		Sum	401.08	
		Mean	3.8565	.01509
		Std. Deviation	.15389	
		Variance	.024	
		Skewness	-1.420	.237
		Kurtosis	1.754	.469
TpoMAI	**(VH Strategy) 2**	N	101	
Valid N (listwise)	101	Range	.68	
		Minimum	3.32	
		Maximum	4.00	

		Sum	386.79	
		Mean	3.8296	.01772
		Std. Deviation	.17811	
		Variance	.032	
		Skewness	-1.287	.240
		Kurtosis	1.154	.476

	GROUP		Statistic	Std. Error
TpoMAI	**Control group (DM)**	N	103	
Valid N (listwise)	103	Range	.60	
		Minimum	1.98	
		Maximum	2.58	
		Sum	222.41	
		Mean	2.1593	.01399
		Std. Deviation	.14198	
		Variance	.020	
		Skewness	1.083	.238
		Kurtosis	1.136	.472

GENDER

Descriptive

	GENDER		Statistic	Std. Error
TprMAI (PEOE Strategy)	**Male**	N	61	
		Range	.89	
		Minimum	1.00	
		Maximum	1.89	
		Sum	84.52	
		Mean	1.3856	.02743

		Std. Deviation	.21421	
		Variance	.046	
		Skewness	.228	.306
		Kurtosis	-.052	.604
	Female	N	43	
		Range	.89	
		Minimum	1.00	
		Maximum	1.89	
		Sum	58.51	
		Mean	1.3607	.03335
		Std. Deviation	.21869	
		Variance	.048	
		Skewness	.414	.361
		Kurtosis	.476	.709

	GENDER		Statistic	Std. Error
TpoMAI (PEOE Strategy)	**Male**	N	61	
		Range	.62	
		Minimum	3.38	
		Maximum	4.00	
		Sum	236.05	
		Mean	3.8697	.01630
		Std. Deviation	.12734	
		Variance	.016	
		Skewness	-1.824	.306
		Kurtosis	4.293	.604
	Female	N	43	

	Range	.66	
	Minimum	3.34	
	Maximum	4.00	
	Sum	165.03	
	Mean	3.8339	.02824
	Std. Deviation	.18521	
	Variance	.034	
	Skewness	-1.029	.361
	Kurtosis	.171	.709

	GENDER		Statistic	Std. Error
TprMAI (VH Strategy)	**Male**	N	56	
		Range	.87	
		Minimum	1.00	
		Maximum	1.87	
		Sum	76.69	
		Mean	1.3695	.02737
		Std. Deviation	.20481	
		Variance	.042	
		Skewness	.135	.319
		Kurtosis	.135	.628
	Female	N	45	
		Range	.45	
		Minimum	1.11	
		Maximum	1.56	
		Sum	60.81	
		Mean	1.3513	.01820

	Std. Deviation	.18092	
	Variance	.015	
	Skewness	-.417	.354
	Kurtosis	-.219	.695

	GENDER		Statistic	Std. Error
TpoMAI (VH Strategy)	**Male**	N	56	
		Range	.68	
		Minimum	3.32	
		Maximum	4.00	
		Sum	215.23	
		Mean	3.8434	.02217
		Std. Deviation	.16588	
		Variance	.028	
		Skewness	-1.505	.319
		Kurtosis	2.367	.628
	Female	N	45	
		Range	.66	
		Minimum	3.34	
		Maximum	4.00	
		Sum	171.56	
		Mean	3.8124	.02873
		Std. Deviation	.19276	
		Variance	.037	
		Skewness	-1.085	.354
		Kurtosis	.354	.695

```
DESCRIPTIVES VARIABLES=VAR00037 VAR00038 VAR00039 VAR00040 VAR00041 VAR00042
VAR00043 VAR00044 VAR00045 VAR00046 VAR00047 VAR00048 VAR00049
VAR00050/STATISTICS=MEAN SUM STDDEV VARIANCE RANGE MIN MAX SEMEAN KURTOSIS
SKEWNESS.
```

Descriptives

[DataSet1] C:\Users\VICTOR\Documents\Victor_O._Ajayi_Data analysis.sav

Descriptive Statistics

	GROUP		Statistic	Std. Error
TprOCSEB	**(PEOE Strategy) 1**	N	104	
Valid N (listwise)	104	Range	.89	
		Minimum	1.00	
		Maximum	1.89	
		Sum	139.31	
		Mean	1.3395	.02052
		Std. Deviation	.20930	
		Variance	.044	
		Skewness	.342	.237
		Kurtosis	.236	.469
TprOCSEB	**(VH Strategy) 2**	N	101	
Valid N (listwise)	101	Range	.87	
		Minimum	1.00	
		Maximum	1.86	
		Sum	132.42	
		Mean	1.3111	.02165
		Std. Deviation	.21760	
		Variance	.047	
		Skewness	.227	.240
		Kurtosis	-.231	.476

