**UNIVERSITY OF EDUCATION, WINNEBA**

# EFFECTS OF PREDICT-OBSERVE-EXPLAIN INSTRUCTIONAL APPROACH ON SCIENCE STUDENT-TEACHERS' PERFORMANCE AND ATTITUDES TOWARDS SELECTED ORGANIC CHEMISTRY TOPICS

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# DECLARATION

## STUDENT'S DECLARATION

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

Signature:........................................................................

Date: ..................................................................................

## SUPERVISORS' DECLARATION

We hereby declare that the preparation and presentation of this thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Education, Winneba.

Name: Professor John K. Eminah (Principal Supervisor)

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Date: .....................................................................................

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Date: .....................................................................................

# DEDICATION

To My lovely Family Members

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# ABSTRACT

The study was conducted to assess the effects of predict-observe-explain instructional approach (POEIA) on the selected College of Education (COE) science student-teachers' performance and attitudes towards the selected organic chemistry topics mainly hydrocarbons, alkanols, carbonyl compounds, alkanoic acids, alkanoates and amines. Action research was the design employed for the study. A total sample size of 40, 2021-2022 second year science student-teachers made up of 32 (80.0%) males and 8 (20.0%) females were used for the study. A purposive sampling technique was used to select the sample in an intact class for the study. Tests, questionnaires and interviews were the instruments used to collect data for the study. The POEIA intervention activities was implemented for ten weeks. The data were analysed using both quantitative and qualitative data analysis methods. The SPSS version 21.0 for window was used for data analysis; and Microsoft excel program was used to present the data pictorially into Tables and charts. It was revealed that almost all 38(95.0%) perceived organic chemistry to be very difficult for them to learn. Again, alkenes, alkynes, alkanols, aldehydes, ketones, alkanoic acids, alkanoates, acid anhydrides and amines were identified as the nine most difficult topics to learn in their COE organic chemistry curriculum; with ketones being the most difficult topic. All the 40 (100%) respondents unanimously agreed that lack of remedial action by COE tutors for them and organic chemistry syllabus being too broad were the two major causes of their conceptual difficulties in learning the selected topics. It was observed that majority (50% or more) of the respondents demonstrated very good conceptual understanding with respect to functional group identification; but almost all of them demonstrated low conceptual understanding with respect to IUPAC nomenclature, organic reaction mechanisms and correct balancing of equations involving combustion of hydrocarbons and had misconceptions on these topics. It was found that science student-teachers' performance had improved significantly and also had higher positive attitudes towards the selected organic chemistry topics after they had been exposed to the POEIA intervention activities. The post-intervention test results showed a significant increase in performance ($t = -6.639$, $p < 0.05$). Finally, the views of the research subjects on the POEIA were very positive, they wanted it to be continued, and that they indicated that the designed POE module could be used to enhance the teaching and learning of the selected organic chemistry topics at the colleges. It was therefore, recommended that chemistry tutors should adopt innovative teaching strategies such as POEIA so as to help COE science student-teachers to learn organic chemistry topics such hydrocarbons, alkanols, carbonyls, alkanoic acids, esters and amines better in colleges.

# CHAPTER ONE

## INTRODUCTION

### 1.0 Overview

This chapter presents the background to the study, statement of the problem, purpose of the study, objectives of the study, research questions, significance of the study, delimitation of the study and limitations of the study. Also included are the definition of terms, list of abbreviations and the organization of the study reports.

### 1.1 Background to the Study

One of the goals of science education is to develop learners' ability to acquire knowledge in specific subjects and improve their conceptual understanding. The need for designing instruction that will promote better conceptual understanding of abstract scientific concepts is very critical to the development of science education (National Research Council (NRC), 1996; 2006).

Research in science education shows that students have difficulties in acquisition of abstract scientific concepts particularly in chemistry (Taber, 2002a; Gafoor & Shilna, 2013). Chemistry is a difficult subject for learners (O'Dwyer & Childs, 2010; Taber, 2014). Part of this difficulty can be traced to factors inherent in the content; primarily its multi-level knowledge base (Johnstone, 1993; Khoo & Koh, 1998; Taber, 2002b). Johnstone (1993) identified three levels of chemistry. These levels of chemistry are "macrochemistry" or that which can actually be seen, touched or eaten, "microchemistry" or the particulate level of matter, and "representational or symbolic," the chemistry of symbols, equations, stoichiometry and mathematics". Conceptualizing them as a point of an equilateral triangle is very crucial in understanding any chemical concept (Khoo & Koh, 1998; Taber, 2009).

Whereas experts can wok simultaneously at all levels and shift between them, novices like students are unable to do so. Attest to this fact, Johnstone (1993, p.704) posited that “students are like drivers in a strange town who don’t know what to attend to and in trying to process too much, they tend to overload”. This problem of distinguishing “signal” from “noise” (Johnstone, 1991, p.80) can result in each knowledge level being viewed as independent of the others. Therefore, for concept to be taught and learnt meaningfully in chemistry there should be a link between these three levels. However, students do not seem to master chemistry to the same extent at all the three levels, nor are they able to make connections among these three essential levels.

Studies (Johnstone, 1993; Taber, 2009; O’Dwyer & Childs, 2014) have shown that while chemistry can be taught at these three (3) levels, most chemistry courses only concentrate on the symbolic level of chemistry teaching, neglecting the other two aspects. However, some good teachers may go an extra mile to organize their instructional activities at both macroscopic and symbolic levels, such as demonstrating experiments and conducting practical work to show chemical phenomena (at the microscopic level), and explaining concepts using chemical equations or symbols (the symbolic level).

Nevertheless, students may still find it difficult to understand certain chemical concepts particularly the organic chemistry concepts. This is because such concepts occur at the microscopic level which makes it difficult to be seen at the macroscopic level. At the microscopic level, students find it very difficult to conceptualise them. Supporting this statement, Uchegbu, Ahuchaogu and Amanze (2017) posited that these abstract concepts are very necessary and useful because further chemistry concepts cannot be easily understood if these underpinning concepts are not sufficiently grabbed by the students. Thus, chemistry educators should design effective instructional approaches that facilitate the teaching and learning of any chemistry concept to students.

In a study, Senese (2013) indicated that chemistry is an experimental science that systematically studies the composition, properties and activities of organic and inorganic substances and various elementary forms of matter. Generally, chemistry as a school subject can be classified into three namely organic, inorganic and physical chemistry. The organic chemistry which is the main focus of this study deals with the study of hydrocarbons (alkanes, alkenes, alkynes), alcohols, carbonyl compounds, alkanoic acids, alkanoic acid derivatives (mainly esters, acid anhydrides, acid amides) and amines.

Organic chemistry is a very essential subject as its knowledge is required for the successful study in many important professions and it has been found very useful in many different fields of science and technology. It application is seen or felt in the petroleum and petrochemical industries, beverage and food industries. Attesting to the importance of organic chemistry, Hanson (2017) posited that adequate understanding of organic chemistry is a pre-requisite for many graduate and professional programs. It is the basis for the production of food flavours, plastics, fuels and pharmaceuticals.

Organic chemistry occupies a central position in the Ghanaian Colleges of Education chemistry (both practical and theory) curriculum; and it is one of the courses offered by both science and non-science student-teachers. At the college level, science student-teachers are expected to understand the needed content and pedagogical knowledge in organic chemistry, so that they can impart the knowledge gained to their students at the Junior High Schools (JHS) after their successful graduation. Thus, science student-teachers studying college chemistry should have in-depth knowledge in various organic chemistry topics and apply the needed knowledge to their everyday interactions with the ever changing environment, so that they can live successfully in their society.

The study of organic chemistry has been part of Colleges of Education (COE) chemistry curriculum for many years; yet several studies over the years (Ferguson &

Bodner, 2008; Childs & Sheehan, 2009; Wasacz, 2010; O'Dwyer, 2012; Eticha & Ochonogor, 2017; Uchegbu et al., 2017; Garg, 2019) have indicated that students including science student-teachers at college level and even at the university level have conceptual difficulties in learning or understanding these organic chemistry concepts due to the multifaceted and abstract nature of the topics. Garg (2019) opined that organic chemistry is one of the most challenging chemistry courses taught during undergraduate years; and it is such an onerous course with attrition rates ranging 30-50% even at some universities. This means that globally students have difficulties in organic chemistry.

For example, Wasacz (2010) investigated 25 final year chemistry students' conceptions of organic chemistry concepts from five (5) tertiary institutions; three western universities (University A; University B; and University C), one midwestern college (College D) and one northeastern college (College E). The study revealed that majority (71%) of the students indicated that organic chemistry was very difficult to understand, and they had learning difficulties in IUPAC nomenclature and organic reactions. The study concluded that most of these students had inadequate conceptions about these concepts and that most of them could not even explain organic chemistry.

A similar study conducted by Eticha and Ochonogor (2017) in Ethiopian higher education regarding organic chemistry courses among 177 students revealed another shocking statistics. The study revealed that 143(80.79%) of the 177 student-teachers strongly indicated that organic chemistry was very difficult to understand and also hard to solve organic chemistry problems. The study further concluded that majority of the students had conceptual difficulties in areas such as IUPAC nomenclature; functional group identification, stereochemistry and organic reaction mechanisms.

In another study, Uchegbu et al. (2017) investigated 251 final year students' conceptual difficulties in various organic chemistry concepts. These 251 final year students were from three tertiary institutions (i.e. AlvanIkoku Federal College of Education, Owerri; Federal polytechnic, Nekede; and Federal University of Technology, Owerri) all in Imo state of Nigeria. Their study revealed that majority of the students indicated that organic chemistry concepts were very difficult to understand or never understood it at all. The study further revealed that majority of the students had conceptual difficulties in eleven organic chemistry topics including organic reaction mechanisms, stereochemistry, isomerism, spectroscopy, petroleum, petrochemicals and alternative fuels, nitro-alkanes, peptides and proteins, aromatic compounds, polynuclear aromatic hydrocarbon and synthetic polymers. The study concluded that the performance was disappointing in general and that science student-teachers at the university had performed better than their counterparts in the college. This finding confirms that science student-teachers at college perceived organic chemistry topics to be very difficult. This may be observed among science student-teachers in the Ghanaian Colleges of Education.

From the above analyses, it presupposes that science student-teachers' difficulties in understanding organic chemistry concepts, together with the presence of their misconceptions with respect to these concepts is universal and invariably the science student-teachers in the COE in Ghana are of no exception and science student-teachers in Foso College of Education in particular cannot be exempted from this predicament.

Numerous research studies over the years (Nwagbo, 2001; Ogunniyi, 2002; Bajah, 2003; Stieff, 2007; Taber, 2009; O'Dwyer & Childs, 2017) have identified a number of factors that are responsible for students' conceptual difficulties in learning organic chemistry concepts; and these factors include teacher-centred teaching, lack of motivation, presence of students and teachers' misconceptions and ineffective teaching methods used by teachers in teaching these concepts in schools. Out of these numerous factors, the commonest factor that has been identified and blamed by these researchers is the ineffective and uninspiring traditional teaching methods often used by the chemistry teachers in teaching organic chemistry topics/concepts in schools.

Studies by Adeyemi (2014), Haruna (2016) and Ajayi (2019) have indicated that lecture, discussion, demonstration and questioning techniques are the traditional teaching methods often used by the chemistry teachers in teaching the concepts. Adeyemi (2014) and Haruna (2016) noted that the lecture and discussion methods were the two (2) common instructional strategies often used by chemistry teachers. Of these two (2) teaching strategies, Adebayo (2015) noted that lecture method interspersed with demonstration is the most popular instructional strategy used by teachers in teaching organic chemistry in tertiary institutions. Similar instructional approaches are used in COE in Ghana. This is evident from informal talks the researcher had with his colleagues in other colleges. These research reports indicated that the use of traditional lecture method does not enhance meaningful learning but leads to rote learning without conceptual understanding of organic chemistry topics. For example, Grove and Bretz (2010) indicated that many of the difficulties students experience in learning organic chemistry occurred as a result of relying on rote memorization rather than developing better conceptual understanding of various organic chemistry concepts.

Ogunniyi (2002) and Koosimile (2005) reported that the persistent use of the traditional lecture method would continue to hamper students' performance and attitudes in science (particularly chemistry) if proper measures were not taken. Additionally, Hanson (2017) found that majority of teachers used the lecture as well as the question and answer methods. The study revealed that teachers spent less interactive sessions with their students and conducted virtually no hands-on activities for them and this makes it difficult for them to understand the needed concepts embedded in organic chemistry topics.

In this line of reason, the question that comes into one's mind is:- What changes in chemistry instruction ensure permanent and meaningful learning resulting in improved performance and desirable changes in science student-teachers' attitudes towards chemistry, particularly the organic chemistry topics in the colleges of education?.

The above stated questions cannot be answered without engaging science student-teachers in meaningful learning. Meaningful learning requires the learner to communicate deeper understanding of a problem or issues rather than memorise sets of isolated facts and it must result in achievements that have relevance beyond school (Brown, 1997). Therefore, for meaningful learning to take place in science particularly chemistry to bring about improved performance and desirable changes in the science student-teachers' negative attitudes in colleges; the instructional methods used by COE chemistry tutors in teaching organic chemistry concepts need to be innovative.

One of such innovations is through the design and implementation of activity-oriented lessons based on the Predict-Observe-Explain instructional approach (POEIA). This POE instructional approach was originally designed as Demonstrate-Observe-Explain (DOE) by Champagne, Klopfer and Anderson (1979) and was first modified as Predict-Observe-Explain (POE) by Gunstone and White (1981; as cited in Acar-Seşen & Mutlu, 2016). Moreover, Ozcan and Uyanik (2022) indicated that students need to make their predictions to make their beliefs explicit and support their predictions with reasons. The "Observe" stage deals with the integration of practical activities based on scientifically accepted theory into the teaching of the concepts, so that students can consolidate their theoretical gains. Then, the students need to "Explain" their observations, compared with their initial predictions and reconcile any differences between their earlier predictions and observations made. These basic processes constitute the "Predict-Observe-Explain' instructional approach.

According to Hilario (2015), the POE instructional approach is an effective instructional tool that seeks to improve conceptual understanding, performance, attitudes, and problem solving abilities of students in science classes. Organic chemistry concepts including hydrocarbons, alcohols, carbonyl compounds, alkanoic acids, alkanoic acid derivatives such as esters, etc is one of the essential chemistry subject in the Colleges of Education chemistry curriculum for some time now. It is one of the compulsory courses that should be taken by the science student-teachers at the college level in Ghana.

However, studies (O' Dwyer & Childs, 2010; Coll, 2014; Hanson, 2017; Bain & Towns, 2018; Yaayin, Oppong & Hanson, 2022) have revealed that students, including science student-teachers have difficulties in learning organic chemistry topics such as hydrocarbons, alcohols, carbonyls, alkanoic acids, alkanoic acid derivatives and amines. Studies (Yara, 2009; Hanson, Sam & Antwi, 2012; Decocq & Bhattacharyya, 2019) have attributed science student-teachers' difficulties in learning organic chemistry concepts to ineffective lecture method often used by chemistry instructors in teaching these topics.

Numerous studies (Bilen & Aydogdu, 2010; Vadapally, 2014; Harman & Yenikalayci, 2022; Özcan & Uyanık, 2022) have indicated that the POE instructional approach is a very effective tool in improving learners' performance in any scientific concept including organic chemistry than the traditional uninspiring lecture method. For example, Özcan and Uyanık (2022) in a study found that student-teachers who were taught using POE instructional approach had better conceptual understanding; improved performance and developed positive attitudes towards the organic chemistry concepts.

It is, however, noted that even though quite a number of studies have been conducted elsewhere to assess the effects of POE instructional approach on other science concepts, only a few or no studies have been conducted to find out the effectiveness of such instructional approach on the science student-teachers' performance and attitudes towards organic chemistry topics in chemistry at the college level in Ghana. Since organic chemistry topics were very difficult for science student-teachers to understand; it is imperative that an innovative teaching strategy such as the POE instructional approach be used in teaching these topics so as to improve science student-teachers' performance and attitudes towards the selected organic chemistry topics at college level.

It is against this background that this study was undertaken to improve the performance of Foso College of Education (FOSCO) science student-teachers' performance and attitudes towards the selected topics in organic chemistry using "Predict-Observe-Explain Instructional Approach" (POEIA) intervention activities.

## 1.2 Statement of the Problem

In Ghana, science student-teachers in Colleges of Education (COE) are expected to study both theory and practical chemistry particularly in organic chemistry. Organic chemistry has been part of the level 200 General Chemistry Theory II Curriculum, with Course Code EBS 254 for the COE affiliated to the University of Cape Coast for science student-teachers. Over the years science educators, parents and other stakeholders in science education at college level have been worried about the poor performance of these science student-teachers in their quizzes, mid-semester and the end-of-semester chemistry examinations.

A recent study by Yaayin et al. (2022) reported low academic achievements among level 200 pre-service science teachers in two Ghanaian Colleges of Education regarding organic chemistry concepts. My experience in Foso College of Education as a tutor shows that science student-teachers in this College cannot be exempted from this issue. Although the study did not give statistics on their performance, it could be inferred that these students had conceptual difficulties in organic chemistry topics.

During a chemistry lesson in February, 2022 within the first semester, with the 2021/2022 batch of level 200 (second-year) science student-teachers at Foso College of Education, it was observed that the level 200 science student-teachers had conceptual difficulties learning organic chemistry aspects of the General Chemistry Theory II Curriculum. Persistent interactions with these science student-teachers (as a college chemistry tutor) revealed that almost all of them had learning difficulties in topics such as hydrocarbons, alkanols, carbonyl compounds, alkanoic acids, esters and amines.

Various studies (Hanson et al., 2012; Tenaw, 2015; Decocq & Bhattacharyya, 2019) have attributed these conceptual difficulties to the theoretical and uninspiring lecture methods with little or no practical activities often used by chemistry tutors in teaching these abstract organic chemistry topics to these young and novice science student-teachers. This ineffective and obsolete lecture method used by the chemistry tutors have made it difficult for these science student-teachers to understand the needed knowledge and skills embedded in the organic chemistry topics understudy.

This development has impacted negatively on these science student-teachers' performance and attitudes in organic chemistry as a college subject. If this poor performance and negative attitudes among these science student-teachers in organic chemistry is left unresolved; then the country Ghana may soon lose a high proportion of its potential science teachers. Hence, there is an urgent need to adopt innovative teaching strategies in teaching these organic chemistry topics to these learners.

Numerous studies (Hilario, 2015; Acar-Sesen & Mutlu, 2016; Ojo & Owolabi, 2021; Çalış & Özkan, 2022) have indicated that "Predict-observe-explain instructional approach" (POEIA) intervention activities could be used to improve students' performance and attitudes towards the selected topics in organic chemistry. Since COE science student-teachers' have difficulties in understanding organic chemistry concepts, it is imperative that an innovative approach such POEIA should be used to improve their performance and attitudes towards the selected organic chemistry topics. Despite the numerous studies done by other science educators elsewhere with success, no studies of such nature have been done in the Ghanaian COE settings. This grey academic area or gap need to be filled. Therefore, much remain to be empirically studied on assessing the effects of POEIA on science student-teachers' performance and attitudes towards the selected organic chemistry topics.