	GROUP		Statistic	Std. Error
TprOCSEB	**Control group (DM)**	N	103	
Valid N (listwise)	103	Range	.87	
		Minimum	1.00	
		Maximum	1.89	
		Sum	135.94	
		Mean	1.3295	.01837
		Std. Deviation	.18642	
		Variance	.035	
		Skewness	-.165	.238
		Kurtosis	.230	.472

Descriptives

	GROUP		Statistic	Std. Error
TpoOCSEB	**(PEOE Strategy) 1**	N	104	
Valid N (listwise)	104	Range	.66	
		Minimum	3.34	
		Maximum	4.00	
		Sum	398.78	
		Mean	3.8344	.01688
		Std. Deviation	.17213	
		Variance	.030	
		Skewness	-1.283	.237
		Kurtosis	.947	.469
TpoOCSEB	**(VH Strategy) 2**	N	101	
Valid N (listwise)	101	Range	1.00	
		Minimum	3.00	
		Maximum	4.00	

	Sum	382.00	
	Mean	3.7822	.02310
	Std. Deviation	.23219	
	Variance	.054	
	Skewness	-1.754	.240
	Kurtosis	3.225	.476

	GROUP		Statistic	Std. Error
TpoOCSEB	**Control group (DM)**	N	103	
Valid N (listwise)	103	Range	.44	
		Minimum	1.98	
		Maximum	2.42	
		Sum	219.74	
		Mean	2.1334	.01128
		Std. Deviation	.11452	
		Variance	.013	
		Skewness	.593	.238
		Kurtosis	-.225	.472

GENDER

Descriptive

	GENDER		Statistic	Std. Error
TprOCSEB (PEOE Strategy)	**Male**	N	61	
		Range	.89	
		Minimum	1.00	
		Maximum	1.89	
		Sum	82.30	

			Statistic	Std. Error
		Mean	1.3492	.02767
		Std. Deviation	.21614	
		Variance	.047	
		Skewness	.298	.306
		Kurtosis	-.038	.604
	Female	N	43	
		Range	.89	
		Minimum	1.00	
		Maximum	1.89	
		Sum	57.01	
		Mean	1.3258	.03064
		Std. Deviation	.20092	
		Variance	.040	
		Skewness	.401	.361
		Kurtosis	.947	.709

	GENDER		Statistic	Std. Error
TpoOCSEB (PEOE Strategy)	**Male**	N	61	
		Range	.56	
		Minimum	3.44	
		Maximum	4.00	
		Sum	234.75	
		Mean	3.8484	.01843
		Std. Deviation	.25398	
		Variance	.021	
		Skewness	-1.308	.306
		Kurtosis	1.524	.604

			Statistic	Std. Error
	Female	N	43	
		Range	.66	
		Minimum	3.34	
		Maximum	4.00	
		Sum	164.03	
		Mean	3.8147	.03139
		Std. Deviation	.20582	
		Variance	.042	
		Skewness	-1.090	.361
		Kurtosis	.018	.709

	GENDER		Statistic	Std. Error
TprOCSEB (VH Strategy)	**Male**	N	56	
		Range	.87	
		Minimum	1.00	
		Maximum	1.87	
		Sum	73.45	
		Mean	1.3116	.02988
		Std. Deviation	.22364	
		Variance	.050	
		Skewness	.219	.319
		Kurtosis	-.269	.628
	Female	N	45	
		Range	.83	
		Minimum	1.00	
		Maximum	1.83	
		Sum	58.97	

	Mean	1.3104	.03166
	Std. Deviation	.21237	
	Variance	0.45	
	Skewness	.245	.354
	Kurtosis	-.064	.695

	GENDER		Statistic	Std. Error
TpoOCSEB (VH Strategy)	**Male**	N	56	
		Range	1.00	
		Minimum	3.00	
		Maximum	4.00	
		Sum	211.44	
		Mean	3.7757	.03072
		Std. Deviation	.22992	
		Variance	.053	
		Skewness	-1.658	.319
		Kurtosis	3.021	.628
	Female	N	45	
		Range	1.00	
		Minimum	3.00	
		Maximum	4.00	
		Sum	170.56	
		Mean	3.7902	.03538
		Std. Deviation	.23734	
		Variance	.056	
		Skewness	-1.933	.354
		Kurtosis	4.019	.695

```
UNIANOVA TpoOCAT BY Group Gender WITH TprOCAT
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /PLOT=PROFILE(Group*Gender)
  /EMMEANS=TABLES(Group) WITH(TprOCAT=MEAN) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Group*Gender) WITH(TprOCAT=MEAN)
  /PRINT=ETASQ HOMOGENEITY DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /DESIGN=TprOCAT Group Gender Group*Gender.
```

Univariate Analysis of Variance

```
[DataSet1] C:\Users\VICTOR\Documents\Victor Ajayi 2.sav
```

Between-Subjects Factors

		Value Label	N
Group	1	PEOE Strategy	104
	2	VH Strategy	101
	3	Discussion Method	103
Gender	1	Male	174
	2	Female	134

Descriptive Statistics

Dependent Variable: TpoOCAT

Group	Gender	Mean	Std. Deviation	N
PEOE Strategy	Male	29.6721	5.26536	61
	Female	28.8140	5.53025	43
	Total	29.3173	5.36668	104
VH Strategy	Male	28.2143	5.25258	56
	Female	27.5333	5.02087	45
	Total	27.9109	5.13634	101
Discussion Method	Male	15.8772	3.90087	57
	Female	15.1739	3.98500	46
	Total	15.5631	3.93494	103
Total	Male	24.6839	7.85328	174
	Female	23.7015	7.87022	134
	Total	24.2565	7.86298	308

Levene's Test of Equality of Error Variances[a]

Dependent Variable: TpoOCAT

F	df1	df2	Sig.
.795	5	302	.554

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + TprOCAT + Group + Gender + Group * Gender

Tests of Between-Subjects Effects

Dependent Variable: TpoOCAT

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	12185.784[a]	6	2030.964	89.967	.000	.642
Intercept	11702.639	1	11702.639	518.399	.000	.633
TprOCAT	346.379	1	346.379	15.344	.000	.049
Group	11525.883	2	5762.942	255.284	.000	.629
Gender	24.332	1	24.332	1.078	.300	.004
Group * Gender	3.817	2	1.909	.085	.919	.001
Error	6794.953	301	22.575			
Total	200201.000	308				
Corrected Total	18980.737	307				

a. R Squared = .642 (Adjusted R Squared = .635)

Estimated Marginal Means

Group

Estimates

Dependent Variable: TpoOCAT

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
PEOE Strategy	29.242[a]	.473	28.311	30.173
VH Strategy	27.877[a]	.476	26.941	28.813
Discussion Method	15.553[a]	.471	14.627	16.480

a. Covariates appearing in the model are evaluated at the following values: TprOCAT = 10.1591.

Pairwise Comparisons

Dependent Variable: TpoOCAT

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
PEOE Strategy	VH Strategy	1.365	.671	.128	-.250	2.980
	Discussion Method	13.689*	.667	.000	12.082	15.296
VH Strategy	PEOE Strategy	-1.365	.671	.128	-2.980	.250
	Discussion Method	12.324*	.669	.000	10.713	13.935
Discussion Method	PEOE Strategy	-13.689*	.667	.000	-15.296	-12.082
	VH Strategy	-12.324*	.669	.000	-13.935	-10.713