It is in the light of this that this study was carried out to help improve Foso College of Education (FOSCO) level 200 science student-teachers' performance and attitudes towards the selected organic chemistry topics using POEIA intervention activities.

## 1.3 Purpose of the Study

The purpose of the study was to assess the effects of predict-observe-explain instructional approach (POEIA) on Foso College of Education science student-teachers' performance and attitudes towards the selected organic chemistry topics.

## 1.4 Objectives of the Study

The objectives of this study were six-fold.

1) To find out the COE science student-teachers' difficulties in learning the selected topics in organic chemistry.
2) To identify the possible causes of the COE science student-teachers' conceptual difficulties in learning the selected topics in organic chemistry.
3) To explore the science student-teachers' conceptions of the selected topics in organic chemistry.
4) To evaluate the effects of POEIA on the science student-teachers' performance in the selected topics in organic chemistry.

5) To assess the impact of POEIA on the science student-teachers' attitudes towards the selected topics in organic chemistry.
6) To design a module that could be used to enhance the teaching and learning of the selected organic chemistry topics in the target institution.

## 1.5 Research Questions

The study was guided by the following research questions.

1) What difficulties do the COE science student-teachers encounter during the learning of the selected topics in organic chemistry?
2) What are the possible causes of the COE science student-teachers' conceptual difficulties in learning the selected topics in organic chemistry?
3) What conceptions do the science student-teachers possess about the selected organic chemistry topics?
4) What are the effects of the POEIA on the science student-teachers' performance in the selected organic chemistry topics?
5) What is the impact of the POEIA on the science student-teachers' attitudes towards the selected organic chemistry topics?
6) What module can be designed to enhance the teaching and learning of the selected organic chemistry topics in the target institution?

## 1.6 Significance of the Study

The significance of this study is enormous. The study would outline COE science student-teachers' difficulties in learning the selected organic chemistry topics. This would enable COE chemistry tutors become aware of such difficulties and help address such conceptual difficulties among these science student-teachers during the teaching of these concepts in their colleges.

The study would also outline the possible causes of COE science student-teachers' conceptual difficulties in learning the selected organic chemistry topics. This would make COE chemistry tutors to become aware of the causes of science student-teachers' difficulties so that an innovative teaching strategy could be used to solve such difficulties in colleges. Also, the study would highlight the conceptions COE science student-teachers have regarding the selected organic chemistry topics. It would further outline specific misconceptions research subjects have about these selected topics.

The study would also bring to bear the effects of POE instructional approach in improving science student-teachers' performance in the selected topics in organic chemistry. This would enable COE chemistry tutors to adopt such innovative teaching strategies into their daily teachings at the college level.

Again, the study would highlight COE science student-teachers' attitudes towards organic chemistry concepts after the implementation of the POE instructional approach. This would enable stakeholders to be aware of whether the COE science student-teachers like or dislike the selected organic chemistry concepts.

Another significance of this study is focused on improving theoretical chemistry teaching in the Colleges of Education by targeting tutors in adopting this strategy in their everyday teaching. Thus, this study would design a module in the form of lesson plans and their corresponding worksheets and activity guides based on the POE instructional approach that could be used to enhance the teaching and learning of the selected organic chemistry topics at COE level.

Finally, the study would serve as a source of reference for those who wish to carryout studies into similar issues in using POE instructional approaches to improve science student-teachers' performance and attitudes towards the selected organic chemistry topics in schools and colleges.

## 1.7 Delimitation of the Study

The study was delimited to all the Colleges of Education in the Central region of Ghana. Within the said region, the study was further delimited to only Foso College of Education, (FOSCO). Within FOSCO, the study was further narrowed down to only the 2021/22 second year science student-teachers pursuing General Chemistry Theory II. Among the 2021/22 second year science student-teachers, the study was delimited to only 40 second year science student-teachers, made up of 32 males and 8 females.

Finally, the study focussed on only the selected organic chemistry topics. Other chemistry topics in the syllabus for the chemistry course were excluded.

## 1.8 Limitations of the Study

There were some significant challenges or problems that the study encountered which were seen as limitations of the study. Some limitations encountered include:

Firstly, the designed and implementation of POEIA required the use of some simple chemicals or reagents. These chemicals or reagents were very expensive and not easily available. This situation affected the design of the POEIA intervention activities. Secondly, the time scheduled for the compilation of data and completion of the study was seriously affected by the worldwide pandemic of COVID-19. The COVID-19 pandemic delayed the reopening of Colleges of Education for the arrival of the level 200 respondents used for the study.

Thirdly, there may also be the possibility of the respondents providing false and untrue data or information during the study. This could affect the validity and reliability of the results of the study. Finally, the use of smaller sample size of 40 science student-teachers was a major limitation. The use of smaller sample size for the study had the tendency of affecting the validity and reliability of the results of the study. As a result of this small sample size, the results of this study could not be generalised.

## 1.9 Definition of Terms

**Constructivism:** It is a learning theory that describes learning as an active process where learners are involved in constructing their own knowledge. This theory is based on the idea that learners are active participants in their learning; and knowledge is constructed based on their experiences.

**Misconceptions:** This also known as alternative conceptions. They are used to describe science students-teachers' ideas or opinions which are different from the scientifically accepted facts or views.

**Performance:** It is the learning attainment of science student-teachers taught organic chemistry concepts using POEIA as expressed in scores in this study.

**Predict-Observe-Explain:** It is a pedagogical approach that serves as an efficient teaching and learning strategy for eliciting students' ideas, encouraging critical observation through practical activities and promoting students' discussion about their ideas (Gunstone & White, 1981).

**Traditional Lecture Method (TLM):** It is a form of expository learning. It is an instructional strategy in which a teacher tells students both the generalizations and specifics which are expected to be learned; and presents declarative information in a step-by-step way through oral drills.

**Instructional Approach**: An instructional strategy is a way or means of organizing and facilitating learning experiences. It occurs in two forms namely the expository (transmission) and heuristic (discovery) strategies.

## 1.10 List of Abbreviations

**COE:** Colleges of Education

**DOE:** Demonstrate-Observe-Explain

**FOSCO:** Foso College of Education

| | |
|---|---|
| **GCOE:** | Ghanaian Colleges of Education |
| **POE:** | Predict-Observe-Explain |
| **POEIA:** | Predict-Observe-Explain Instructional Approach |
| **SHS:** | Senior High School |
| **UCC:** | University of Cape Coast |
| **UEW:** | University of Education, Winneba |

### 1.11 Organization of the Study Reports

This study was organized into five (5) chapters. Chapter One presents the background to the study, statement of the problem, purpose of the study, research questions, significance of the study, delimitation of the study and limitations of the study. Also included are definition of terms, list of abbreviations and the organization of the study reports.

Chapter Two describes the review of related literature that underpins the study. Various themes and sub-themes based on the objectives or research questions have been presented including theoretical and conceptual frameworks of the study respectively.

Chapter Three discusses the methodology employed in the study and it includes research design, population, sample and sampling procedure, instruments, data collection procedure and data analysis methods.

Chapter Four presents the analysis of the results and discussion of the findings of the study in relation to the research questions. Finally, Chapter Five being the last chapter, covers the summary of the study, key findings, conclusions, recommendations, educational implications and suggestions for further studies. Also, included are the contributions of the study to science education and contributions of the study to knowledge respectively.

# CHAPTER TWO

## REVIEW OF RELATED LITERATURE

### 2.0 Overview

This chapter describes the review of related literature that underpins the study. The sub-headings to be discussed in this aspect of the study are:

1) Theoretical Framework of the Study
2) Conceptual Framework of the Study
3) Definition and Conceptualization of Predict-Observe-Explain Approach
4) Students' Conceptual Difficulties In Learning Organic Chemistry
5) Causes of Students' Difficulties in Learning Organic Chemistry
6) Students' Conceptions In Organic Chemistry
7) Effects of POEIA on Students' Academic Performance in Organic Chemistry
8) Impact of POEIA on Students' Attitudes Towards Organic Chemistry
9) Summary of Review of Related Literature

The above nine stated points have been enumerated extensively below as follows:

### 2.1 Theoretical Framework of the Study

The term theoretical framework of the study has been conceptualised by several authors in various fields of endeavour. For example, Grant and Osanloo (2014) see theoretical framework of a study as a blue print for a research and it consists of theoretical principles, concepts and tenants of a theory. Adom, Hussein and Agyem (2018) also conceptualised the theoretical framework of a study as a framework based on an existing theory in a field of inquiry that is related to and reflects the hypothesis of a study. Based on the above definitions or explanations given, the two authors have different optics or perspectives regarding the theoretical framework of a study.

Commenting on the importance of the theoretical framework of a study to a research work, Grant and Osanloo (2014) indicated that theoretical framework offers several benefits to a research work; and that it provided the structure in showing how a researcher defines his/her study philosophically, epistemologically, methodically and analytically. In affirmation of the significance of theoretical framework of a study to a research work, Ravitch and Carl (2016) concurred that the theoretical framework assists researchers in situating and contextualizing formal theories into their studies as a guide. This statement places their studies in scholarly and academic fashion. In simple term, the theoretical framework of a study serves as the focus for the research and it is linked to the research problem understudy.

In line with this, the relevant theories that anchored this study have been reviewed in the sub-sections below; and the theories discussed include: Constructivism Theory, Ausubel's (1962) Assimilation Learning Theory, Vygotsky's (1978) Social Constructivism Theory and Conceptual Change Instructional Model (Posner et al., 1982).

### *2.1.1 Constructivism theory*

Constructivism is a theory of learning that has its roots in both philosophy and psychology. Philosophically, constructivism theory of learning relies on an epistemology that stresses subjectivism and relativism; that while reality may exist separate from experience, it can only be known through experience, resulting in a personally unique reality. Psychologically, this theory stressed that learners actively construct their own knowledge and meaning from their experiences (Taber, 2009; McLeod, 2019).

Constructivism theory was propounded by Jerome Bruner in 1966 (Olorode & Jimoh, 2016). The theory states that people construct their own understanding and knowledge of the world, through experiencing things and by reflecting on those experiences (Adesanya, 2009). Elliott, Kratochwill, Littlefield and Travers (2000) saw constructivism as an approach to learning that held that people actively constructed their own knowledge and that reality was determined by the experiences of the learner. Kubiatko (2007) also conceptualised constructivism as an active learning process in which students take information from the surrounding environment and then build personal interpretations and meanings based on their prior knowledge and experiences.

In contributing to this debate of constructivism theory; Sibomana, Karegeya and Sentongo (2021) posited that constructivist instructional models are associated with the innovative teaching and learning strategies that encourage active learning or learning by doing. Thus, in simple terms, constructivism theory is a learning theory based on scientific study about how people learn by constructing their own knowledge of the world by experiencing things around them and reflecting on those experiences.

The five basic principles of constructivism are that knowledge is constructed, rather than innate or passively absorbed, learning is an active process, all knowledge is constructed, all knowledge is personal and that learning exists in the mind. Von-Glasersfeld (1990) also proposed three epistemological tenets of constructivism to which a fourth has been added in light of recent writings and these are that:

1) Knowledge is not passively accumulated, but rather it is the result of active cognizing by the individual's experience.
2) Cognition is an adaptive process that functions to make an individual's behaviour more viable given a particular environment.
3) Cognition organizes and makes sense of one's experience and it is not a process to render an accurate representation of reality; and
4) Knowing has roots in both biological/neurological construction as well as social, cultural and language based interactions (Maturana & Varela, 1992).

Specifically, constructivist learning theory underpins a variety of student-centered instructional approaches which contrast with traditional passive education, whereby knowledge is simply passively transmitted by teachers to students. Tam (2000) listed the following four basic characteristics of constructivist learning environments, which must be considered when implementing constructivist instructional strategies.

1) Knowledge will be shared between teachers and students.
2) Teachers and students will share authority.
3) Learning groups will consist of small numbers of heterogeneous students.
4) The teacher's role is one of a facilitator or a guide.

The implication of this theory for science teaching is that teachers should create an enabling environment where students become active participants in their own learning. Teachers should have dialogue with students and thereby helping them to construct their own knowledge. In the instructional delivery, teachers should act as a facilitator of learning rather than an instructor whiles that students are expected to work primarily in groups or in cooperative manner. During lesson delivery, teachers should make sure they understand their students' pre-existing conceptions and guide the activity to address them and then build on them. This theory also stressed that the mode of learning should be interactive, building on what the student already knows. The theory also deemphasizes memorizing the conceptions and definitions of terms; but insists that learners create their own definitions, meanings and understanding based on discovery. Therefore, teachers should adopt strategies that would exposed learners to create their own definitions, meanings and better understanding of the various scientific concepts.

The constructivism theory is relevant to this present study, as it emphasizes that learners actively construct new knowledge as they interact with their environment. This means that learning by doing is essential for the development of cognitive structures in this theory. In this context, the predict-observe-explain instructional approach used in this study would help learners in the development of cognitive structures through abstract thinking (Predict); concrete-explanation activities (Observe-Explain). For instance, each organic chemistry POE task exposed learners to abstract thinking through predict-with reason and to concrete activities through observe-explain, thereby facilitating the construction of the new knowledge. Also, the POE instructional approach used in this study would help student-teachers to understand the structure and process of active knowledge construction by linking their thinking experiences (conceptual framework) to the learning by doing (methodological framework) of organic chemistry thereby resulting in the construction of new knowledge or development of their cognitive structures.

### *2.1.2 Ausubel's (1962) assimilation learning theory*

Ausubel is an American constructivist, psychologist and pedagogue whose most significant contribution is in the fields of educational psychology, cognitive science and science education. Influenced by Piaget, Ausubel believed that understanding concepts, principles and ideas are achieved through deductive reasoning. This theory stressed that learning of new knowledge relies on what the learner already knows, and it states that "the most important single factor influencing learning is what the learner already knows: Ascertain this and teach him accordingly" (Ausubel, 1968, p.6).

In Ausubel's (1968) view of learning meaningfully, students must relate new knowledge (concepts, rule, principles, etc.) to what they already know. According to this theory, learning occurs through assimilation of new concepts into existing schema or concept frameworks of the learner. If the targeted concept is logically connected to the learners' knowledge structure and if the structure of knowledge is organized clearly, then learning the concept meaningfully will be easier in the light of these two conditions (logical connection and clarity of cognitive organization) (Ausubel, 2000). Also, this theory emphasizes that learning occurs through development of new cognitive structures that will hold newly acquired information. Moreover, Ausubel believed in the idea of meaningful learning as opposed to rote memorization. This led him to develop an interesting theory of meaningful learning and advance organizers.

Meaningful learning, according to Friesen and Scott (2013), is learning that has the purpose of building knowledge based on students' experiences, feelings and interactions with other students. These scholars indicated that meaningful learning requires knowledge to be constructed by the learner but not transmitted from the teacher to the student. It occurs when learners actively interpret their experiences using internal cognitive operations and have prior idea to which they can relate new ideas. Meaningful learning differs from rote learning in that a connection is obtained between the previous knowledge of the students and the newly acquired knowledge, while rote learning consists of memorizing concepts without the need for understanding (Ivie, 1998).

Dahar (2011) saw meaningful learning as a process that involves linking newly acquired information to ideas that are already present in the cognitive framework. Ausubel in Dahar (2011) stated that learning is said to be meaningful if the information to be learned is arranged according to cognitive structures owned by the students so that they can associate new information with the cognitive structures they have. Studies (Novak, 2002; Dahar, 2011) have outlined benefits of meaningful learning as follows:

1) Information learned meaningfully promotes active learning by the students.
2) Information learned meaningfully promotes personalized learning based on the students' previous experiences.
3) Information learned meaningfully are stored in the long-term memory.
4) Information learned meaningfully ensures lasting retention of the knowledge.
5) Information learned meaningfully can be remembered longer.

6) Information learned meaningfully ensures successful connection of new knowledge with prior knowledge.
7) Information learned meaningfully facilitates subsequent learning processes for similar subject matter.

In a study, Ajayi (2019) stated that meaningful learning helps a learner to understand the relationships between the objects of study in hierarchical manner. This is because meaningful learning involves recognition of the links between concepts; and it has the privilege of being transferred into the long-term memory. For meaningful learning to occur, the new concepts must be integrated into the existing knowledge structure or connecting existing concepts with the new knowledge (Bao & Koenig, 2019).

Meaningful learning allows students to associate acquired material with previous knowledge or experiences that serve as an anchor when obtaining new knowledge. When meaningful learning occurs, the facts are stored in a relational manner. The brain stores them together because they are related to each other and when one fact is recalled the other facts are also recalled at that moment or shortly after. This is called spread of activation; and this makes problem solving for students very easier.

Similarly, Ausubel's theory of meaningful learning claims that new concepts to be learned can be incorporated into more inclusive concepts or ideas; and these more inclusive ideas/concepts are advance organizers. Ausubel (1968) proposed the notion of an advanced organizer as a way to help students to link previous ideas with the new materials. According to Ausubel (1968), advance organizers are designed to provide what cognitive psychologist call mental scaffolding to learn new information. According to Safdar, Hussain, Shah and Rifa (2012), advance organizers are concepts given to students prior to the material actually to be learned to provide a stable cognitive structure in which the new learning can be subsumed. Advance organizers serve three purposes: (1) they direct attention to what is important in the coming material, (2) they highlight relationships among ideas that will be presented, and (3) they remind the students of relevant information already in memory (Safdar et al., 2012). This means that by providing students with deliberately prepared work in advance of the material to be learned, students' learning of subsequent material was facilitated very effectively.

To sum up, the Ausubel's assimilation learning theory incorporating meaningful learning and advance organizers is very relevant to this present study; as it emphasizes that meaningful learning is essential for the development of cognitive structure through "scaffolding of information" in the lesson delivery.

By educational implication, for information to be learnt effectively, it must be presented in a more meaningful way. Science educators and teachers should implement events which facilitate meaningful learning in their classroom settings. According to Darling-Hammond, Flook, Cook-Harvery, Barron and Osher (2019), to ensure meaningfully learning, the information is actively selected, ordered and constructed for better understanding of the learners since all existing knowledge, concepts and the strategies of processing the information plays a dynamic role in determining the output.

In this present study, each organic chemistry POE instructional approach task is composed of different parts. In this approach, preliminary questions about an event are presented to the student-teachers in which they make their own predictions with reasons. They then perform the experiments and write their observations. Finally, they compare their predictions with the data they have gathered through the observations. This is done to reconcile contradictions between their predictions and observations; thereby facilitating meaningful learning. These tasks can help science student-teachers engage in critical thinking, improve their performance and also develop positive attitudes towards the concepts taught effectively (Hanani, 2020).

### *2.1.3 Vygotsky (1978) social constructivism theory*

The root of predict-observe-explain instructional approach (or POE instructional approach) is anchored in social constructivism theory. Philosophically, this theory of learning relies on an epistemology that stresses that “learning is a collaborative process” and that knowledge develops from ones’ interactions with their culture and society.

The social constructivism theory, sometimes called social development theory, was propounded by a Russian psychologist called Lev Vygotsky in 1978 (Akpan, Igwe, Mpamah & Okoro, 2020) who suggested that: every function in the child’s cultural development appears twice: first, on the social level and on the individual level later. First between people (interpsychological) and then inside the child (intrapsychological).

In literal terms, Lev Vygotsky implies that all the functions in the learner’s development culturally appeared twice. The first appearance was observed on the social level (interpsychological) and the second within the child (intrapsychological). This statement implies that social constructivism upholds that knowledge develops as a result of social interactions and is not an individual possession but a shared responsibilities. This means that learning concepts are transmitted by means of language, interpreted and understood by experience and interactions within a cultural setting. Since it takes a group of people to have language and culture to construct cognitive structures; knowledge therefore is not only socially constructed but co-constructed. The link here is that while the constructivist sees knowledge as what students construct by themselves based on the experiences they gather from their environment, the social constructivist sees knowledge as what students do in collaboration with others. Thus, social constructivism theory is a learning theory that emphasizes the collaborative nature of learning among students under the guidance of a facilitator or a guide.

This theory also called sociocultural theory of cognitive development emphasizes the importance of culture and interaction in the development of cognitive structures or abilities. In social constructivism, Akpan et al. (2020) proposed three epistemological tenets that defines the teacher's responsibilities in the teaching and learning process. This means that for meaningful learning to take place in classroom, teachers should adopt teaching methods that are:

1) Learner centred: At this stage the focus is on the students rather than the teacher. This means the students are urged to be actively involved in their own learning processes. They are allowed to come up with their own ideas and make-ups.
2) Collaborative in nature: Here emphasis is placed on learning through social interaction. This is done by making students to work in groups to solve problems, investigate and explore topics/situations in order to arrive at conclusions. By so doing, they construct knowledge by themselves in a collaborative manner.
3) Teacher guided: In social constructivist classrooms, collaborative learning is a process of peer interaction that is mediated, structured and guided by the teacher.

Based on these three essential epistemological tenets that define the teacher's responsibilities (Sarita, 2017; Sharkey & Gash, 2020) posited that the teacher is expected to provide a learning environment that will boost collaborative or group interaction by:

1) Discouraging competition whiles encouraging collaboration among students.
2) Considers the students contributions as important whether right or wrong.
3) Ensures that more and less brilliant students learn from each other.
4) Provides vital support where necessary in the teaching and learning processes.
5) Ensures that students feel secured to ask/answer questions, interact and contribute to group discussions freely.
6) Provides scaffolding support where necessary, at the right time and the right level.

Sarita (2017) was of the view that the commonly used method of teaching in social constructivism learning theory is scaffolding. In this method, the teacher regularly adjusts their help to match with the learner's performance or struggles. Sarita concluded that using this method ensures that each learner's approach to problem-solving is accommodated. Fernando and Marikar (2017) also indicated in social constructivist classroom settings, the teacher must understand each of the students' existing misconceptions. The teacher can then guide their activities to address these existing misconceptions. Once this is done, the teacher can then build upon them.

Studies (Sarita, 2017; Kanno, 2018; Akpan et al., 2020; Misra, 2020) have outlined the importance of social constructivism theory in the effective teaching and learning process. These scholars posited that social constructivism lends credence to the teaching and learning process and in that it:

1) Encourages active participation of the students; and the interactions among learners, the teacher and other components of the teaching and learning process.
2) Discourages rote learning and passivity on the part of the students.
3) Develops critical thinking, problem solving, stimulate interests and aids retention.
4) Concretizes learning and knowledge in the sense that students are more likely to retain the facts that they discover and construct by themselves than those they are told or given by the teacher.
5) Promotes high self-esteem on the part of the students based on their trust in self-approach to learning. The teacher guides the students to trust, believe in themselves and demonstrate that they can accomplish the given tasks.

Vygotsky believed that life long process of development is dependent on social interactions and that social learning actually leads to cognitive development. In other words, all learning tasks (irrespective of the level of difficulty), can be performed by learners under adult guidance or with peer collaboration. Thus, social constructivism is also called collaborative learning because it is based on interactions, discussions and sharing information among peers. The underlying factor to this theory is that learners work in groups, share ideas and try to discover cause and effect to problem(s).

By educational implication, the information to be learnt must be presented in a way to encourage active participation and interaction among learners. In the classroom settings, the teacher functions more as a facilitator who coaches, mediates and helps students develop their understanding through learning. In the teaching and learning processes, teachers should allow students with more knowledge to assist students who need more guidance. Especially in the context of collaborative learning, group members who have higher levels of understanding can help the less advanced members learn within their zone of proximal development. Kelly (2012) suggested that social constructivism theory could be applied in the classroom using instructional methods such as group work, guided discovery learning and among others. In contributing to this debate, Kibirige, Osodo and Tlala (2014) indicated that POE strategies involve learner-centred teaching that emphasises socially-constructed knowledge. These scholars were of the view that the POE strategies were anchored on the social constructivism theory.

This theory is related to the present POE study, as it stressed that learning is a collaborative process and knowledge develops from individuals' interactions with their culture and society. In this POEIA study, each organic chemistry POE task is composed of different parts; and student-teachers are put into groups to learn in a collaborative manner. In this approach, preliminary questions about an event are presented to the student-teachers in groups which they make their own predictions and justify with reasons. These student-teachers in groups performed experiments based on their earlier predictions and write their observations either qualitatively or quantitatively.

Finally, they compare their predictions with the data they have gathered from the observations; and reconcile any contradiction between their predictions and their observations, thereby facilitating meaningful learning. These tasks can help student-teachers to engage in critical thinking, remove or reduce their misconceptions, improve their performance and also develop their attitudes towards organic chemistry topics.

### *2.1.4 Conceptual change instructional model (Posner et al., 1982)*

The POE instructional approach (POEIA) used in this present study is also rooted in Conceptual Change Instructional Model (CCIM). A conceptual change instructional model is a special type of learning instruction that takes place when individuals change their knowledge from naïve, conflicting and misconceived (referred in this study as misconceptions) to more scientifically-accepted knowledge (Vosniadou & Verschaffel, 2004). The idea of conceptual change instructional approach, according to Agiande, Williams, Dunnamah and Tumba (2015), came into educational settings as an analogy drawn from the history and philosophy of science that was helpful in understanding the difficulties people experienced in changing from one explanatory framework to another.

Several conceptual change instructional models have been proposed to facilitate effective teaching and learning processes of sciences specifically chemistry. One of the most prominent conceptual change model, which correspond to Kuhn's notion of scientific revolution theory of paradigm shift or Piaget's notion of disequilibrium (assimilation and accommodation), was first theorised and defined by these researchers (Posner, Strike, Hewson & Gertzog, 1982) also cited by researchers (Phanphech, Tanitteerapan & Murphy, 2019). Posner et al. (1982) model stressed that for a successful conceptual change to take place, learners need to become dissatisfied with their existing beliefs and the new concept has to be shown to be intelligible, plausible and fruitful.

On their part, Supriatna, Samsudin and Efendi (2019) indicated that one of the instructional strategy that is more effective in increasing students' understanding of scientific concepts and also facilitate in changing students' misconceptions is the POE instructional approach. This is because the POE instructional approach fulfils the four conditions of Posner et al's conceptual change instructional model.

At the predict (P) stage, students are required to make predictions of an event; and then give reason(s) to justify their thoughts or beliefs. Their predictions of an event with their assigned reasons are to be discussed in group; and then given to the teacher. The teacher then probes the results of the students' discussion. This is intended to diagnose students' thinking and create cognitive conflicts in their minds. At this stage, the learner feel dissatisfied with the knowledge they have or possessed.

At the observe (O) stage, the students conducts experiments under the guide of a teacher. At this stage, it is acceptable that students can find discrepancies between what they think and what actually happened through the experimentation. Also, after the students realize that there is a discrepancy between their predictions and observations, the teacher can begin the learning, convey the material in the syllabus and at the right time explain why a particular concept was correct so that new concept can be accepted by the students clearly (intelligibility) and reasonably (plausibility).

Finally, at the explain (E) stage, students are required to provide an explanation regarding their findings of the observation and the differences with the predictions based on scientifically accepted facts. In addition, the students are asked to apply new concepts by resolving the problem(s) given by the teacher, so that the teacher and the students can measure whether the concept has been understood by students or not (Cinici & Demir, 2015; Syuhendri, 2017). The level of success (fruitfulness) is observed when the students explain their results, especially by reconciling any discrepancy between what they have predicted and observed; and also apply the new concept(s) in solving related problems.

According to Acar-Sesen and Mutlu (2016), the POE instructional strategy is one of the effective means that has been used in conceptual change studies for several years. Studies (Liew & Treagust, 1995; Ozdemir & Clark, 2007; Astiti, Ibrahim & Hariyono, 2020) in science education have indicated that POE instructional approach which is a typical conceptual change instructional approach has been effective in dispelling students' misconceptions. For example, in their study, Astiti et al. (2020) revealed that the students' conception profile before learning with POE strategy was an average of 67%. However, the conception profile after learning with POE strategy obtained was an average of 7.4%. The POE instructional approach and conceptual change instructional model can be compared or related to each other as shown in the Figure 1.

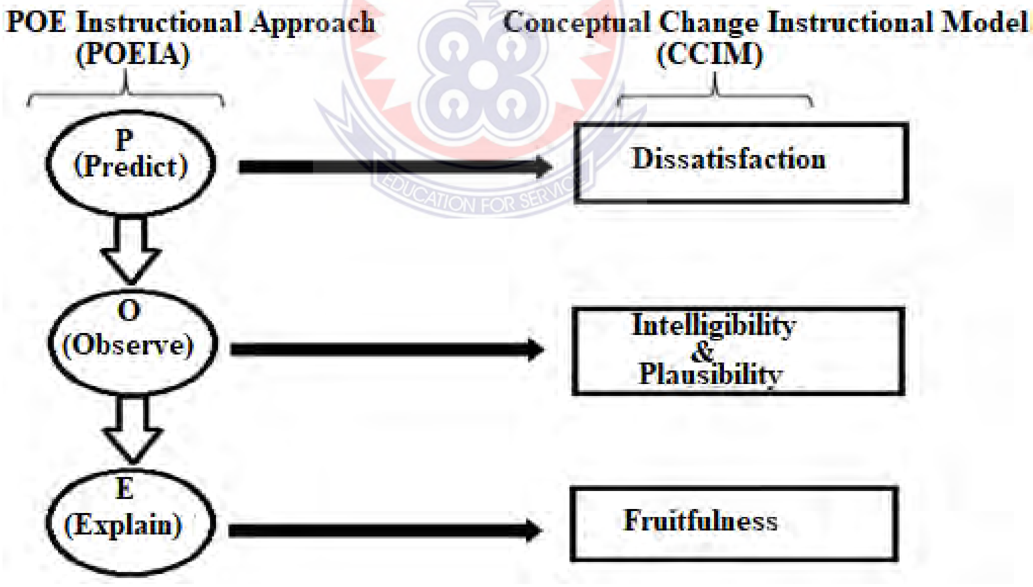



Figure 1: Relationship between POEIA and CCIM (Supriatna et al., 2019)

Liew and Treagust (1995) in their research concluded that POE learning strategies can create opportunities for students to change their previous misconceptions. Banawi, Sopandi, Kadarohman and Solehuddin (2019) posited that applying POE learning strategies can change the conceptions of both teachers and students in accordance with existing scientific concepts. According to Ozdemir and Clark (2007), the conceptual change theory proposed by Posner et al sees conceptual change as more than just a teaching strategy but as a process of identifying misconceptions which the learners carries into the learning environment in order to help the learner exchange his/her misconceptions or add new conceptions that are more useful, plausible and intelligible.

By educational implication, for successful conceptual change to take place and allow for meaningful learning to occur, science student-teachers' prior conceptions regarding the organic chemistry concepts to be learn must be elicited. The elicitation is done by allowing learners to make predictions about an event and justify their predictions with reason(s). Teacher then probe the learners' ideas further through discussions to find out their misconceptions about the event. This makes the learners becoming dissatisfy with their ideas. After the elicitation, teachers must present the concept(s) to be learnt in an intelligible and plausible (reasonably true) through experimentations. Finally, they compare their predictions with the data they have gathered through the experiments. This comparison is done to reconcile contradictions between their predictions and their observations, thereby facilitating meaningful learning (fruitfulness).

The conceptual change instructional model is relevant to this present POE instructional approach study, as it emphasizes that for effective learning to take place, student-teachers must be dissatisfied with their unscientific prior conceptions; and the new concept to be assimilated must be intelligible, plausible and fruitful. In this context, the POE instructional approach used in this study would help student-teachers in the development of their cognitive structures with scientific facts through their predictions with reason(s), and hands-on and minds-on activities through observe-explain, thereby facilitating the development of their cognitive structures with accepted scientific facts.

## 2.2 Conceptual Framework of the Study

A conceptual framework of a study, according to Camp (2001), is a structure which the researcher believes can best explain the natural progression of the phenomenon to be studied. Attesting to this fact, Ravich and Carl (2016) stated that conceptual frameworks are generative frameworks that reflects the thinking of the entire research process; and mostly in the form of diagrams that are created to define the variables of the research topic and their relationships are shown by the use of arrows.

In their presentation, Grant and Osanloo (2014) indicated that a conceptual framework is arranged in a logical structure to provide a picture or visual display of how ideas in a study related to one another. With regards to its nature, Miles and Huberman (1994, p.18) noted that conceptual framework can be "graphical or in a narrative form showing the key variables to be studied and the presumed relationships among them". The conceptual framework that supports this study has been presented in Figure 2.

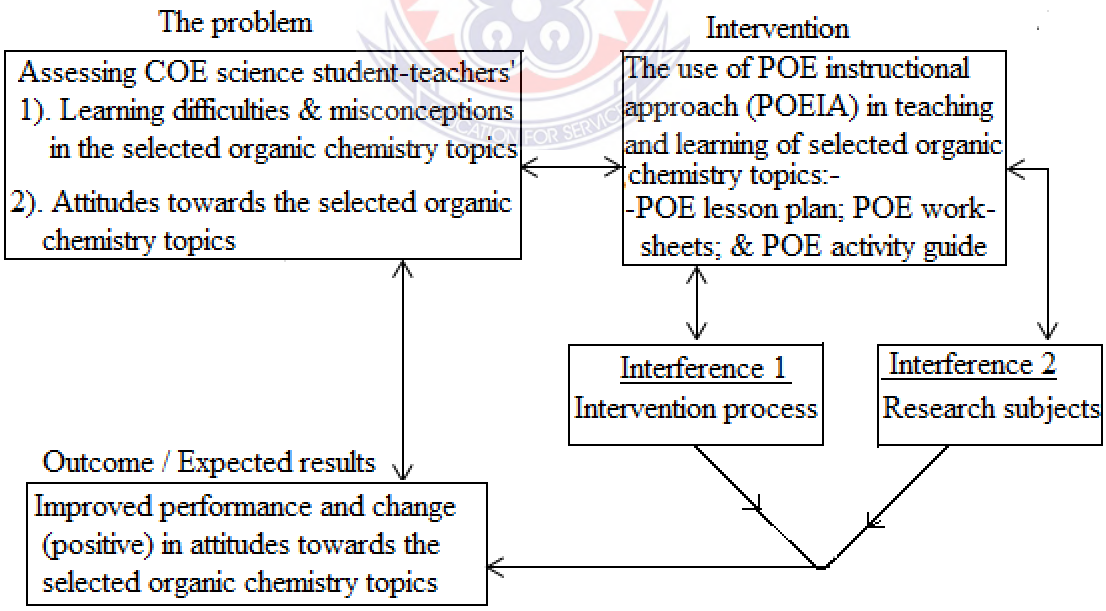



Figure 2: Schematic representation of the conceptual framework of the study

The Figure 2 consists of five separate boxes that depicts the schematic conceptual framework that anchored this study. Each of the boxes could be described in terms of the problem, intervention, interference 1, interference 2 and the outcome/expected results.

The problem box deals with the assessment of the science student-teachers' learning difficulties (poor performance), misconceptions and attitudes towards the selected organic chemistry topics. The intervention box in this study is the POE instructional approach made up of POE lesson plans, worksheets and activity guides (in the form of a module). The interference 1 box presents the factors that could influence the intervention process; whereas the interference 2 box also deals with factors that could influence the research subjects during the implementation of the intervention strategy. The outcome/expected results box deals with the improved performance of the research subjects and changes in their attitudes towards the selected organic chemistry topics.

In this study, the science student-teachers' learning difficulties (or poor performance), their misconceptions and attitudes towards the selected organic chemistry topics were assessed and the POE instructional approach intervention was implemented for the period of ten weeks. Every effort was made to address both interference 1 and 2 during the study. At the end of the implementation of the POEIA, this study expected an improvement in the science student-teachers' performance and also change (positive) in attitudes towards the selected topics in organic chemistry.

From the schematic representation of the conceptual framework of the study above, the POEIA approach as a social-constructivist approach has the potential to improve research subjects' performance and attitudes towards the selected organic chemistry topics and their misconceptions. Thus, this study utilized the POE instructional approach to assess research subjects' learning difficulties; improved performance and developed their positive attitudes towards the selected organic chemistry topics through predictions, observations and explanations during POE organic chemistry lessons. Again, it is assumed that the research subjects' improved conceptions would in turn reflect in their performance and attitudes towards the selected organic chemistry topics/lessons.

## 2.3 Definition and Conceptualization of Predict-Observe-Explain Approach

The Predict-Observe-Explain abbreviated as "(POE)" instructional approach is basically used as an instructional strategy where learners are engaged in making predictions of an event and assign reasons for their predictions; then conduct an experiment and they are required to compare their observations with their earlier predictions through extensive explanations; thereby enhancing their understanding of concept understudy. This instructional approach focuses on linking students to existing knowledge or ideas relevant to a situation and exploring the appropriateness of these knowledge or ideas (Phanphech & Tanitteerapan, 2017).

The POE instructional approach was first modified by Gunstone and White (1981) from Demonstrate-Observe-Explain (abbreviated as "DOE") strategy. The DOE strategy was designed by Champagne et al. (1979) and was use to assess first year physics students' understanding of force at the University of Pittsburg in 1979 (Hilario, 2015). In the DOE instructional strategy, the teacher demonstrates an experiment, whiles students observe and explain their answers. According to Champagne et al. (1979), the merits of DOE strategy is a reduction in the quantity of verbal description and a reliance on questions that provide data to make inferences about students' ideas.

Based on the ideas embedded in the DOE strategy, Gunstone and White (1981) redeveloped the first ever Predict-Observe-Explain (POE) instructional approach. These scholars used the POE instructional approach to diagnose students' understanding of science concepts in elementary-school science (Hilario, 2015; Samsudin, Suhandi, Rusdiana, Kaniawati & Coştu, 2017). Both the POE and DOE were strategies for probing students' understanding in sciences and that each consists of three stages. The difference between the "POE" and "DOE" is the prediction (P) as the first stage in the POE.