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

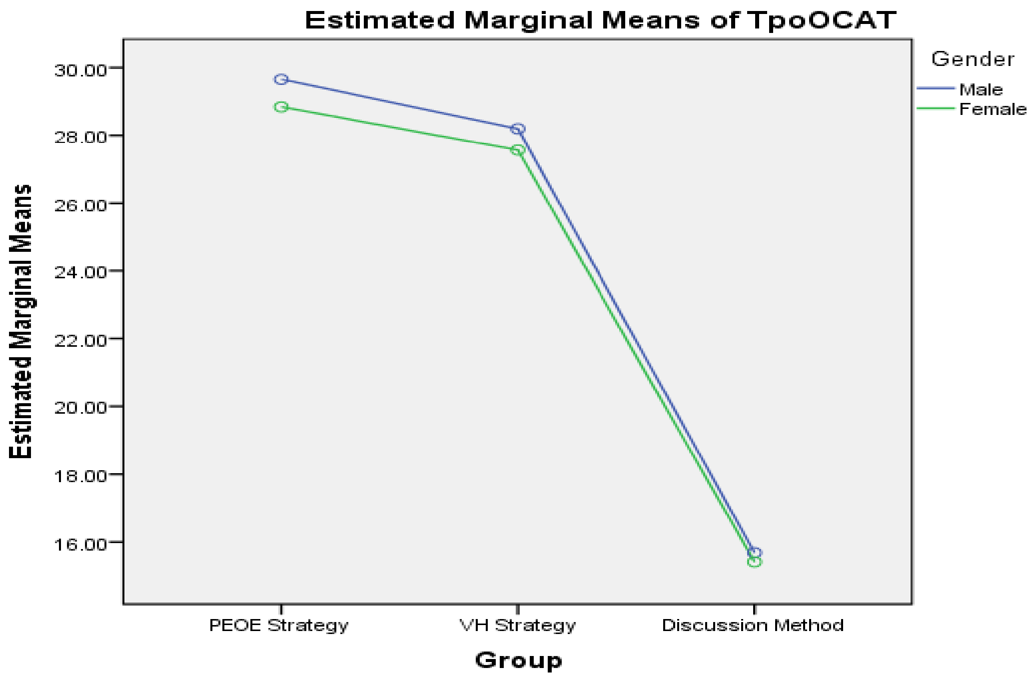
Univariate Tests

Dependent Variable: TpoOCAT

	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Contrast	11525.883	2	5762.942	255.284	.000	.629
Error	6794.953	301	22.575			

The F tests the effect of Group. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Profile Plots



Covariates appearing in the model are evaluated at the following values: TprOCAT = 10.1591

```
UNIANOVA TpoOCAT2 BY GenderPEOE WITH TprOCAT
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /EMMEANS=TABLES(GenderPEOE) WITH(TprOCAT=MEAN)
  /PRINT=ETASQ HOMOGENEITY
  /CRITERIA=ALPHA(.05)
  /DESIGN=TprOCAT GenderPEOE.
```

Univariate Analysis of Variance

[DataSet1] C:\Users\VICTOR\Documents\Victor Ajayi 2.sav

Between-Subjects Factors

		Value Label	N
Gender	1	Male	61
	2	Female	43

Tests of Between-Subjects Effects

Dependent Variable: TpoOCAT (PEOE)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	903.799[a]	2	451.899	22.127	.000	.305
Intercept	3770.959	1	3770.959	184.642	.000	.646
TprOCAT	885.224	1	885.224	43.344	.000	.300
Gender	13.589	1	13.589	.665	.417	.007
Error	2062.730	101	20.423			
Total	92355.000	104				
Corrected Total	2966.529	103				

a. R Squared = .305 (Adjusted R Squared = .291)

Estimated Marginal Means

Gender (PEOE)

Dependent Variable: TpoOCAT (PEOE)

Gender (PEOE)	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Male	29.621[a]	.579	28.473	30.769
Female	28.887[a]	.689	27.519	30.254

a. Covariates appearing in the model are evaluated at the following values:

TprOCAT (PEOE) = 10.1731.

```
UNIANOVA TpoOCAT4 BY GenderVH WITH TprOCAT
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /EMMEANS=TABLES(GenderVH) WITH(TprOCAT=MEAN)
  /PRINT=ETASQ
  /CRITERIA=ALPHA(.05)
  /DESIGN=TprOCAT GenderVH.
```

Univariate Analysis of Variance

[DataSet1] C:\Users\VICTOR\Documents\Victor Ajayi 2.sav

Between-Subjects Factors

		Value Label	N
Gender	1	Male	56
	2	Female	45

Tests of Between-Subjects Effects

Dependent Variable: TpoOCAT (VH)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	15.224[a]	2	7.612	.284	.753	.006
Intercept	6811.882	1	6811.882	254.507	.000	.722
TprOCAT	3.655	1	3.655	.137	.713	.001
Gender	11.231	1	11.231	.420	.519	.004
Error	2622.974	98	26.765			
Total	81319.000	101				
Corrected Total	2638.198	100				

a. R Squared = .006 (Adjusted R Squared = -.015)

Gender (VH)

Dependent Variable: TpoOCAT (VH)

Gender (VH)	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Male	28.210[a]	.691	26.838	29.582
Female	27.539[a]	.771	26.008	29.070

a. Covariates appearing in the model are evaluated at the following values: TprOCAT (VH) = 10.1584.

```
UNIANOVA TpoMAI BY Group Gender WITH TprMAI
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /PLOT=PROFILE(Group*Gender)
  /EMMEANS=TABLES(Group) WITH(TprMAI=MEAN) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Gender) WITH(TprMAI=MEAN) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Group*Gender) WITH(TprMAI=MEAN)
  /PRINT=ETASQ DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /DESIGN=TprMAI Group Gender Group*Gender.
```