Conceptually, the POE instructional approach developed by Gunstone and White (1981) and used in this study consists of three hierarchical steps that must be followed by students; and these three steps have been explained below as follows:

**1). Predict (P) step**

This is the first stage of this instructional strategy. In the Predict (P) step, information about an event is given to students and the students are supposed to predict the outcome of this event and also justify their predictions with reasons. In this step, the students' understanding and misconceptions are identified through their prediction(s) and the assigned reason(s). This stage also provides opportunities for the students to explicitly recognize their prior ideas which is important as a starting point for conceptual change.

**2). Observe (O) step**

The Observe (O) step is the second stage. This step requires the students to observe the experiment or video clip about the phenomena they had predicted earlier and write down the results of their observations. All students should be able to see the experiment or video clip to be observed effectively. The phenomenon may be repeated in order to make an accurate observations. At this stage, students should record their quantitative or qualitative observations, regardless of whether they use tools or not.

**3). Explain (E) step**

The Explain (E) step is the third and final stage in POE instructional strategy. At this stage, the students compare the results of their observation (O) and their prediction (P). Moreover, students reconcile any discrepancy between their prediction (P) and observation (O) and explain (E) their findings in the form of discussions. The students discuss and share their explanations of the phenomenon in their own sentences. Students should be encouraged to express themselves correctly while given them sufficient time.

Based on the three steps involved in this approach, Widhiyanti (2016) posited that the POE has the potential to support the teaching and learning processes effectively. Anisa, Masykuri and Yamtinah (2013) also stated categorically that the steps in POE are efficient for encouraging students to be active in learning, because they involve students in predicting an event, making observations and explaining the results of observations. These assertions were supported by other scholars including Dalziel (2010), Hudson (2010), Burçin (2013) and Hilario (2015) who indicated that the POE is an effective instructional approach that lets the students explore concepts, improve students' performance and also develop their positive attitudes towards the concepts understudy. Dalziel (2010, p.12) outlined the "role of the teacher when applying POE instructional approach" in the teaching and learning processes as follows:

**Role 1:**

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

**Role 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 students' 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.

**Role 3:**

After observation, teacher facilitates a discussion where students attempt to understand their incorrect stating assumptions and try to construct new theories that better match the reality they have observed. Depending on the topic and any added materials that the teacher provides at this stage, the teacher should guide the general discussion of the students as they develop their new understanding.

Epistemologically, Liew (2011) stated that the POE instructional approach helps student to build his/her knowledge based on the direct experience during the teaching and learning process. Moreover, the effectiveness of the POE as an instructional strategy to diagnose students' understanding (Samsudin et al., 2017); elicit students' misconceptions (Ayvaci, 2013; Cinici & Demir, 2015); change students' misconceptions into correct ones (Klangmanee & Sumranwanich, 2011); improve students' performance (Mosca 2007; Widhiyanti, 2016) and attitudes (Hilario, 2015; Özcan & Uyanık, 2022) at the various levels of education have been reported with success in the literature.

Hilario (2015) stated emphatically that the POE is one of the efficient strategies used to create students' discussions about the concepts in sciences. Attest to this fact, ChiLiang (2011) outlined some benefits of the POE instructional approach as follows; it can be used to explore students' initial ideas; and generate good discussions among students themselves and their teachers; thereby facilitate effective learning in classroom.

Learning, according to Cicognani (2011), 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. In simple terms, collaborative connote sharing ideas. According to Gao (2012), the POE approach promotes collaborative learning experiences among students. Studies (Liew & Treagust, 1995; Astiti et al., 2020) have indicated that POE strategy is one of the effective conceptual change tool that help in eliminating or reducing students' misconceptions in the teaching and learning processes in a collaborative manner.

Various studies (Chris, 2006; Wahyuni, 2013; Bajar-Sales, Avilla & Camacho, 2015; Rosdianto, 2017) have outlined the merits of POE approach as follows:

1) POE is a strategy that allows students to think creatively; express their predictions about a problem that arises in the community and encourage students to prove their predictions with an effort to investigate so they can answer the problem.
2) POE model can be chosen as an effective learning model that can be implemented in schools because it can improve students' understanding of concepts.
3) POE model improves students' learning outcomes and performance.
4) POE is an efficient strategy for encouraging students to discuss about their ideas.
5) POE strategy is a powerful instructional approach that guides and motivates learners to express their own ideas about certain topics based on their experiences.

Despite the merits of POE as outlined by various scholars above. Some scholars have also identified disadvantages associated with it. According to Kearney (2003), a particular challenge with using POE approach in the classroom is providing students with opportunities to observe scientific event in a way that is real and safe. Studies (Chris, 2006; Chen, Pan, Sung & Chang, 2013; Karamustafaoğlu & Mamlok-Naaman, 2015) have also outlined some limitations of POE as follows:

1) For younger primary school students, writing the answer or predictions can be a barrier to useful communication of ideas.
2) It is not suitable for younger primary school students because they may have difficulty explaining their reasoning.
3) 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.

4) Students are more likely to learn from observations that confirm their predictions without concentrating on other concepts. This cautions us to be careful that predictions are not wild guesses. A joint conversation about what we might expect to see and why, based on the underlying science idea, could help avoid this trap.

## 2.4 Students' Conceptual Difficulties in Learning Organic Chemistry

Organic chemistry concepts are difficult for many students to learn, as the very fundamental concepts are insufficiently understood by students (Stieff, 2007; Wasacz, 2010). O'Dwyer and Childs (2010) opined that organic chemistry is a difficult subject for students to conceptualise it. In contributing to students' conceptual difficulties in organic chemistry, Stieff (2007) posited that organic chemistry is found to be problematic and that students resort to memorizing formulae that is not a good method for meaningful learning. Attesting to students' difficulties, Hanson (2017) opined that adequate understanding of organic chemistry is a pre-requisite for many graduate and professional programs. The scholar added that it is a key to the development of new products in the society and it forms the basis for production of food, dyes and other products. This means that students should have a firm grasp and better understanding of organic chemistry concepts so that one could live successful life in the society.

Numerous studies (Taagepera & Noori, 2000; Gilbert, 2005; McClary & Bretz, 2012; Graulich, 2015; Nartey & Hanson, 2021; Anim-Eduful & Adu-Gyamfi, 2022) have shown that students have conceptual difficulties in learning organic chemistry at all levels of education. Gafoor and Shilna (2013) were of the view that students in secondary school, colleges and even at the universities have conceptual difficulties in learning organic chemistry. Studies on students' conceptual difficulties in learning or understanding organic chemistry concepts available in the literature are as follows:

In a pioneer study, Taagepera and Noori (2000) observed that students had conceptual difficulties regarding organic chemistry reactions and intermolecular bonds in organic compounds. The scholars concluded their study by posited that majority of the students could not categorize types of reactions and bonds in organic compounds; and that they trust that a hydrogen bond includes a covalent bond.

Studies (Wu, Krajcik & Soloway, 2001; Stieff, 2007) have shown that students had learning difficulties in chirality and stereochemistry. Wu et al. (2001) indicated that students experience difficulties understanding, interpreting and translating structural representations due to content gaps or lack of visuospatial skills especially rotations. Moreover, Stieff (2007) also indicated that when determining the stereochemistry of enantiomers as defined by Cahn-Ingold-Prelog R/S designation, students rely on their mental rotation of given objects and molecules; and such a task can get sophisticated as molecules increase in size with different stereocenters. The author concluded that relying on mental rotation in determining stereochemistry of structures is confusing for students.

Taber (2002a; 2009) pointed out that students encounter learning difficulties in resonance structures of aromatic compounds. The study revealed that the students have difficulties conceptualizing resonance; and they think of resonance as alternating structures between different states just like in the case of benzene ring. This implies that students had conceptual difficulties in learning resonance in organic chemistry.

On their part, Ferk, Vrtacnik, Blejec and Gril (2003) also observed that most students have learning difficulties regarding structural and skeletal formulae of organic compounds, Newman and sawhorse projections and perspective drawings using dashed and wedged bonds. These scholars were of the view that students had learning difficulties and that students' presentations are usually inconsistent with the acceptable ways of presenting them. Similarly, Treagust, Chittleborough and Mamiala (2004) also found that secondary students' had conceptual difficulties in learning molecular representations of organic structures and correct drawings of organic compounds. The study concluded that students' conceptual difficulties could be addressed using effective teaching and learning models.

Topal, Oral and Ozden (2007) conducted a study among 140 first and third grade students attending Department of Chemistry in Faculty of Sciences, Arts and Education in Dicle University and 65 eleventh grade secondary students from secondary schools in Diyarbakır city centre. The study found that students had difficulties in differentiating aromatic compounds from condensed structure formulae. Again, it was observed that most students had learning difficulties in cyclic properties, conjugated double bond, reactions of aromatic compounds and aromatic compounds obeying Huckel's Rule. This finding indicated that students at the senior high schools and even at the university have difficulties regarding aromatic compounds such as benzene.

Studies (Gilbert, 2005; Carey & Sundberg, 2007) have indicated that students including pre-service science teachers have difficulties in spectroscopy, stereochemistry organic reactions and heterocyclic compounds. Gilbert (2005) concluded in a study that stereochemistry requires the use of visiospatial strategies because it requires explicit spatial relationships and lack of it makes it difficult for students to understand.

Studies (Bhattacharyya & Bodner, 2005; Anderson & Bodner, 2008) have revealed that students have learning difficulties in organic reaction mechanisms. Bhattacharyya and Bodner (2005) posited that students are not aware of the benefit of utilizing curved arrows in reaction mechanisms as a tool to predict the stepwise process towards the final product. The scholars added that students do not consider the feasibility of each step they write, but rather draw arrows that lead to electron pair and atom replacement associated with each product. They concluded that the failure to properly use curved arrows in mechanistic tasks could be due to students relying on rote memorization rather than developing a cohesive conceptual understanding. On their part, Anderson and Bodner (2008) gave an overview of the emergent problems students face during an organic class. The authors observed that students had difficulties in learning structural representations; the appropriate use of curved-arrow notation and reaction mechanisms in terms of their conditions and reagents.

Studies by Hand and Choi (2010) and Baah and Ghartey (2012) also indicated that students had learning difficulties in multi-modal representations of organic chemistry in the form of graphs, drawings, mathematical representation and balancing of chemical equations involving organic compounds. Şendur (2012) also conducted a study among 73 prospective science teachers from Dokuz Eylul University, in 2010-2011 academic year. The study revealed that majority of these students had learning difficulties in some organic chemistry topics including geometric isomerism, application of Markovnikov's and anti-Markovnikov's rule, nomenclature of cycloalkenes, the synthesis of alkenes from the alcohols and alkyl halides.

In a similar study, McClary and Bretz (2012) also observed that undergraduate students faced difficulties in learning alkyl halide reactions particularly in determining if a compound is a nucleophile or a base; description of the stages of alkyl halide reactions and also determining the transitional reaction formed in the alkyl halide reaction. Kumi, Olimpo, Bartlett and Dixon (2013) also found that students had learning difficulties and that they tend to struggle in converting dash-wedge structures to Newman projection. The study also revealed that students' performance decreased as the complexity of the rotations in Newman projections are increased. The authors concluded that the ability of students to translate from dash-wedge structures to Fisher projection is directly related to the conformation and spatial arrangement of substituents on the dash-wedge structures. This makes it difficult for students to learn or understand them.

Omwirhiren and Ubanwa (2016) observed that most students had difficulties in learning IUPAC nomenclature of organic compounds. The scholars indicated that students' difficulties occur when applying IUPAC rules in naming a given organic compounds, writing of structural formulae; classification of saturated and unsaturated hydrocarbons, distinguishing substitution and addition reactions.

In a study among 60 undergraduate students, Akkuzu and Uyulgan (2016) found out that these students had difficulties in learning certain topics regarding functional groups including physical properties of functional groups; acidity and basicity of organic compounds; isomerism; aromaticity and aliphaticity; intermolecular bonds; and many other organic chemistry concepts (e.g. decarboxylation, oxyacide, and phenol). These scholars concluded that students' difficulties could be attributed to their lack of understanding of related topics in general chemistry; and that they failed to accurately transfer their knowledge to the proper learning of organic chemistry topics.

Similarly, Hanson (2017) posited that students had learning difficulties and could not apply the organic concepts like addition reactions, saturation, unsaturation, molecular structure, bonding, polarity and electronegativity effectively as expected. The study concluded that students' reasoning patterns after an intervention changed for better and they could apply their gained concepts to solve problems in different contexts. This means that students perceived organic chemistry topics like addition reactions, saturation, unsaturation, electronegativity, molecular formula, molecular structure, bonding, polarity and electronegativity very difficult to learn or understand.

In a descriptive cross-sectional survey design to identify organic chemistry topics students find difficult to learn, Donkoh (2017) observed that all the 235 SHS students had difficulties in learning eight topics in their chemistry curriculum including carbon compounds description and classification, identification of organic compounds, structure and properties of organic compounds, characteristics and representation of organic reactions, alkane, alkenes, alkyne and alkanols. In the same study, 13 chemistry teachers who took part also indicated that SHS students have learning difficulties with 15 topics including carbon compounds description and classification, identification of organic compounds, structure and general properties of organic compounds, reactivity of organic compounds, characteristics and representation of organic reactions, alkanes, petroleum, alkenes, alkynes, benzene, alkanols, alkanoic acids, alkanoic acids derivatives, natural and synthetic polymers and amino acid functional groups. This means that students' difficulties in organic chemistry might be pre-dated from their senior high school days.

Similarly, Adu-Gyamfi, Ampiah and Appiah (2017) conducted a study to determine the knowledge level of SHS students in IUPAC nomenclature of organic compounds in the Kumasi Metropolis. The study revealed that the students had learning difficulties in naming structural formulae of branched-and substituted-chains of alkanes and alkenes, geometrical isomers, unbranched alkynes, primary and tertiary alkanols, alkanoic acids and alkylalkanoates. The study concluded that students' difficulties in IUPAC naming of organic compounds included their inability to identify the correct number of carbon atoms in parent chain, to identify a substituent or functional group and correct position and number of multiple bonds in an organic molecule.

Eticha and Ochonogor (2017) conducted a study among 177 first year chemistry students and four organic chemistry lecturers who have minimum five years teaching experience in organic chemistry. The study revealed that students had learning difficulties in functional groups, stereochemistry, organic reactions, organic reactions mechanisms and among other selected topics. The specific difficulties identified among most students in relation to functional groups included writing appropriate reaction for different functional groups, writing correct methods for preparation of different functional groups and proposing right mechanism of reaction for the functional groups.

In assessing undergraduate chemistry students' difficulties in learning organic reactions, Bain, Rodriguez, Moon and Towns (2018) found out that these students have difficulties in organic reactions in terms of type and name of the products to be formed and correct pathways to reach the reaction products. On their part, Webber and Flynn (2018) posited that students have conceptual difficulties in learning acid-base reactions in organic chemistry, functional groups identification and spectroscopy. Sharma and Decicco (2018) in their study also found that students had learning difficulties in isomerism, hybridization and organic reactions. The study concluded that most of these students had difficulties in learning geometric "cis- and trans-" isomers of alkenes.

In a recent study, Salamea, Casinoa and Hodges (2020) reported that students have learning difficulties in relation to acid-base reactions in organic chemistry. The study concluded that the difficulties students encountered when dealing with different theories of acid-base reactions make it challenging for them to apply these theories into organic acid-base reactions. Cartrette and Mayo (2011) stated that identifying the nucleophile as Lewis base and electrophile as Lewis acid is what often causes students to experience difficulties in electrophilic and nucleophilic reactions in organic chemistry.

Similarly, Mistry, Singh and Ridley (2020) also indicated that students face greater difficulties representing molecular images by placing substituents in the right positions (either axial or equatorial) when dealing with chair conformations, which alter the stereochemistry of the molecule. These scholars stated that students struggle with drawing the correct orientation of the groups attached to the front or back carbon in Newman projections and this leads to incorrect stereochemistry of the whole molecules.

Nartey and Hanson (2021) conducted a study among 100 elective chemistry SHS students and their 10 chemistry teachers. The study revealed that these SHS students have a fairly positive perception while their teachers had a highly positive perception of organic chemistry topics. The study further revealed that preparation and chemical reactions of alkenes, structure and stability of benzene, reactions of benzene, comparison of reactions of benzene and alkenes, naming of alkanes and structural isomerism were perceived by students as difficult to understand. The top five most difficult topics for students and their percentages were polymers and polymerization (69%), structure and stability of benzene (65%), reactions of benzene (60%), naming of alkanes and structural isomerism (56%), and petroleum (54%). Also, the teachers perceived that all the SHS organic chemistry topics as easy to teach with the exception of reactions of benzene. These scholars concluded that the insights gained about teachers' and students' perceived difficulties in organic chemistry implied that teachers' perceptions and how they communicated to students can have significant effects on their learning.

In a more recent study, Anim-Eduful and Adu-Gyamfi (2022) revealed that students had factual difficulties in detecting functional groups through the use of suitable organic reagents. The study observed that even though majority of the students could not identify most organic chemical reactions; the very few who were able, failed to state and explain clearly the functional groups present in those compounds. The study further revealed that students had learning difficulties in organic reagents needed to test functional groups and expected outcome of their reactions with respect to exact colour changes that occurs during these functional group detections.

It is obvious that literature is full of adequate evidence with respect to students' conceptual difficulties in learning organic chemistry topics at all levels of education.

## 2.5 Causes of Students' Difficulties in Learning Organic Chemistry

Several studies (Zoller, 1990; Taber, 2001; Yara, 2009; Hand & Choi, 2010; O'Dwyer & Childs, 2014; Afadil & Diah, 2018) have indicated that there are several causes of students' difficulties in learning organic chemistry. Studies on the causes of students' learning difficulties in organic chemistry available in literature are as follows:-

In a pioneer study, McDermott (1984) indicated that lack of teachers' knowledge on students' prior knowledge about concepts was the major factor that cause students' difficulties in learning organic chemistry. This observation presupposes that students' prior knowledge of concepts in organic chemistry could have negative or detrimental effects on the students' learning abilities of organic chemistry topics.

In a similar pioneer study, Zoller (1990) attributed the overwhelming abstract concepts in the organic chemistry which are not related to one another logically as the major cause of students' difficulties in learning organic chemistry. In another pioneer study, Johnstone (1991) posited that the nature of organic chemistry concepts; the way organic concepts are represented (macroscopic, microscopic, or representational) to the students; and ineffective traditional methods used by teachers are the major causes of students' difficulties in learning organic chemistry. The study concluded that the teaching methods by which students learn these concepts are potentially in conflict with the nature of organic chemistry, thus teachers are encouraged to use learner-centered approaches in teaching rather resorting to the traditional lecture method of teaching.

Millar (1991) cited in O'Dwyer (2012) categorized the causes of students' difficulties in learning organic chemistry into two factors namely extrinsic and intrinsic factors. The extrinsic factors that cause the difficulties refers to issues that are beyond the control of learners and they included the multidimensional nature of organic chemistry, complex language, relationship with mathematics, lack of laboratory work and broad nature of organic chemistry curriculum. On the other hand, the intrinsic factors refers to difficulties faced by individual learners and supposed to be within their control. These factors include students' cognitive ability, students' information processing model, students' attitudes towards learning and presence of students' misconceptions.

On their part, Garnett and Treagust (1992) observed that compartmentalization of physical science subjects, students' inadequate prerequisite knowledge, misuse of everyday language in chemical situations and rote application of algorithms in organic chemistry are the causes of students' difficulties in learning organic chemistry. In an investigative study, Ellis (1994) found out that students' difficulties in learning organic chemistry can be attributed to the following three major factors:

1) Lack of problem-solving algorithms in organic chemistry.
2) Students' inability to think in three-dimensional way, and the
3) Extensive use of new vocabulary in teaching organic chemistry.

This finding implies lack of problem-solving strategy, students difficulties in visualising organic chemistry concepts in three-dimensional way, and frequent use of new terms could serve as stumbling block to students' learning of organic chemistry in schools.

In a study, Taber (2001) attributed students' difficulties in learning organic chemistry to illogical and sequential arrangements of organic chemistry concepts. The scholar suggested that the various concepts in organic chemistry should be logically and coherently arranged, because it is expected that students have to draw on their previous knowledge and worked examples so that the new concepts could be learn meaningfully.

Taber (2002a) attributed students' difficulties in learning organic chemistry to the broad and abstract nature of organic chemistry topics. The study suggested that to teach these abstract concepts require teachers to use multiple representations that captures students' attention in the learning process. Tan (2006) attributed the causes of students' difficulties in learning to teachers' lack of understanding regarding reactions and procedures involved in organic chemistry. The scholar indicated that teachers' lack of understanding in organic reactions would have negative effects on students' learning of these concepts. Similarly, Suparno (2005) mentioned poor conditions of students when learning the concepts, presence of teachers' misconceptions, students' ineffective learning methods, context in which students' learn and the text books used by the students as the major causes of the students' difficulties in learning organic chemistry concepts.

Ealy and Hermanson (2006) also attributed the causes of students' difficulties in learning organic chemistry to teacher's inability to revisit and cover in-depth the rules ad principles learned in general chemistry when teaching organic chemistry classes. The study suggested that teachers should adopt innovative strategy and teach those rules in-depth when teaching organic chemistry concepts to the students.

Studies (McCormick & Li, 2006; Simsek, 2009) revealed that teachers' lack of accurate awareness of their students' prior knowledge, presence of teachers and students' misconceptions, students' approaches to learning and students' poor attitudes towards organic chemistry were the causes of their difficulties in learning organic chemistry. Sirhan (2007) also stated that lack of motivation, curriculum content, language and communication as well as overload of students' working memory space are the causes of students' difficulties in learning organic chemistry.

According to Yara (2009), the two major causes of students' difficulties in learning organic chemistry were the teachers' negative attitudes towards students and the ineffective teaching methods used by teachers in teaching organic chemistry. Studies by Orleans (2007) and Carballo (2009) showed that poor teacher quality, the presence of teachers' misconceptions and teacher-centered classroom pedagogies were the factors that are responsible for students' difficulties in learning organic chemistry. Grove and

Bretz (2010) attributed the causes of students' difficulties in learning organic chemistry to students' over-reliance on rote memorization rather than developing better cohesive understanding in learning organic chemistry. This means that for learning to be effective, students should go beyond memorization and develop better conceptual understanding of the topics presented in the organic chemistry.

O' Dwyer and Childs (2010) indicated that abstract, complex and dynamic nature of organic concepts to be covered, frequent use of teacher-centred teaching methods, erroneously constructed students' knowledge due to lack of clear vision, lack of students' and teachers' motivation and the presence of students' misconceptions are the causes of students' difficulties in learning organic chemistry. This finding implies that there are several factors that could cause students' learning difficulties in organic chemistry.

Cardellini (2012) attributed the causes of students' difficulties in learning organic chemistry to lack of students' interests in organic chemistry; and students' perception that organic chemistry is difficult, irrelevant and boring. In their studies, Hanson et al. (2012) identified poor method of instruction, lack of organizational skills, improper exposure to laboratory activities, inadequate exposure to problem-solving procedures and abstract nature of the organic concepts as the causes of students' difficulties in learning the subject. Takawira and Admire (2012) attributed students' difficulties in learning organic chemistry to the following causes:

1) Students' inability to master organic concepts.
2) Students' inability to distinguish characteristics of organic chemistry concepts.
3) Number of students' irrelevant attributes towards organic chemistry.
4) Students' colloquial terms or mother language that were not appropriate.
5) Lack of learning resources and/or inappropriate learning resources, and
6) Socio-economic background of the students.

In a study, Gafoor and Shilna (2013) posited that students' inability to conceptualise organic chemistry among the macroscopic, submicroscopic and symbolic levels of thought was the main cause of the students' difficulties. Similarly, O'Dwyer and Childs (2014) pointed out that improper sequential arrangement of topics in terms of difficulty levels in their textbooks was the cause of students' difficulties in learning organic chemistry in schools. These researchers suggested that science educators should do well to present organic chemistry topics in sequential order to facilitate meaningful learning. Tenaw (2015) was of the view that the lack of scientific vocabulary and inadequate time for effective practice are the major factors that are responsible for students' difficulties in learning organic chemistry in schools.

Childs, Markic and Ryan (2015) stated that the language used by teachers in teaching was the major cause of students' difficulties in organic chemistry. They added that the language of organic chemistry involves complex themes; it is multifaceted; there are many unfamiliar words with Greek and Latin roots alongside technical vocabulary that are not in use outside of the school. Tilahun and Tirfu (2016) in their study observed that absence of laboratory work; lack of remedial actions by teachers; inadequate explanations from the teachers; wide chemistry syllabus; lack of motivation; lack of teaching and learning aids; lack of mathematical skills and heavy teaching loads on teachers are the causes of students' difficulties in learning organic chemistry.

Eticha and Ochonogor (2017) in their study revealed that inappropriate teaching methods, abstract nature of the subject itself, students' attitudes and learning experiences as well as the learning style of the students are the causes of students' difficulties in learning organic chemistry. Similarly, Hanson (2017) found out that non-performance of practical activities in organic chemistry due to lack of science equipment and related working consumables like organic solvents are the main cause of students' difficulties in learning organic chemistry. The study further revealed that some students deliberately avoid doing practical activities because they deemed working with the often volatile and flammable organic solvents are very dangerous and prone to catch fire.

Bilgin, Yurukel and Yigit (2017) mentioned that non-connectivity between the subject and one's personal life was the cause of students' difficulties in learning organic chemistry. The scholars pointed out students are incapable of associating organic chemistry with everyday life and ask about the importance of certain topics and disciplines in their lives when teachers introduce them to new lessons.

In a study conducted in Nigeria, Uchegbu et al. (2017) outlined the following factors as the causes of students' difficulties in learning organic chemistry:

1) Ill-equipped organic chemistry laboratory in schools.
2) Insufficient number of lecturers for teaching organic chemistry in schools.
3) Lack of relevant instructional materials necessary to arouse students' interests.
4) Teachers' lack of knowledge of the subject matter.
5) Students being scared of organic chemistry practical activities.

Afadil and Diah (2018) conducted a study to assess the causes of students' difficulties in learning organic chemistry. The study revealed that the abstract nature of the organic chemistry concepts, poor methods used by teachers in teaching and students' preconceived beliefs are the causes of students' difficulties in learning organic chemistry. Similarly, Decocq and Bhattacharyya (2019) stated categorically that students' failure to transfer their knowledge in general chemistry into the learning of organic chemistry and memorization-oriented methods used by chemistry teachers are the causes of students' difficulties in learning organic chemistry.

It is obvious that literature is full of adequate evidence regarding the causes of students' difficulties in learning organic chemistry at all levels of education. Thus, this study would add to the store of knowledge in terms of the causes of science student-teachers' difficulties in learning organic chemistry at the colleges of education level.

### 2.6 Students' Conceptions in Organic Chemistry

Conception (conceptual understanding level) is an important goal in the teaching and learning in general but it is particularly relevant in science education because such understanding is required to make sense of a phenomena. Unlike conceptual understanding, conceptual misunderstanding involves conceptions that are "wrong and flawed" (Gurel, Eryılmaz & McDermott, 2015) and in conflict with scientific claims. These conceptions may be termed as "misconceptions, alternate conceptions, preconceptions or naive conceptions" (Coştu, Ayas & Niaz, 2012, p.49).

Conceptions of students in various organic chemistry concepts have been studied in national and international literature. These studies (Bhattacharyya & Bodner, 2005; Ibe & Umoren, 2009; Baah & Ghartey, 2012; Omwirhiren & Ubanwa, 2016; Anim-Eduful & Adu-Gyamfi, 2022) have indicated that most students often demonstrate low level of conceptual understanding in organic chemistry and that they possessed several misconceptions with respect to organic chemistry concepts. Studies on students' sound conceptual understanding and their specific misconceptions in the various organic chemistry concepts available in literature.

Bodner and Domin (2000) conducted a pioneer study to assess students' conceptual understanding levels in condensed or skeletal structures and reaction mechanisms in organic chemistry. The finding of the study revealed that few students exhibited better conceptions and that majority of them had misconceptions in the organic compound structures and reaction mechanisms. In a similar study, Treagust et al. (2004) also found out that only a significant number of students showed better conceptions with respect to representation and drawing of organic structures, and that majority of them had misconceptions in representation and drawing of structures for organic compounds.

In a qualitative study, Bhattacharyya and Bodner (2005) investigated the extent to which organic chemistry graduate students made use of the electron pushing formalism while proposing mechanisms for $S_{N1}$, $S_{N2}$, and Diels-Alder reactions. These scholars observed that even at the graduate level, the curved arrows used in the electron-pushing formalism held no physical meaning for the graduate students. Their study concluded that these students had misconceptions regarding implicit meaning of curved-arrow formalism and the certain path of reaction mechanism.

Topal et al. (2007) conducted a study to determine the conceptions of 140 university students and 65 students randomly selected from secondary schools in the aromaticity concept in organic chemistry. The study revealed that only few students had sound conceptual understanding; however, majority of the students had misconceptions in cyclic properties, planer structure, conjugated double bond, reactions of aromatic compounds and aromatic compounds obeying Huckel's Rule. In their conclusion, they expressed the view that the aromaticity concept was given less teaching time in secondary schools and also misconceived form in some chemistry books by reviewing the last grade of secondary school chemistry text books.

In a study conducted in Taiwan, Chiu (2007) found that most students had low conceptual understanding regarding alkanol and the phenol groups. The scholar indicated that most students had many misconceptions in the areas where the –OH group and phenols do not show any visible reaction with carboxylic acids. They also lacked knowledge that both phenols and carboxylic acids are acids. In a similar study, Ibe and Umoren (2009) examined the conceptions held by 73 respondents, made up of 54 male and 19 female pre-service chemistry teachers and four chemistry teachers of secondary schools in various concepts such as alkanols, natural products, esters and alkanoic acids. The study revealed that both respondents had some misconceptions in these concepts. However, teachers had better conceptual understanding than the students. The study concluded that the presence of students' misconceptions might have been impacted negatively by their teachers' misconceptions during classroom interactions.

In assessing students' conceptions in Germany, Schmidt, Kaufmann and Treagust (2009) observed that undergraduate regular students who took part in the study had low sound conceptions in the boiling point of organic compounds; and that most of them had misconceptions regarding boiling points of organic compounds. In a similar study done in Singapore, Kay and Yiin (2010) revealed that only a small percentage of students had correct conceptions but most of them had misconceptions in introduction to organic chemistry; properties of organic compounds; isomerism in hydrocarbons; reactivity of alkanes and alkenes, halogenoalkanes, alcohols, esters and benzene.

Baah and Ghartey (2012) conducted a study to assess Ghanaian senior high school students' level of conceptions in balancing equations of combustion reactions involving hydrocarbons. The study found out that the performance of students in correct balancing of the equation:- $C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$ was quite poor. The study observed that out of 334 students, only 71(21.3%) of them were able to balance this combustion equation correctly; and that as many as 263 (78.7%) had misconceptions regarding this equation. The study concluded that the difficulty students' face in balancing this equation was due to students' superficial knowledge of combustion with hydrocarbons. This means that students had conceptual difficulties in writing correct balancing equations of combustion reaction with respect to an alkane (ethane).

Sendur (2012) investigated the level of conceptions of prospective chemistry teachers in alkenes. Alkene Concept Test (ACT) was administered to 73 prospective science teachers as respondents. The results of the study showed that only 22 (31.4%) of these subjects showed good conceptual understanding; and that 48 (68.6%) of them had misconceptions about alkenes including geometric/cis-trans isomerism, physical properties of cis-trans isomers, IUPAC nomenclature of aliphatic alkenes and cycloalkenes, chemical reactions and synthesis of alkenes. The study further revealed that majority of these prospective science teachers had misconceptions in areas such as the application of Markovnikov's and anti-Markovnikov Rule and synthesis of alkenes from alcohols and alkyl halides.

McClary and Bretz (2012) conducted a study in America among undergraduate students. The study found out that undergraduate students exhibited low conceptual understanding and that most of them had several misconceptions in four major areas:-

1) Characterization of acid/base strength of an organic compound by thinking that the stability and functional group regulate acid/base strength of an organic compound.
2) Alkyl halide reactions, such as determining if a compound is a nucleophile or base; determining the base and nucleophile strength of a compound,
3) The description of the stages of alkyl halide reaction, and
4) Determine the transitional reaction formed in the alkyl halide reaction.

These findings imply that most students' had low conceptions in organic chemistry and that they possessed several misconceptions on organic chemistry.

Studies by Sendur and Toprak (2013) and Sharma and Decicco (2018) have indicated that most students perceived isomerism as a difficult organic chemistry concept and that most students possessed misconceptions in it. Sharma and Decicco (2018) concluded in their study that almost all the students believed that only 1, 2-dichloroethene could exhibit geometric isomer. This implies that these students lacked good conceptual understanding with respect to isomerism particularly geometric isomerism in alkenes.

In a study conducted in Turkey, Cooper, Underwood and Williams (2015) reported that most students in schools had conceptual difficulties in relation to intermolecular forces existed among the given sets of organic compounds. Their study concluded that students showed inadequate understanding of intermolecular forces in organic compounds; and that most of them possessed misconceptions with respect to the intermolecular forces existed among the given sets of organic compounds.

Omwirhiren and Ubanwa (2016) in their study revealed shocking statistics. These researchers observed that chemistry students who participated in their study demonstrated low conceptual understanding; and that most of them had misconceptions regarding IUPAC nomenclature; writing of structural formulae of saturated and unsaturated hydrocarbons; distinguishing between substitution and addition reactions; and polymerization reaction. The study concluded that there was no significant difference in the level of misconception between the male and female students. Furthermore, the study revealed that there was no significant difference between male and female students' misconceptions and their academic performance in the organic chemistry concepts taught. This finding implies that only small proportion of the students had better conceptual understanding; with majority of them had low conceptual understanding and that they possessed several misconceptions in the various organic chemistry concepts.

Similarly, Akkuzu and Uyulgan (2016) also carried out a study to investigate conceptions among 60 undergraduate students at a state university in Turkey. The study revealed that generally, these students had low levels of understanding and that most of them had misconceptions with respect to functional group identification, intermolecular forces, isomerism, aliphaticity and other organic concepts (*e.g.* decarboxylation and phenols). The study concluded that numerous misconceptions identified among students could be attributed to their inability to master these concepts in general chemistry; and therefore unable to transfer their knowledge into organic chemistry.

To determine students' level of conceptions, Hanson (2017) assessed undergraduate university students' knowledge in organic concepts such as addition reactions, saturated and unsaturated hydrocarbons, electronegativity, molecular formula, molecular structure, bonding, polarity and electronegativity. The study revealed that majority of the students (108 out of 121) representing 89.3% had misconceptions; with only 13 (10.7%) students showed better conceptual understanding and performed well in these concepts. Analysis of the students answer sheets showed that they had many misconceptions and some of their misconceptions identified were:

1) Lack of knowledge about the tetravalent nature of carbon.
2) Lack of knowledge on the covalent nature of organic compounds.
3) Reactivity of organic compounds and derivatives with common functionality.
4) $CH_3COOH$ drawn was named methanoic acid because there is only one observable methyl on carbon; and that the other carbon was not part of a stem.

In assessing the conceptions of students and their lecturers, Eticha and Ochonogor (2017) conducted a study with 177 first year chemistry students and four organic chemistry lecturers who had minimum five years teaching experience in organic chemistry. The study revealed among other things that all the students and the four lecturers had some form of misconceptions in functional groups (identification and tests), organic reactions and reaction mechanisms. However, the study concluded that the students had more misconceptions than that of their lecturers. This implies that the four organic chemistry lecturers exhibited better conceptual understanding in these organic concepts than the students, even though they also had misconceptions.

Sibomana et al. (2021) also found out that students who participated in their study had very low conceptual understanding regarding the characteristic properties of organic compounds and that most participants possessed significant number of misconceptions in the characteristic properties of organic compounds. Some of the students' common misconceptions identified were that bond polarity should be contingent on atom's electronegativity, inability to distinguish between the concepts of boiled and burned, and finally they believed that covalent bond would break when an organic compound boils.

In a more recent qualitative study, Anim-Eduful and Adu-Gyamfi (2022) revealed that students demonstrated low level of conceptual understanding and therefore, had misconceptions with respect to functional group detection in hydrocarbons and the derivatives of hydrocarbons such as alkanols, alkanoic acids, esters, alkanals, alkanones and amides. The study concluded that the demonstration of low conceptual understanding among students in the functional group detections means that these students had learning difficulties and that they had not fully conceptualizing these concepts.

It is obvious that literature is full of enough evidence for students' sound conceptual understanding and their misconceptions in organic chemistry concepts. Thus, this study would add to the store of knowledge in terms of science student-teachers' sound conceptual understanding and their specific misconceptions regarding organic chemistry concepts at the college of education level.

### 2.7 Effects of POEIA on Students' Academic Performance in Organic Chemistry

The effects of Predict-Observe-Explain Instructional Approach (POEIA) on the academic performance of students have been reported in literature. According to Lamas (2015, p.353), "academic performance is an issue that deeply concerns students, parents, teachers and authorities and the complexity of the academic performance starts from its conceptualization". Academic performance has been conceptualized by plethora of scholars in their fields of endeavour including psychologists, counsellors and educators. Some of the definitions of academic performance available in literature are as follows:

Torres and Rodríguez (2006; quoted by Willcox, 2011) conceptualized academic performance as the level of knowledge shown in an area or subject compared to the norm, and it is generally measured using the grade point average. From a humanistic approach, Martínez-Otero (2007, p.34) sees academic performance as "the product given by the students and it is usually expressed through school grades". For Yusuf, Onifade and Bello (2016) academic performance can be understood as the quantifiable and apparent behaviour of a student within a definite period and it is an aggregate of scores fetched by a scholar in various evaluations through class tests, mid- and the end-of-semester examinations. The purpose of academic performance is to achieve an educational goal. When a gap between the academic performance and the student's expected performance occurs, it refers to a diverging performance. "An unsatisfactory academic performance is the one that is below the expected performance" (Marti, 2003, p. 376).