Univariate Analysis of Variance

```
[DataSet2] C:\Users\VICTOR\Documents\Victor Ajayi 2.sav
```

Between-Subjects Factors

		Value Label	N
Group	1	PEOE Strategy	104
	2	VH Strategy	101
	3	Discussion Method	103
Gender	1	Male	174
	2	Female	134

Descriptive Statistics

Dependent Variable: TpoMAI

Group	Gender	Mean	Std. Deviation	N
PEOE Strategy	Male	3.8697	.12734	61
	Female	3.8339	.18521	43
	Total	3.8565	.15389	104
VH Strategy	Male	3.8434	.16588	56
	Female	3.8124	.19276	45
	Total	3.8296	.17811	101
Discussion Method	Male	2.1659	.16258	57
	Female	2.1540	.12414	46
	Total	2.1593	.14198	103
Total	Male	3.2992	.81367	174
	Female	3.2554	.81076	134
	Total	3.2801	.81137	308

Levene's Test of Equality of Error Variances[a]

Dependent Variable: TpoMAI

F	df1	df2	Sig.
3.854	5	302	.002

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + TprMAI + Group + Gender + Group * Gender

Tests of Between-Subjects Effects

Dependent Variable: TpoMAI

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	194.499[a]	6	32.417	1282.860	.000	.962
Intercept	65.585	1	65.585	2595.466	.000	.896
TprMAI	.009	1	.009	.337	.562	.001
Group	189.144	2	94.572	3742.616	.000	.961
Gender	.020	1	.020	.801	.371	.003
Group * Gender	.030	2	.015	.600	.550	.004
Error	7.606	301	.025			
Total	3515.955	308				
Corrected Total	202.105	307				

a. R Squared = .962 (Adjusted R Squared = .962)

Estimated Marginal Means

1. Group

Estimates

Dependent Variable: TpoMAI

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
PEOE Strategy	3.855[a]	.021	3.814	3.895
VH Strategy	3.828[a]	.021	3.787	3.869
Discussion Method	2.237[a]	.021	2.197	2.277

a. Covariates appearing in the model are evaluated at the following values: TprMAI = 1.3552.

Pairwise Comparisons

Dependent Variable: TpoMAI

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
PEOE Strategy	VH Strategy	.026	.022	.767	-.028	.080
	Discussion Method	1.693*	.022	.000	1.639	1.747
VH Strategy	PEOE Strategy	-.026	.022	.767	-.080	.028
	Discussion Method	1.667*	.022	.000	1.613	1.721
Discussion Method	PEOE Strategy	-1.693*	.022	.000	-1.747	-1.639
	VH Strategy	-1.667*	.022	.000	-1.721	-1.613