Studies (Liew & Treagust, 1998; Mosca, 2007; Yavuz & Celik, 2013; Hilario, 2015; Ubi, 2015; Ojo & Owolabi, 2021; Özcan & Uyanık, 2022; Harman & Yenikalayci, 2022) have indicated that POE instructional approach is very effective tool in improving students' performance in scientific concepts than the traditional lecture method of teaching. Attest to this fact, Alfiyanti, Jatmiko and Wasis (2020) revealed that POE instructional approach can make school and college students improve on their performance in topics they are studying. Studies on the effects of POE instructional approach on the students' performance available in the literature are as follows:

In a pioneer study, Burkam, Lee and Smerdon (1997) found that students who received instruction based on the POE instructional strategy had better conceptual understanding and improved performance in their organic chemistry laboratory work.

The study further revealed that the female students did better in their test scores than their male counterparts' achievements. This study concluded that the POE instructional approach environments favours the female students than their male counterparts.

In another pioneer study to explore the effectiveness POE instructional approach in diagnosing 11th grade students' understanding and achievement in science; Liew and Treagust (1998) observed that students who received POE based instruction had better conceptual understanding and improved achievement in the various concepts. They concluded that the POE activities were very effective in profiling students' achievements.

Capistrano (2000) attempted to use an improvised apparatus in teaching chemistry concepts via POE approach. The study revealed that students who were taught using POE instructional strategy, on the average had higher scores in their post-test than that of their pretest. In a similar study, Hernandez (2002) opined that students who were exposed to POE instructional approach performed better in their achievement test scores than their control group counterparts with respect to the same scientific concepts. The difference in the mean score showed that there were significant difference between the experimental group scores and their control group counterparts.

In another study, Mosca (2007) revealed that that students who were exposed to POE approach performed better in their post-achievement test scores than their control group counterparts. The study found out that there was significant difference between the performance of experimental and their control group counterparts. Similarly, McGregor and Hargrave (2008) also found out that the experimental group students who had POE based instruction had improved performance in their post-test scores than their control group counterparts. The study concluded that there was a significant difference in the performance in favour of the experimental group in the chemistry concept taught.

In a similar study, Lucilo (2010) observed that science students who were exposed to the POE instructional approach had significant improved performance and metacognition awareness than their control group who received expository instruction. The scholar concluded that POE instructional approach was very effective in improving students' performance and their metacognition awareness. Similarly, Costu, Ayas and Niaz (2010) also observed that students who received POE based instruction performed significantly better in their achievement test than the students who received instruction in lecture method. The study concluded that the POE instructional technique was effective in achieving better students' understanding in the concepts taught.

A study conducted by Yavuz and Celik (2013) using POE tasks to remedy the pre-service elementary teachers' misconceptions and to improve their performance in the organic chemistry. An organic chemistry concept tests were used for data collection. Eight POE tasks were applied during three weeks in the experimental group whereas the control group was taught with traditional lecture method. The study revealed that the research subjects who were taught using POE tasks had better performance in the concepts taught than those in the control group.

Similarly, Vadapally (2014) in a study found that students who took part in the POE based instructional strategy had significant improved performance at the end of the study. This study also showed that female students gained new knowledge through their experiences with the POE tasks and to a greater extent performed better than the boys. This means that POE strategy was in favour of the females than their male counterparts.

In another study, Hilario (2015) found that students who received POE based instructions had statistically significant improved performance at the end of their study than their colleagues in lecture based instructions. The study showed that the experimental group had a mean score of 25.83 in pre-test scores, which was higher by

3.00 than the score of the control group with 22.83. The difference had a computed t-value of 1.80, which was not significant at the 0.05 level for 10 degrees of freedom. However, the experimental group got a higher score in the post-test with a mean score of 33.83 whiles the control group obtained 25.50. The computed t-value of 3.31 showed a significant improved performance in favour of the experimental group students.

Ubi (2015) carried out a study on relative effectiveness of POE and lecture methods of teaching organic chemistry on the academic performance of secondary students in Akwa Ibom State, Nigeria. 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 analysing the data at 0.05 levels of significance. The study revealed that students taught with the POE were superior in terms of performance than those taught using the lecture method. This implies that POE had impacted positively on the students' performance during the study.

In another study, Sreerekha, Arun-Raj and Swapna (2016) found out that the girls who had POE based instruction showed superior performance than the other girls who received lecture method based instructions. The result showed that there was significant difference in the post-test scores between school girls who were exposed to POE strategy and the lecture method. In a similar study, Awalia, Sitompul and Hamdani (2016) revealed that university students who were exposed to the POE instructional strategy had significantly improved performance than their control group counterparts. The study concluded that the POE instructional strategy was able to reduce the students' misconceptions by 46.8%. This means that POE strategy was very effective in improving students' performance and reduce their misconceptions in the concepts taught.

Acar-Sesen and Mutlu (2016) also conducted a study to investigate the effects of laboratory activities based on POE tasks related to selected chemistry topics on 56 pre-service elementary teachers' understanding in chemistry lessons and laboratory. Fifty-six pre-service elementary teachers were randomly assigned to experimental (N = 26) and control (N = 30) groups. The experimental group was instructed using laboratory POE tasks activities and the control group was taught using traditional cook-book design laboratory activities for ten weeks duration. The study revealed that the pre-service elementary teachers who were taught with the laboratory POE tasks activities had significantly higher scores in terms of achievement in chemistry lessons than those taught with the traditional approach. The study concluded that instruction for laboratory activities based on POE tasks was more successful in remediation of the predetermined alternative conceptions among the pre-service elementary teachers.

Demircioğlu, Demircioğlu and Aslan (2017) also investigated the effects of POE technique on the understandings of grade 11 students in chemistry concepts in Trabzon. Two classes were randomly selected for the study. One of the classes was assigned as experimental group (N = 36), and the other as a control group (N = 37). The results indicated that the experimental group taught with the POE showed a higher success in performance than the control group students who were taught with the lecture method.

In a study to identify students' misconceptions and assess the effects of POE strategy on vocational school students' performance in chemistry, Dewantoro, Subandi and Fajaroh (2017) observed that the POE strategy helped to reduce the students' misconceptions and thereby improved on their performance in the concept taught. These scholars revealed that there were several misconceptions among the students in the concept taught with an average of 32.97%; and the details on each sub-material were as follows: unit conversion 18.75%; law of conservation of mass 21.88%; and stoichiometry 40.63%. The study concluded that the use of POE strategy as a remedial action was very effective in improving students' misconceptions with an average efficacy of 76.02%.

In a study conducted by Furqani, Feranie and Winarno (2018) among 8th grade students in a junior high school in Bandung the following statistics was revealed. There was enhancement in students' conceptual mastery, indicated by average normalized gain of 0.29, there was enhancement in students' critical thinking abilities from level 1.30 to 2.07. The study concluded that the POE was very effective tool and students can easily predict, observe and explain scientific concepts they previously had difficulties on them.

In a recent study, Prabawati, Nugrahaningsih and Alimah (2020) found that the experimental group students in POE strategy performed better than their control group in terms of cognitive, affective and psychomotor domains of the study. The result of N-gain t-test showed that there was a significant difference in their posttest-pretest scores between the experimental and control groups. The levels of affective and psychomotor domains of the experimental group was better than the control group.

Ojo and Owolabi (2021) in their study, also found that students in the POE instructional strategy group had mean score of 6.83 whiles those in conventional laboratory strategy group had mean score of 6.70 prior to their treatments. On exposure to treatments, students taught with POE model had the mean score of 27.38 whiles those in the conventional strategy group had the mean score of 17.70. The study showed that there was significant difference in students' performance after the treatments. This means that the POE treatment had positive effects on the students' academic performance.

Özcan and Uyanık (2022) conducted a study to assess the effects of the POE strategy on the academic achievement and retention in organic chemistry learning. The study revealed that students' in the experimental group had better performance than those in the control group. In addition, a retention test was applied five weeks later after the post-test application. The retention test results revealed that the difference between the experimental group and the control group was statistically significant in favour of the experimental group. Similarly, Harman and Yenikalayci (2022) also observed that the 20 pre-service teachers who had POE based instruction had improved performance in the concepts taught and also expressed positive opinions about the POE based instructions.

Recently, Hartanto, Dinata, Azizah, Qadariah and Pratama (2023) conducted a study to assess the impact of POE instructional model on students' science process skills and understanding of organic chemistry topics. The results of the study showed an increase in students' conceptual understanding, which was indicated by an N-gain score of 0.63 (moderate increased category). Also, the results of the process skills test showed that 30% of students acquired science process skills with the category of "excellent", 40% with the category of "good" and 25% with the category of "adequate". The study concluded that POE instructional model can be used to improve students' conceptual understanding and science process skills in various scientific concepts.

It is obvious that literature is full of enough evidence for positive effects of the POE instructional approach in improving students' performance; and it must therefore, be explored to broaden the scope of knowledge in this regard at the college level.

## 2.8 Impact of POEIA on Students' Attitudes towards Organic Chemistry

Attitude, according to Siddique, Ahmed, Feroz, Shoukat and Jabeen (2022), is very complex and sticky construct. An attitude is a relatively enduring organization of beliefs, feelings and behavioural tendencies towards socially significant objects, groups, events or symbols (Hogg & Vaughan, 2005). According to Nja, Orim, Neji, Ukwetang, Uwe and Ideba (2022), attitude refers to the predisposition to categorize objects and events, to react to them with assessment consistency and that it consists of one's information, reverence, emotions, incitement and self-esteem designing an individual's outlook on a certain discipline. Conceptually, attitudes can be described in terms of three components: affective component (involves a person's thoughts/feelings/emotions about an attitude object); behavioural (or conative) component (the way the attitudes we have influences how we act/behave) and cognitive component (involves a person's knowledge, concentration, sensation and trust about an attitude object) (Nja et al., 2022).

Students' attitudes towards the course plays an important role in the learning achievement of the students. Studies (Sejčová, 2006; Kubiatko, 2013; Sutopo, Berek & Munzil, 2016; Hanson, 2017) have posited that learners' attitudes toward subject matter, especially in sciences are as important as academic performance. According to Sejčová (2006), an important factor contributing to good performance of students in individual subjects is their attitudes towards these subjects. Kubiatko (2013) opined that if attitudes towards a subject are positive, then the achievement of students also gets better.

In chemistry education, attitude is an important factor that affects students' achievement (Adesoji & Raimi, 2004). Students' own attitudes according to Hanson (2017), is one of the crucial factors that affects their performance in organic chemistry. Salta and Tzougraki (2004) opined that attitude in chemistry is one's disposition towards the study of chemistry which can be a positive or negative feeling about chemistry; and it deals with how one looks at chemistry as be it difficult or very simple to understand.

Numerous studies (Koseoglu, Tumay & Kavak, 2004; Bilen & Aydogdu, 2010; Ayvaci, 2013; Muna, 2017) have shown that POE instructional approach could be used to develop students' positive attitudes towards teaching and learning of sciences particularly in chemistry. Attesting to this fact, Alfiyanti et al. (2020) revealed that POE instructional strategy can make school and college students developed positive attitudes towards the topics they are studying. Studies on the impact of POE instructional approach on the students' attitudes towards sciences available in literature are as follows:

In a chemical reaction study, Koseoglu et al. (2004) developed a POE chemical activity named as "water can be boiled with ice". This activity was applied to 44 pre-service chemistry teachers. They collected data using observations and interviews. The study revealed that the POE activity was very effective in promoting the pre-service science teachers' attitudes towards the concepts taught in schools.

Similarly, Bilen and Aydogdu (2010) conducted a study to investigate the effects of a laboratory instruction based on POE model on the 122 pre-service science teachers' attitudes towards organic chemistry concepts. The study revealed that the pre-service elementary teachers' attitudes had improved positively towards the organic chemistry concepts taught. These scholars concluded that the POE model was very effective in improving subjects' attitudes towards chemical concepts understudied positively.

In a study, Ayvaci (2013) found that students who received POE based instructions had positive attitudes towards the concepts taught than those who received instruction in the lecture method. The scholar concluded that the experimental group students were very happy and enthusiastic in learning the concepts taught. In a similar study, Muna (2017) also observed that students who had POE based instructions in the organic chemistry concepts had positive attitudes towards the concepts taught than those who had lecture based instruction.

Studies (Aydın, 2010; Akgün, Tokur & Özkara, 2013) found that there was no difference between experimental and control groups at the beginning of the implementation of POE strategy in terms of their attitudes. At the end of the implementation, although there was a difference between the groups in favour of the experimental group in attitudes, but the observed difference was not statistically significant. These scholars attributed their no significant difference findings to the duration of their implementation. They considered the duration of their implementation as a limitation to positively change their students' attitudes. They concluded that for statistically differences to exist, then the implementation period should be quite longer (about 8-10 weeks) in order to bring the change in attitudes. Moreover, Akgün et al. (2013) also indicated that the use of POE in only one science concept or unit was not enough to affect students' attitudes towards science. These scholars concluded that future studies should incorporate longer implementations periods and also included various concepts in sciences and in other disciplines to examine the POE's effectiveness.

In a similar study, Hilario (2015) observed that students who were exposed to the POE instructional activities had a mean difference of 12.00 in the post-test scores which was significant in favour of the experimental group than their control group counterparts. The study concluded that the students in the experimental group who received POE instructions enjoyed the chemistry subject taught and had developed positive attitudes as well as interests in the chemistry concept taught. Gernale, Arañes and Duad (2015) investigated the effects of POE approach on 220 students' attitudes towards organic chemistry. The results showed that the gain scores in the attitudes of students in experimental group was far better than their control group counterparts.

Acar-Sesen and Mutlu (2016) also conducted a study to investigate the effects of laboratory activities based on POE tasks on pre-service elementary teachers' attitudes towards chemistry laboratory tasks. Fifty-six pre-service elementary teachers were randomly assigned as experimental (N = 26) and control (N = 30) groups. The study revealed that the experimental group pre-service teachers had significantly higher scores in terms of attitudes than those in the control group.

In a similar study, Taqwa and Putra (2017) observed that students who were taught with POE bases tasks had positive attitudes towards the concepts taught at the end of the study.  In their study, Salame and Samson (2019) also found that students who were exposed to the POE instructional model developed positive attitudes towards the concepts taught. They concluded that learning with POE learning model had positive impact on the students' attitudes towards the subject matter.

Ferty, Wilujeng and Kuswanto (2019) conducted a research study among grade 11th groups 1 and 2 students to assess their attitudes in terms of their critical thinking skills. The study revealed that the score of students' attitudes in terms of their critical thinking skills had increased after the implementation of POE learning model and both groups presented positive responses and also showed developed positive attitudes. In another study, Arslan and Emre (2020) observed that there was no difference between the groups at the beginning of the implementation in terms of their attitudes. At the end of the implementation, although there was a difference between the groups' attitudes in favour of the experimental group; but this difference was not statistically significant.

In a recent study, Siddique et al. (2022) found out that students who had POE treatment had improved positive attitudes towards chemistry. The study further revealed further shocking statistics. It was revealed that the female students had better attitudes than the male students; in the context of academic stream, biology students had better attitudes than computer students; in terms of location, urban students had more positive attitudes than rural students; furthermore, public school students possessed more positive attitudes than the private school students towards POE chemistry learning. This finding means that POE instruction favours female students than boys, science students than non-science students, urban than rural students and public than private school students.

It is obvious that literature is full of enough evidence for both positive and negative impact regarding POE instructional approach in developing students' attitudes towards scientific concepts particularly in organic chemistry.

## 2.9 Summary of Review of Related Literature

Studies in chemistry education have shown that science student-teachers have difficulties in acquisition of scientific concepts in organic chemistry at the various levels of education including colleges of education and even at the university levels. These difficulties coupled with the presence of varied misconceptions had adverse effects on science student-teachers' performance and attitudes towards organic chemistry topics mainly hydrocarbons, alkanols, carbonyls, alkanoic acids, esters and amines understudy.

These difficulties encountered by science student-teachers at the college level have been attributed to the inappropriate and uninspiring traditional lecture method devoid of practical activities often used by chemistry tutors in presenting these concepts to students who are novices in the realms of organic chemistry. Attesting to this fact, studies (Ogunniyi, 2002; Koosimile, 2005) had indicated that within Sub-Saharan Africa including Ghana, the prevalence of chalk and talk teaching styles, devoid of hands-on activities and other factors would continue to hamper students' performance and attitudes towards the sciences if proper measures are not taken.

In addressing science student-teachers' low performance and negative attitudes towards the selected organic chemistry topics, calls on chemistry educators to adopt innovative teaching strategy such as POE instructional approach (POEIA). This approach would help to improve their conceptual understanding, performance and attitudes towards these topics. Despite the numerous studies done by other science educators elsewhere with success; however, only a few or no studies of such nature have been done in the Ghanaian COE settings. This grey academic area needs to be filled. Hence, the urgent need for this study to be carried out to assess the effectiveness of POEIA in improving science student-teachers' performance and attitudes towards the selected organic chemistry topics.

# CHAPTER THREE

## METHODOLOGY

### 3.0 Overview

Methodology, according to Antwi and Hamza (2015), refers to how the researcher goes about practically finding out whatever he or she believes can be known. This chapter discusses the methodology employed in this study and it covers the areas including research design, research settings, population, sample and sampling procedure, instruments, data collection procedure, data analysis methods and ethical considerations.

### 3.1 Research Design

The design used for this study was an action research. The rationale for using this design was that the study sought to improve science student-teachers' performance and attitudes towards the selected organic chemistry topics using "predict-observe-explain (POE) instructional approach" (POEIA) as an intervention strategy.

Bassey (1998, p.93) offered a very practical definition and describes "action research as an inquiry which is carried out in order to understand, to evaluate and to change in order to improve educational practice." Also, Clark, Porath, Thiele and Jobe (2020, p. 8) posited that "action research is an approach to educational research that is commonly used by educational practitioners and professionals to examine and ultimately improve their pedagogy and practice". These scholars added that an action research is participative and collaborative; undertaken by individuals with a common purpose and knowledge which is created through action and application. Moreover, action research is situation or context-based and can be based on problem-solving, if the solution to the problem results in the improvement of practice. Thus, in this way, action research represents an extension of the reflection and critical self-reflection that an educator employs on a daily basis in their classroom setting.

Cohen, Manion and Morrison (2013, p.192) situated action research differently and describe "action research as emergent and essentially an on-the-spot procedure designed to deal with a concrete problem located in an immediate situation". This means that ideally, the step-by-step process is constantly monitored over varying periods of time and by a variety of mechanisms (questionnaires, interviews and case studies, for example) so that the ensuing feedback may be translated into modifications, adjustment, directional changes and redefinitions so as to bring about lasting benefit to the ongoing process itself rather than to some future occasion.

These definitions highlight the distinct features of action research and emphasize the purposeful intent of this design to improve, refine and problem-solving issues in the educational context. Thus, this design is relevant to the study since this study focusses on to improve research subjects' performance and attitudes towards the selected organic chemistry topics using "POE instructional approach" as an intervention strategy.

According to Anane and Anyanful (2016), an action research design has an advantage by allowing teachers to address specific and unique problems that are closest to them in their local settings and also bring changes in their classroom. Again, the design was used because it can be used by researchers to achieve valid and reliable results. Moreover, the design was used because it can be adjusted to meet varied conditions and situations which help in getting accurate and reliable results. Also, this design allows for gathering quantifiable data that could be used for statistical inference on target audience through data analysis.

Attesting to the merits of action research, Cabaroglu (2014) posited that action research is not the usual thinking of teachers but a more systematic and collaborative way of obtaining data based on reflection; and it is conducted by particular people in order to improve their work. Indeed, action research provides a framework that incorporates both the reflections of the researcher and systematic and rigorous process of research study.

Despite the numerous advantages associated with action research design, there are contrasting views as it weaknesses. Anane and Anyanful (2016) pointed out that action research requires the tenacity and resilience of the teacher in solving the problems. Mertler (2017) also stated that action research lacks strict adherence to ethical rules. The scholar added that in academic research there are clear ethical rules to be followed, but in action research in many schools, there are usually no official ethical rules in operation. However, the general ethical rules for the teaching practice largely overlap with ethical research considerations in action research in the classroom.

The same weakness confronts most teachers in action research paradigm in Ghanaian Colleges of Education. There are conflicting views on this issue as some consider it necessary to gain consent both from the students and their parents but others consider it sufficient to get students consent if the school has approved the study.

## 3.2 Research Settings

The study was conducted in the Science Education Department of Foso College of Education in the Assin-Central Municipality. This Municipality is geographically located at 1’00’W - 1’300’W and 5’30N-6’00N with Assin Foso township as the Capital. The Assin Foso town, which doubled as the capital of Assin-Central Municipality is in the central region of Ghana, and it branches off at Yamoransa junction northward towards Kumasi, a distance of about 45km. This Municipality shares common boundaries with Twifo-Heman lower Denkyira on the West, Ajumako-Enyan Essiam on the east, Assin-South on the South, and Assin-North on the North (see Figure 3). This Municipality is noted for its commercial activities due to its strategic place in the map of Ghana, and can boast of at least a College of Education and three senior high schools. The map below shows the study area or the research settings.


Figure 3:- Map of the Central Region of Ghana showing location of the study area.

**Key**

▲ - Foso College of Education (FOSCO)

The Foso College of Education (abbreviated as FOSCO) is one of the 46 public College of Education in Ghana. This College offers sciences (mainly chemistry, biology, physics and science methodology) as one of its academic programmes. The medium of instruction was English language and it has both classrooms and laboratories for some courses, especially, the sciences. The college has three well-furnished laboratories for chemistry, biology and physics lessons. For the sciences, most of the lectures took place at the laboratory. This study took place at the chemistry laboratory which also doubled as lecture room. The laboratory/lecture room for the study was furnished with a white board and one fume cupboard. The room was equipped with laboratory benches with sinks, gas tap, electrical switch and wooden stools. The benches were permanently fixed horizontally facing the whiteboard. This made students had better view and assess to the tutor's demonstration table. This also facilitated group work and practical sessions.

The researcher was also one of the chemistry tutor's in the college. There was one laboratory technician, five teaching practice officers who assisted in the conduct of the activities and a cameraman responsible for photographing (samples of photographs could be seen in Figures 4 - 6) of and recording practical work on a daily basis.

## 3.3 Population

Population of study for any research work has been variously defined by different scholars and their definitions pointed towards the same direction. According to Creswell and Creswell (2017), population of a study refers to a group of individuals or objects capable of providing the whole or part of the answers that satisfy the research questions of the study. Again, Rahi (2017) also conceptualised research population as all the people that possess some characteristics that the researcher seeks to understand whiles Akinade and Owolabi (2009, p.72) defined population as "the total set of observations from which a sample is drawn". This means that population often connotes all members of the target of the study as defined by the aims and objectives of the study. Thus, population of a study deals with entire aggregates of people that a researcher has interest in and can obtain relevant information from them for his or her study.

The target population was all second year science student-teachers pursuing science programme as a general course in two (2) science-based Colleges of Education in the Central regions of Ghana. As part of their course, these students offered chemistry as elective course in addition to biology, physics and other educational courses.

However, the accessible population was all level 200 science student-teachers in Foso College of Education in the Assin-Central Municipality who were pursuing organic chemistry as a component course of General Chemistry Theory II, for 2021/2022 academic year. The college has students' enrollment of 1,595 of which male students numbered 1017 and female students numbered 578. The college has a principal, vice principal, 39 teaching staff (27 males & 12 females) and 53 auxiliary staff (41 males & 12 females) as the time of conducting this study.

This College of Education was purposively chosen due to its proximity to the study. Besides the proximity, the college was also selected because of: (a) willingness of the respondents (science student-teachers) to take part in the study, (b) almost all of these student-teachers had difficulties learning some topics in their organic chemistry curriculum, (c) availability of a reasonable number of second year students in the science classes, and (d) the topics being studied matches with the topics under investigation.

### 3.4 Sample and Sampling Procedure

A total sample size of forty (40), 2021-2022 second year science student-teachers in Foso College of Education pursuing organic chemistry (as a component of General Chemistry Theory II) participated in the study. The 40 science student-teachers were made up of 32 (80.0%) males and 8 (20.0%) of them being females. The ages of the respondents ranged between 20 and 34 years, with an average age of 23 years. Per Ghana's 1992 constitution, they are considered as matured and adults. Thus, their responses were considered to come from matured science student-teachers.

A purposive sampling technique of the non-probability sampling procedure was used to select all the 40 subjects in an intact class for a specific purpose. This was due to the fact that all the level 200 science student-teachers in that class offered chemistry as an elective course. Again, the participation of the second year science student-teachers was dictated by two factors. Firstly, the organic chemistry concept featured prominently in the level 200 General Chemistry Theory II curriculum or course outline (Unit 3; pp. 6 -10) and these science student-teachers were studying it at the time of conducting the study. Secondly, almost all of them in that class had difficulties in learning some topics in organic chemistry. The whole class was used for the study because the study was incorporated into the normal teaching period without disrupting the academic calendar of the College.

## 3.5 Instruments

The study used both quantitative and qualitative data gathering instruments namely interview, test and questionnaire. The interview constituted qualitative data gathering instrument whereas test and questionnaire formed the quantitative parts.

In addition, written documents such as daily observational notes, documents analysis and audiotapes were made to augment information that were obtained from the main instruments. The combination of these approaches ensured triangulation of the collected data (Kane, 1996; Khald, 2017). Triangulation, according to Khald (2017), is a powerful way of demonstrating concurrent and participants' validity in research and can enhance credibility, dependability and conformability aspects of a piece of study. The instruments used for this study have been listed and described briefly below as follows:

1) Interview
2) Test.
3) Questionnaire.

***1). Description of Interview Items***

Two (2) sets of semi-structured interview items called the Science Student-Teachers' Pre-Interview Schedule (SSTPIS) and POEIA Post-Interview Schedule (POEPIS) were developed and were used to collect data from the research subjects. Interviews truly express participants' sentiments. Interviews were employed to assess respondents' true impressions about their learning difficulties in some aspects of organic chemistry. This is because written texts (tests and questionnaires) show mute evidence from the subjects and could be interpreted wrongly. The interview sessions were audio-taped or recorded and transcribed. The nature of these two different sets of interview schedules have been described briefly.

***a). Description of Science Student-Teachers' Pre-Interview Schedule Items***

The Science Student-Teachers' Pre-Interview Schedule (SSTPIS) was developed and used to collect data from the research subjects before the implementation of POE instructional approach intervention activities. The SSTPIS consisted of two (2) parts namely Section A and B respectively. Section A contained bio-data of the respondents (science student-teacher's, SST's code, sex and date) whereas Section B also had five (5) questions items; and the respondents were required to answer them by writing or providing the correct answers.

The question items (1) (i.e. 1a-j) was formulated to assess the respondents' conceptions in writing correct IUPAC nomenclature of some organic compounds. Question item (2) (i.e. 2a & b) was formulated to assess subjects' conceptions in organic reaction mechanisms. The question item (3) (i.e. 3a - j) was to assess the subjects' conceptions in correct functional group identification. Question (4) (i.e. 4a - c) was done to assess the subjects' conceptions on balancing of equations for the combustion of hydrocarbons. Question (5a & b) was formulated to assess respondents' views about their perceived difficulties with respect to the four given questions in the SSTPIS and also the causes of their difficulties in understanding organic chemistry concepts.

These questions (i.e. 1- 4) were set based on their General Chemistry Theory II course outline (for UCC affiliated colleges only). Also, some of the questions were drawn from UCC mid-semester and end-of-semester past-questions (i.e. for the past seven years 2012 -2019); and the West African Examination Council (WAEC) Senior High School past question papers (i.e. for the past five years 2015 -2020). Each respondent was required to answer these questions on the given question paper for 60 minutes. Sample of the SSTPIS could be found in Appendix B, whereas the scoring scheme for SSTPIS could also be found in Appendix H.

### 3.6 Scoring of the Subjects' Conceptions from the Pre-Interview Schedule

The research subjects' answers and drawings given in response to the questions in the SSTPIS were evaluated and categorised into three categories namely correct answer, incorrect answer and no answer. The response categorization were coded and scored as 1, 0 and 0 respectively. A similar categorization system was used by other scholars (Özmen, Ayas & Coştu, 2002; Uyulgan & Akkuzu, 2016). These categorisations in terms of symbols, criteria for scoring and the scores are presented in Table 1.

**Table 1: Evaluation scheme for subjects' responses in pre-interview schedule**

| No | Categories | Symbol | Criteria for scoring | Scores |
|---|---|---|---|---|
| 1) | Correct Answer | C. A | Responses that contain all parts of the scientifically accepted concept | 1 |
| 2) | Incorrect Answer | I. A | Scientifically incorrect responses | 0 |
| 3) | No answer | N.A | Blank response or repeated question | 0 |

Source: (Uyulgan & Akkuzu, 2016)

Moreover, the types of research subjects' conceptual understanding levels in the SSTPIS were evaluated with a scheme that was originally guided by the work of Piaget. While studying students' understanding of the conservation concepts, Piaget, as cited in Grubern and Vone'che (1977), found that students' understandings of the conservation concepts can be classified into three namely non-conservation, transitional and conservation. Copeland (1984) indicated that Piaget classified students' understanding into three categories: no understanding, partial understanding and sound understanding.

To adapt this categorization scheme to misconceptions research, researchers added more categories. For example, Haidar and Abraham (1991) added alternative conceptions. Earlier, Renner, Brumby and Shepherd (1981) added specific misconceptions. Marek (1986) preferred to separate the "no understanding" category into:-no understanding and no response. However, in its present form, the scheme consists of five categories namely sound understanding, partial understanding, specific misconception, no understanding and no response as shown in Table 2.

**Table 2: Scheme for assessing subjects' understanding in pre-interview schedule**

| No | Degree of conception | Symbol | Interpretation |
|---|---|---|---|
| 1) | Sound understanding | SU | Responses that contain all parts of the scientifically accepted concept |
| 2) | Partial understanding | PU | Responses that contain a part of the scientifically accepted concept |
| 3) | Specific misconception | SM | Scientifically incorrect responses |
| 4) | No understanding | NU | Repeat question, irrelevant or unclear response, no explanation given for choice of answer |
| 5) | No Response | NR | Blank or no response |

Source: (Özmen et al., 2002; Uyulgan & Akkuzu, 2016)

This scheme was selected for this study because it enabled me to look at the data from two angles: first, subjects' responses can be separated into different levels of understandings; and second, the subjects' misconceptions can be further analysed into different patterns. A similar scale has been used in other studies (Haidar & Abraham, 1991; Ünal, Coştu & Ayas, 2010; Uyulgan & Akkuzu, 2016) which gave cogent results; attesting to the fact that the scheme is reliable and could be used in this study. Hence, its adaptation for this study. However, for the open-ended questions (5a & b), the science student-teachers' responses were qualitatively analysed and transcribed verbatim.

***b). Description of POEIA Post-Interview Schedule Items***

The POEIA Post-Interview Schedule (POEPIS) was developed and used to collect data from the research subjects after the implementation of POE instructional approach activities. The POEPIS consisted of seven questions (i.e. 1-7) formulated based on the research question 6 to find out the research subjects' views or opinions with respect to the POE instructional approach and the module used in the teaching and learning the selected organic chemistry topics/concepts understudied. A sample of the POEPIS could be found in Appendix F.

***2). Description of Test Items***

Two (2) sets of tests of comparable standards called pre-intervention test and post-intervention test were constructed, developed based on the selected organic chemistry topics and were used to collect data from the research subjects for the study. The pre-intervention test called "Science Student-Teachers' Organic Chemistry Diagnostic Test (SSTADT) was used before the implementation of POE instructional approach intervention activities. On the other hand, the post-intervention test called "Science Student-Teachers' Organic Chemistry Achievement Test (STOCAT) was used to assess the research subjects' conceptual understanding of the selected organic chemistry topics after the implementation of the POEIA intervention activities.

Each test (SSTADT and STOCAT) consisted of two (2) parts; Section A and B respectively. The Section A contained the bio-data of respondents in terms of science student-teacher's (SST's) code, sex and date; whereas the Section B also contained 30 multiple-choice objective question items. These questions were set based on the selected organic chemistry topics namely hydrocarbons (alkanes, alkenes & alkynes), alkanols, carbonyl compounds, alkanoic acids, esters and amines of their General Chemistry Theory II course outline (with Course Code: EBS 254 for COE affiliated to UCC only). Again, some of questions were drawn from UCC mid-semester and end-of-semester past-questions (i.e. for the past eight years, 2011 -2019) and the West African Examination Council (WAEC) SHS past question papers (for the past six years, 2014 -2020). Although all the test items were standardized, they were still subjected to thorough evaluation. All the questions on the tests were evaluated by colleague COE tutors and my supervisors to ensure their appropriateness for measuring the content standards in accordance with college of education organic chemistry curriculum.

Each question item in the test had a stem followed by four lettered options A to D; with one correct answer and three plausible distracters. The duration for each test was 90 minutes. Each student-teacher was required to select correct answer for one mark. Thus, the total highest score for the test was 30 marks whiles the total lowest score was zero (0) mark. Although the test items were standardized, they were still subjected to item analysis and were categorised into six cognitive ability levels reflecting principally the knowledge, comprehension, application, analysis, synthesis and evaluation. Determination of the difficulty and discrimination indices of the test items were achieved through the pilot-testing of the test items which consequentially, helped improve the internal consistency of the items in the test instruments. Samples of the pre-intervention and post-intervention tests could be found in Appendix C and Appendix D respectively. The marking scheme for both pre-intervention test and the post-intervention test could be found in Appendix I.

***3). Description of Questionnaire Items***

Two different sets of questionnaires namely Science Student-Teachers' Organic Chemistry Difficult Questionnaire (STOCDQ), and Science Student-Teachers' Attitude Scale Questionnaire (STASQ) were constructed, developed and were used to collect data from the respondents for the study. The nature and contents of these two different sets of questionnaires have been described briefly below as follows:

***a). Description of Organic Chemistry Difficult Questionnaire Items***

The questionnaire called Science Student-Teachers' Organic Chemistry Difficult Questionnaire (STOCDQ) was developed and was used to collect data from the respondents before the implementation of the POE instructional approach activities. The STOCDQ had two Sections A and B. Section A was formulated based on the research question (1) and it consisted of question items 1, 2a, 2b, 3 and 4. Question items 1 and 2a where closed-ended questions that required “Yes” and “No” responses; whiles that of 2b was an open-ended question. Question item 3 (a - p) was based on a four point Likert scale type ranging from Not Difficult [ND]; Slightly Difficult [SD]; Difficult [D]; to Very Difficult [VD]; whereas question item 4(a - j) was based on two point Likert scale type consisting of Not Difficult [ND] to Difficult [D] of which these research subjects were required to tick the appropriate box of their choice.

Question items 5 (a - j) in Section B was formulated based on research questions 2 and was to assess possible causes of research subjects’ difficulties in learning organic chemistry topics. The question item 5 (a - j) required “Yes” or “No” responses from the subjects. Sample of the STOCDQ could be found in Appendix A.

***b). Description of Attitude Scale Questionnaire Items***

The questionnaire called Science Student-Teachers’ Attitude Scale Questionnaire (STASQ) was used to collect data from the research subjects for the study after the implementation of the POE instructional approach intervention activities. The STASQ had two Sections A and B. Section A contained bio-data of the respondent such as code, sex and date, whereas Section B contained 14 statements which conformed to the impact of POEIA on respondents’ attitudes towards the selected organic chemistry topics.

The respondents were asked to indicate the intensity of their responses to each of the 14 question items on a 5-point type Likert scale (Strongly Agree - [SA] to Strongly Disagree -[SD]). Statements that reflected positive attitudes (e.g. “I enjoyed learning organic chemistry through practical activities based on POEIA”) were scored as follows:

| Response Intensity | Symbol | Score |
|---|---|---|
| Strongly Agree | SA | 5 |
| Agree | A | 4 |
| Uncertain | U | 3 |
| Disagree | D | 2 |
| Strongly Disagree | SD | 1 |

Again, statements that reflected negative attitudes (e.g. "Organic chemistry was difficult subject for me to study before the POEIA activities") were scored as follows:

| Response Intensity | Symbol | Score |
|---|---|---|
| Strongly Agree | SA | 1 |
| Agree | A | 2 |
| Uncertain | U | 3 |
| Disagree | D | 4 |
| Strongly Disagree | SD | 5 |

There were 14 attitudes scale items, so the maximum obtainable score was 70 (i.e. 14 x 5) and a minimum score was 14 (i.e. 14 x 1). The total attitudes score for each respondent was thus, expected to range between 14 to 70. A score of 35 means the middle point and this could be due to average attitude in the respondents leading to uncertain responses. A high score above 35 means a positive attitude whiles low scores below 35 means negative attitudes. A sample of the STASQ could be found in Appendix E.

## 3.7 Validity of the Instruments

Renz, Carrington and Badger (2018) conceptualised validity as unique principles that one uses to determine whether or not the research under question is of good quality or not. Khald (2017) posited that validity is crucial in any scientific study as it helps in achieving accurate representation of findings by fusing multiple data collection methods to gather data from the participants.

In order to ensure both face and content validity of the three developed instruments namely the 1) interviews (SSTPIS) and (POEPIS), 2) tests (SSTADT) and (STOCAT), and 3) questionnaires (STOCDQ), and (STASQ) were scrutinized by my course mates and colleague chemistry tutors. These instruments were then presented to two senior chemistry educators in the Chemistry Education Department of the Faculty of Science Education of the University of Education, UEW; with extensive knowledge and research experiences for their expert critique and advice on the content in order to ensure face validity of the instruments. The experts were asked to assess the instruments in terms of scope of coverage, content relevance, ambiguity and vagueness of expression. Corrections and suggestions arising from these experts were used to review the instruments. The inputs, suggestions and comments made by these experts led to the improvement or betterment of the items in the instruments.