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

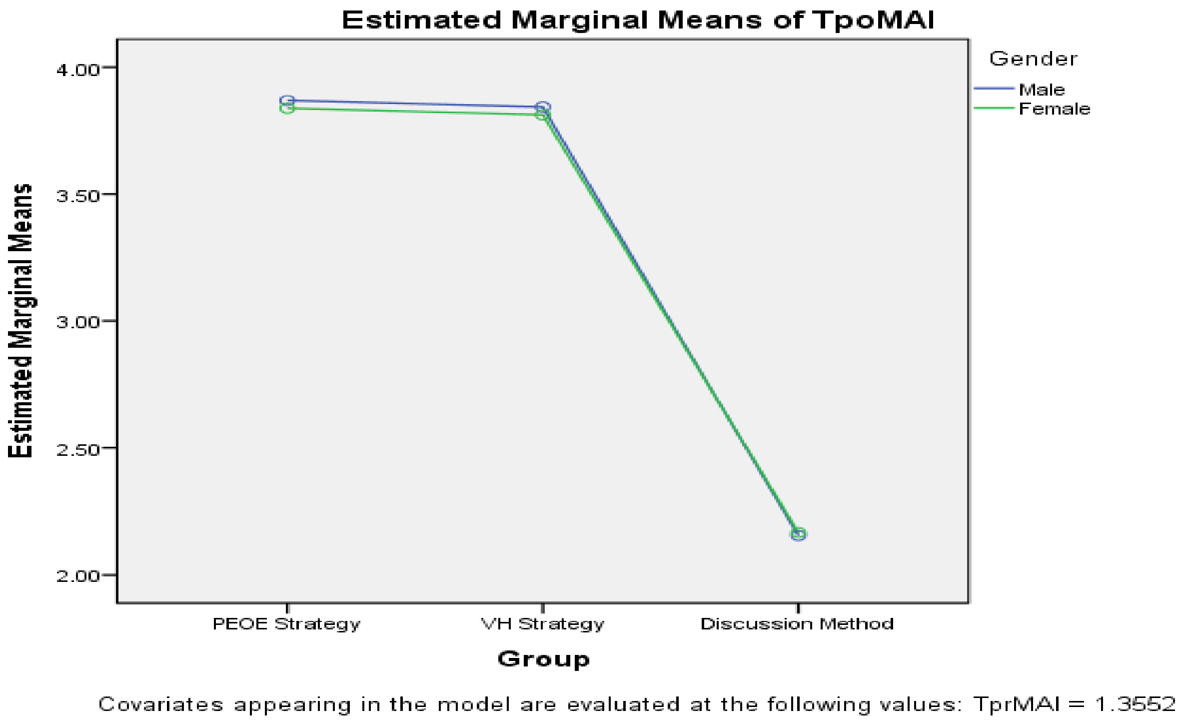
Univariate Tests

Dependent Variable: TpoMAI

	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Contrast	189.144	2	94.572	3742.616	.000	.961
Error	7.606	301	.025			

The F tests the effect of Group. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Profile Plots



```
UNIANOVA TpoMAI BY GenderPEOE WITH TprMAI
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /EMMEANS=TABLES(GenderPEOE) WITH(TprMAI=MEAN)
  /PRINT=ETASQ
  /CRITERIA=ALPHA(.05)
  /DESIGN=TprMAI GenderPEOE.
```

Univariate Analysis of Variance

[DataSet2] C:\Users\VICTOR\Documents\Victor Ajayi 2.sav

Between-Subjects Factors

		Value Label	N
Gender (PEOE)	1	Male	61
	2	Female	43

Tests of Between-Subjects Effects

Dependent Variable: TpoMAI (PEOE) (Gender)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.047[a]	2	.024	.993	.374	.019
Intercept	34.698	1	34.698	1465.031	.000	.936
TprMAI	.022	1	.022	.912	.342	.009
Gender	.021	1	.021	.874	.352	.009
Error	2.392	101	.024			
Total	1549.220	104				
Corrected Total	2.439	103				

a. R Squared = .019 (Adjusted R Squared = .000)

Estimated Marginal Means

Gender (PEOE)

Dependent Variable: TpoMAI (PEOE) (Gender)

Gender (PEOE)	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Male	3.868[a]	.020	3.829	3.908
Female	3.840[a]	.024	3.793	3.886

a. Covariates appearing in the model are evaluated at the following values: TprMAI (PEOE) (Gender) = 1.3753.

```
UNIANOVA TpoMAI BY GenderVH WITH TprMAI
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /EMMEANS=TABLES(GenderVH) WITH(TprMAI=MEAN)
  /PRINT=ETASQ
  /CRITERIA=ALPHA(.05)
  /DESIGN=TprMAI GenderVH.
```

Univariate Analysis of Variance

```
[DataSet2] C:\Users\VICTOR\Documents\Victor Ajayi 2.sav
```

Between-Subjects Factors

		Value Label	N
Gender (VH)	1	Male	56
	2	Female	45

Tests of Between-Subjects Effects

Dependent Variable: TpoMAI (VH) (Gender)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.030[a]	2	.015	.466	.629	.009
Intercept	22.356	1	22.356	697.218	.000	.877
TprMAI	.006	1	.006	.187	.666	.002
Gender	.023	1	.023	.705	.403	.007
Error	3.142	98	.032			
Total	1484.425	101				
Corrected Total	3.172	100				

a. R Squared = .009 (Adjusted R Squared = -.011)

Estimated Marginal Means

Gender (VH)

Dependent Variable: TpoMAI (VH) (Gender)

Gender (VH)	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Male	3.843[a]	.024	3.796	3.891
Female	3.813[a]	.027	3.760	3.866

a. Covariates appearing in the model are evaluated at the following values: TprMAI (VH) (Gender) = 1.3614.

```
UNIANOVA TpoOCSEB BY Group Gender WITH TprOCSEB
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /PLOT=PROFILE(Group*Gender)
  /EMMEANS=TABLES(Group) WITH(TprOCSEB=MEAN) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Gender) WITH(TprOCSEB=MEAN) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Group*Gender) WITH(TprOCSEB=MEAN)
  /PRINT=ETASQ DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /DESIGN=TprOCSEB Group Gender Group*Gender.
```

Univariate Analysis of Variance

```
[DataSet3] C:\Users\VICTOR\Documents\Victor Ajayi 2.sav
```

Between-Subjects Factors

		Value Label	N
Group	1	PEOE Strategy	104
	2	VH Strategy	101
	3	Discussion Method	103
Gender	1	Male	174
	2	Female	134

Descriptive Statistics

Dependent Variable: TpoOCSEB

Group	Gender	Mean	Std. Deviation	N
PEOE Strategy	Male	3.8484	.14398	61
	Female	3.8147	.20582	43
	Total	3.8344	.17213	104
VH Strategy	Male	3.7757	.22992	56
	Female	3.7902	.23734	45
	Total	3.7822	.23219	101
Discussion Method	Male	2.1326	.09839	57
	Female	2.1343	.13296	46
	Total	2.1334	.11452	103
Total	Male	3.2629	.80872	174
	Female	3.2296	.81847	134
	Total	3.2484	.81181	308

Levene's Test of Equality of Error Variances[a]

Dependent Variable: TpoOCSEB

F	df1	df2	Sig.
5.311	5	302	.000

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + TprOCSEB + Group + Gender + Group * Gender

Tests of Between-Subjects Effects

Dependent Variable: TpoOCSEB

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	192.673[a]	6	32.112	1001.321	.000	.952
Intercept	69.528	1	69.528	2168.028	.000	.878
TprOCSEB	.094	1	.094	2.919	.089	.010
Group	189.421	2	94.710	2953.260	.000	.952
Gender	.001	1	.001	.032	.858	.000
Group * Gender	.031	2	.015	.476	.622	.003
Error	9.653	301	.032			
Total	3452.457	308				
Corrected Total	202.326	307				

a. R Squared = .952 (Adjusted R Squared = .951)

Estimated Marginal Means

Group

Estimates

Dependent Variable: TpoOCSEB

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
PEOE Strategy	3.831[a]	.018	3.795	3.866
VH Strategy	3.784[a]	.018	3.749	3.820
Discussion Method	2.133[a]	.018	2.099	2.168

a. Covariates appearing in the model are evaluated at the following values: TprOCSEB = 1.3269.

Pairwise Comparisons

Dependent Variable: TpoOCSEB

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
PEOE Strategy	VH Strategy	.046	.025	.206	-.015	.107
	Discussion Method	1.697*	.025	.000	1.637	1.758
VH Strategy	PEOE Strategy	-.046	.025	.206	-.107	.015
	Discussion Method	1.651*	.025	.000	1.590	1.712
Discussion Method	PEOE Strategy	-1.697*	.025	.000	-1.758	-1.637
	VH Strategy	-1.651*	.025	.000	-1.712	-1.590

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

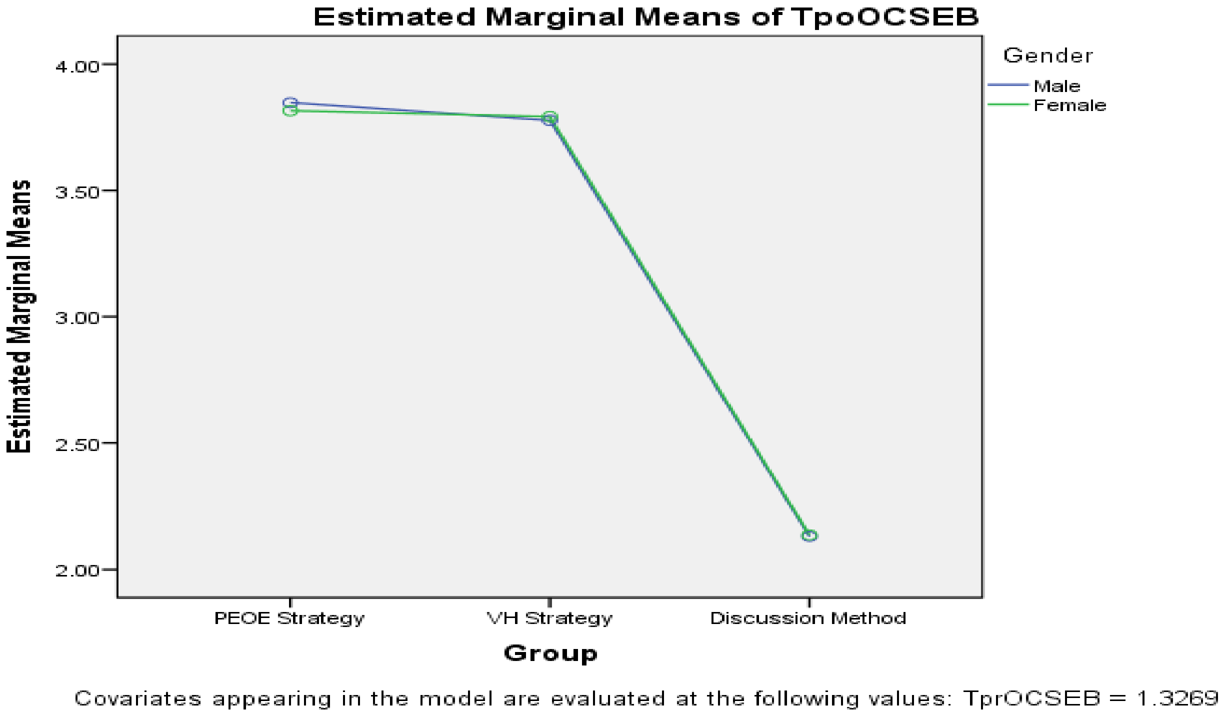
Univariate Tests

Dependent Variable: TpoOCSEB

	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Contrast	189.421	2	94.710	2953.260	.000	.952
Error	9.653	301	.032			

The F tests the effect of Group. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Profile Plots



```
UNIANOVA TpoOCSEB BY GenderPEOE WITH TprOCSEB
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /EMMEANS=TABLES(GenderPEOE) WITH(TprOCSEB=MEAN)
  /PRINT=ETASQ
  /CRITERIA=ALPHA(.05)
  /DESIGN=TprOCSEB GenderPEOE.
```

Univariate Analysis of Variance

[DataSet3] C:\Users\VICTOR\Documents\Victor Ajayi 2.sav

Between-Subjects Factors

		Value Label	N
Gender (PEOE)	1	Male	61
	2	Female	43

Tests of Between-Subjects Effects

Dependent Variable: TpoOCSEB (PEOE) (Gender)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.097[a]	2	.049	1.665	.194	.032
Intercept	32.977	1	32.977	1127.379	.000	.918
TprOCSEB	.069	1	.069	2.351	.128	.023
Gender	.024	1	.024	.817	.368	.008
Error	2.954	101	.029			
Total	1532.143	104				
Corrected Total	3.052	103				

a. R Squared = .032 (Adjusted R Squared = .013)

Estimated Marginal Means

Gender (PEOE)

Dependent Variable: TpoOCSEB (PEOE) (Gender)

Gender (PEOE)	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Male	3.847[a]	.022	3.804	3.891
Female	3.816[a]	.026	3.765	3.868

a. Covariates appearing in the model are evaluated at the following values: TprOCSEB (PEOE) (Gender) = 1.3395.

```
UNIANOVA TpoOCSEB BY Gender WITH TprOCSEB
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /EMMEANS=TABLES(GenderVH) WITH(TprOCSEB=MEAN)
  /PRINT=ETASQ
  /CRITERIA=ALPHA(.05)
  /DESIGN=TprOCSEB GenderVH.
```

Univariate Analysis of Variance

```
[DataSet3] C:\Users\VICTOR\Documents\Victor Ajayi 2.sav
```

Between-Subjects Factors

		Value Label	N
Gender (VH)	1	Male	56
	2	Female	45

Tests of Between-Subjects Effects

Dependent Variable: TpoOCSEB (VH) (Gender)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.142[a]	2	.071	1.326	.270	.026
Intercept	33.980	1	33.980	634.406	.000	.866
TprOCSEB	.137	1	.137	2.553	.113	.025
Gender	.005	1	.005	.101	.752	.001
Error	5.249	98	.054			
Total	1450.183	101				
Corrected Total	5.391	100				

a. R Squared = .026 (Adjusted R Squared = .006)

Estimated Marginal Means

Gender (VH)

Dependent Variable: TpoOCSEB (VH) (Gender)

Gender (VH)	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Male	3.776[a]	.031	3.714	3.837
Female	3.790[a]	.035	3.722	3.859

a. Covariates appearing in the model are evaluated at the following values: TprOCSEB (VH) (Gender) = 1.3111.