### 3.8 Reliability of the Instruments

In order to determine the reliability of the instruments, the three instruments namely the interview schedules (SSTPIS & POEPIS), tests (SSTADT & STOCAT), and the questionnaires (STOCDQ & STASQ) used for the study were trial/pilot-tested in Komenda College of Education using 20 of the 2021/2022 second year science student-teachers pursuing organic chemistry course.

The reliability coefficients of the tests (SSTADT & STOCAT) were calculated using Kuder-Richardson 21 (KR-21). The reason or decision to use KR-21 for testing reliability of these tests (SSTADT & STOCAT) was that the multiple-choice objective questions were not of equal difficulty and were scored dichotomously (Cohen et al., 2013; Ajayi, 2016; 2019). Again, the reliability of the questionnaires were done using Cronbach alpha coefficient. The Cronbach Alpha was used for the questionnaires because the items were not dichotomously scored. In a similar study, Emaikwu (2013) stated that where two items are not dichotomously scored, the use of Cronbach Alpha becomes very appropriate, hence its usage for the questionnaires in this study. The respondents' responses to the interview schedules were transcribed, analysed and summarised based on the key themes. The reliability coefficient of the instruments are summarised in the Table 3.

**Table 3**: **The reliability coefficient indices of the instruments**

| No | Type of instrument | Reliability coefficient |
|---|---|---|
| 1). | **Tests** | |
| | a) Pre-intervention test (SSTADT) | 0.84 |
| | b) Post-intervention test (STOCAT) | 0.86 |
| 2). | **Questionnaire** | |
| | a) Organic Chemistry Difficult Questionnaire (STOCDQ) | 0.81 |
| | b) Attitude Scale Questionnaire (STASQ) | 0.82 |

Source: (Field work, 2022).

According to Borg, Gall and Gall (1993), the reliability coefficients values above 0.75 are considered reliable. Moreover, Maduabum (2011) also posited that the coefficients of 0.84 and 0.86 indicate that the instruments are reliable. Therefore, the above reliability values ranging from 0.81 to 0.86 gave indications that these three developed instruments were reliable and could be used for the study.

## 3.9 Data Collection Procedure

For effective data collection, permission was sought from the authorities of the College, Head of Science Education Department and the colleague chemistry tutors in the Department (with an introductory letter, Appendix G). In addition, the consent of the 40 research subjects used for the study was also sought. Upon series of engagements and meetings with the authorities, date and time were agreed upon to carry out the study. In all, ten weeks were used for the entire study; one week for pre-intervention stage activities, eight weeks for the intervention stage activities, whereas the last one week was for the post-intervention activities. Data collection was done in three stages namely pre-intervention, intervention and post-intervention stages; and these stages are described in sub-sections below.

### 3.10 Pre-Intervention Stage (Week One: 21st Feb-25th 2022)

The major pre-intervention activities involved in this study were extensive discussions with respect to the purpose of the study; administration of the organic chemistry difficult questionnaire, conduction of pre-interview sessions and conduction of pre-intervention test. These four activities under the pre-intervention stage have been described briefly below as follows:

***Day One Activities***:

On the day one of the first week, the researcher met the science student-teachers at the chemistry laboratory in the afternoon. They had an open and frank discussions with respect to the purpose of the study, the study timeline and benefit/significance of the study. Series of engagements in the form of discussions were also held with the participants. They were assured that there would be no risk involved in participating in the study; and that they had the right to withdraw from the study if they so wished. An informed consent form was given to them to read and fill them in my presence; after which the session was closed.

***Day Two Activities:***

On the second day of the first week, the researcher met the subjects at the chemistry laboratory in the morning. Upon series of engagements, the organic chemistry difficult questionnaire (STOCDQ) in Appendix A were given to them to fill in my presence. After the 60 minutes, the questionnaires (STOCDQ) were collected from the research subjects; after which the session was brought to a close.

***Day Three Activities:***

On the third day of the first week, the subjects were met at the laboratory in the morning. Upon series of engagements in a friendly manner, the Pre-interview schedule (SSTPIS) in Appendix B were given to them to read silently for about three minutes and answer them. The pen-paper interview session was done for questions 1 to 4 for 90 minutes. After the stipulated time, the subjects were met and one-and-one interview was conducted with question items (5a & b). After each session, the paper was collected from the student. A similar data collection was done by Uyulgan and Akkuzu (2016). In the afternoon, 60 minutes focus group interview was conducted on the causes of their difficulties in understanding organic chemistry. In order to delve deep into their responses, ten respondents were randomly selected and one-and-one interview was done for them on the causes of their difficulties in organic chemistry. The interview sessions were audio-taped and lasted between 5-10 minutes for each selected research subject.

***Day Four Activities:***

In order to determine each science student-teacher's performance prior to the start of the POE instructional approach intervention activities; a 90 minutes pre-intervention test (SSTADT) in Appendix C was conducted for all the participants at the college's examination centre. The test was done under strict but relaxed supervision. The respondents were to answer the 30 multiple-choice objective questions for 30 marks. After the 90 minutes, the test papers were collected, marked and scored. The marking scheme for this pre-intervention test could be found in Appendix I.

## 3.11 Intervention Stage (Eight weeks)

The intervention stage dealt with the implementation of "Predict-Observe-Explain instructional approach" (POEIA) activities for 2-hour periods per week for eight weeks duration. The POEIA intervention activities started from the second ($2^{nd}$) week to the ninth (9th) week (28th February to 22nd April, 2022). In all, eight POEIA organic chemistry lessons were taught for the eight weeks period. Each week was used to teach one of the selected organic chemistry topics based on POE instructional approach (POEIA) as follows:

Week Two Lesson: The alkanes.

Week Three Lesson: The alkenes.

Week Four Lesson: The alkynes.

Week Five Lesson: The alkanols (alcohols).

Week Six Lesson: The carbonyl compounds.

Week Seven Lesson: The alkanoic (carboxylic) acids.

Week Eight Lesson: The alkanoates (Esters).

Week Nine Lesson: The amines.

The POEIA intervention materials for each lesson consisted of POEIA based lesson plan, activity guide and worksheet. The POEIA lesson plan and worksheet were adapted from the works of researchers (Acar-Seşen & Mutlu 2016; Ajayi, 2019). In all eight POEIA lesson plans and their corresponding POE activity guides and worksheets were designed based on the selected organic chemistry topics and was taught for eight weeks. For each of the selected topics; the lesson plan, its activity guide and worksheet were prepared based on the POE instructional approach (see Appendices K1 to K8).

During each lesson, the science student-teachers were taught one organic chemistry topic using the POE instructional approach in line with lesson's plan procedure prepared by the researcher for each lesson. For example, the lesson plan in "Appendix K1", its activity guide 1 and worksheet 1 were used to teach the week two's lesson (the alkanes); "Appendix K2" for the alkenes, "Appendix K3" for the alkynes; "Appendix K4" for the alkanols,  etc in that order. For each lesson, the science student-teachers were put into groups of four; and were exposed to series of practical activities and some of these activities are shown in Figures 4, 5 and 6.

Figure 4: Subjects in group of four conducting preparation of ethyne gas

Figure 5: Subjects in group of four preparing an ester (ethylethanoate)

Figure 6: Subjects in group of four preparing alkanoic acid (ethanoic acid)

The science student-teachers in their respective groups actively participated in the POE instructional approach lessons. The implementation of the "Predict-Observe-Explain instructional approach intervention activities was done for eight weeks.

**Closure**: After taking science student-teachers through the POEIA intervention activities; a lot of exercises in the form of quiz, project-work, assignments, etc on the selected organic chemistry topics were given to them in groups and individuals to solve. Almost all of them were able to solve almost all the given questions correctly.

### 3.12 Post-Intervention Stage (Week Ten: 25th to 29th April, 2022)

The main post-intervention activities involved conduction of post-intervention test, administration of attitude scale questionnaire and conduction of post-interview session. These three activities under this stage have been described below as follows:

***Day One Activities***:

On the day one of the tenth week, the participants were met and discussions were held with them about the POEIA study. After, the series of discussions, a 90 minutes post-intervention test (STOCAT) in Appendix D was conducted for all them at the college's examination centre. They were to answer the 30 multiple-choice objective questions for 90 minutes. After the 90 minutes, the test papers were collected, marked, scored and compared with the pre-intervention test scores to see variations in their performance. The marking scheme for this test could be found in Appendix I.

***Day Two Activities:***

On the second day of the tenth week, the subjects were again met at the chemistry laboratory in the morning. Upon series of engagements, the Attitude Scale Questionnaire (STASQ) in Appendix E were given to them to fill in my presence. The supervision of the questionnaire administration was done in a relaxed manner. After the 50 minutes, the questionnaires were collected from them; after which the session was closed.

***Day Three Activities:***

In order to assess respondents' views regarding the POE instructional approach module used in the teaching and learning of the selected organic chemistry topics; a focus group interactive interview session was conducted for them. This interview session was done using the POEPIS in Appendix F. This interview session took place at the chemistry laboratory for two hours. The interview session was audio-taped; after which they were appreciated and the session was closed. The data collection procedure followed in this study have been pictorially presented and is shown as Figure 7.

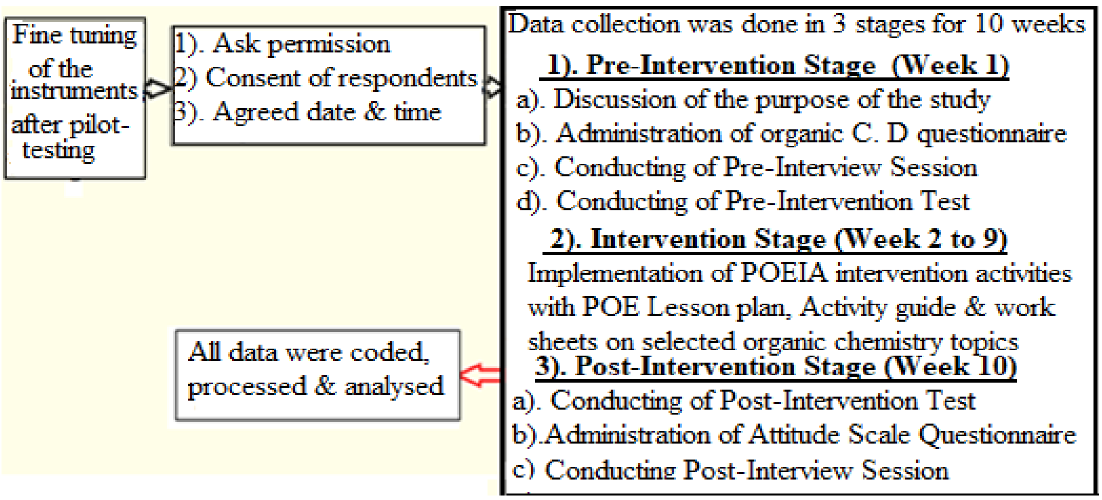



Figure 7: Flow chart of data collection procedure of this study

## 3.13 Data Analysis Methods

The study employed both quantitative and qualitative methods of data analysis. Data analysis from the pre-interview schedule (SSTPIS) was analysed in qualitative and quantitative manner whereas data obtained from the Post-interview schedule (POEPIS) were analysed qualitatively and presented into themes. Levels of conceptions in pre-interview schedule (SSTPIS) were evaluated using Piaget's conception coding scheme.

On the other hand, data obtained from the tests (pre-intervention test, SSTADT & post-intervention test, STOCAT) were analysed quantitatively using descriptive statistics namely frequency, percentage and inferential statistics (sample t-test). Again, science student-teachers' identified mistakes in their pre-interview schedule, tests and worksheets were reported as misconceptions in this study. Furthermore, data obtained from the questionnaires (STOCDQ & STASQ) were analysed quantitatively using descriptive statistics mainly frequency and percentages.

Statistical Package for Social Science (SPSS) version 21.0 for window was used for data analysis, and Microsoft excel program was used to present the data pictorially into Tables and charts (pie-charts and bar charts). The analysis of the results has been presented extensively in the next chapter, (Chapter Four).

## 3.14 Ethical Considerations

This study adhered strictly to ethical standards laid down by the School of Graduate Studies of the University of Education, Winneba as well as the ethical standards in research suggested by Creswell and Creswell (2017). These included informing the respondents about the purpose of the study, their voluntary participation and ensure their confidentiality.

Ethical considerations in a study process should be reflected on throughout each phase of the research process. Based on this, an introductory letter (Appendix G) was obtained from the lead supervisor to enable me use the said college for my study. Also, permission and approvals were sought from the college's authorities including the principal, his vice and the head of science education department. We had open and frank discussions regarding purpose of the study, study timeline and benefit of the study.

Again, the research subjects who met inclusion criteria were approached and informed of the study's purpose and the significance of the study. Series of engagements in the form of discussions were held with the participants. They were assured that there would be no risk involved in participating in the study. They were informed about the context of the study and how the results would be evaluated. An informed consent form was given to them to read and fill them with their detailed information.

Also, participants were assured of their confidentiality over the data that were collected and were informed that only the researcher and supervisor would have access to data collected. The participants were also assured that the completed instruments and consent forms would be kept under lock and key such that they cannot be traced by any other person. Also, pseudonyms and personal codes were assigned to participants in order to maintain their anonymity and also all COVID-19 protocols were duly observed.

To avoid coercion, research subjects were informed of their right to withdraw from the study, and assured them that such a decision would not affect their end-of-semester examinations scores. This means that they were free to choose whether to participate in the study or not (British Educational Research Association, 2011; as cited in Taber, 2014); thus, all the participants in the study participated voluntarily. Finally, the researcher had no conflict of interest to declare, hence there was no bias and the study was self-sponsored by the researcher.

# CHAPTER FOUR

## RESULTS AND DISCUSSION

### 4.0 Overview

This chapter focuses on the analysis of the results and discussion. The analysed data for the study were presented by the research questions. This was followed by the discussion of the results of the study.

### 4.1 Analysis of Aspects of the Data

Data was collected from 40 science student-teachers from a science-based COE, made up of 32 males (80.0%) and 8 females (20.0%). Data was collected using both qualitative and quantitative data collection instruments. Specifically, data were collected by means of three instruments namely interview (SSTPIS & POEPIS), tests (SSTADT & STOCAT), and questionnaires (STOCDQ & STASQ). These three different sets of instruments ensured triangulation of data. Data obtained from these three instruments were analysed using quantitative and qualitative methods of data analysis as follows:

1) Data obtained from question items (1 to 4) in the (SSTPIS) were analysed quantitatively and were used to answer research question 3 that guided the study.
2) Data obtained from question item (5) in the SSTPIS were analysed qualitatively and were used to answer research question 2 that guided the study.
3) Data obtained from the POEIA post-interview schedule (POEPIS) were analysed qualitatively and were used to answer research question 6 that guided the study.
4) Data obtained from the tests (SSTADT & STOCAT) were analysed quantitatively using descriptive and inferential statistics; and used to answer research question 4.
5) Data obtained from the Attitude Scale Questionnaire (STASQ) were analysed quantitatively and were used to answer research question 5 that guided this study.

6) Data from the STOCDQ were quantitatively and qualitatively analysed. Data from the question items 1, 2a, & 5(a-j) were analysed quantitatively. Data from question item 2b were analysed qualitatively. Question items 3(a-p) & 4(a-j) were analysed quantitatively using frequency, percentage and mean. For question items 3(a-p), the mean computation was done on the four point Likert scale type:- Not Difficult [ND]; Slightly Difficult [SD]; Difficult [D]; and Very Difficult [VD] and were coded as 1, 2, 3 and 4 respectively. The formula for the mean is as follows:

$$\bar{X} = \frac{\sum Fx}{N}$$

Where; $\sum$ = Summation; F = Frequency; x = Nominal value; N = Number of responses; $\bar{X}$ = Mean

$$\text{Mean } (\bar{X}) = \frac{4+3+2+1}{4} = \frac{10}{4} = 2.5$$

Since the four point Likert scale type was used for the instruments, the decision rule was based on the mean 2.5. Therefore, item with mean response of 2.5 and above was considered difficult (D) whereas item with mean response below 2.5 was also seen as not difficult (ND).

For question items 4(a-j), the mean computation was done on the two point Likert scale:- Not Difficult (ND) and Difficult (D) and were coded as 1 and 2 respectively. The formula for the mean is as follows.

$$\bar{X} = \frac{\sum Fx}{N}$$

Where; $\sum$ = Summation; F = Frequency; x = Nominal value; N = Number of responses; $\bar{X}$ = Mean

$$\text{Mean } (\bar{X}) = \frac{2+1}{2} = \frac{3}{2} = 1.5$$

Since the two point Likert type scale was used for the instruments, the decision rule was based on the mean 1.5. Therefore, item with mean response of 1.5 and above was considered difficult (D) whereas item with mean response below 1.5 was also seen as not difficult (ND).

These analyses were done and were used to answer the six research questions that guided this study as follows:

## 4.2 Presentation of the Results by Research Questions

### *4.2.1 Research Question 1: What difficulties do the COE science student-teachers encounter during the learning of the selected topics in organic chemistry?*

In answering research question 1, all the 40 COE science student-teachers' responses to question items 1, 2a, 2b, 3(a-p) & 4(a-j) of Section A in the STOCDQ in Appendix A were analysed using both quantitative and qualitative data analysis methods and are presented in chronological order as follows:-

For question item (1), all the 40 science student-teachers were asked to respond to a closed-ended question:- "*Have you ever studied organic chemistry before?*" *"Yes or No"*. Their responses to question item (1) in the STOCDQ in Appendix A were analysed quantitatively using frequency and percentages and are presented in Table 4.

**Table 4: Respondents' responses on ever studied organic chemistry before**

| No | Question item | Yes | No | Total (%) |
|---|---|---|---|---|
| | | F (%) | F (%) | |
| 1) | Have you ever studied organic chemistry before? | 40 (100) | 0 (0.0) | 40 (100) |

Source: (Student-teachers' organic chemistry difficult questionnaire (STOCDQ), 2022)

Data in Table 4 shows that all the 40 (100%) COE science student-teachers responded "Yes". This means that all the respondents who participated in this study have learned organic chemistry before, and that they are expected to have fore knowledge or better understanding of the topics understudy. Thus, they are expected to perform well and also have positive attitudes towards the selected organic chemistry topics.

Again, for question item (2a) in the STOCDQ in Appendix A, all the respondents were asked to respond to a closed-ended question "*Do you think organic chemistry is difficult for you to learn as a student-teacher*? *"Yes or No"*. The respondents' responses to question (2a) were analysed quantitatively and are presented in Table 5.

**Table 5: Student-teachers responses to organic chemistry difficult to learn**

| No | Question item | Yes | | No | | Total (%) |
|---|---|---|---|---|---|---|
| | | F | (%) | F | (%) | |
| 2a) | Do you think organic chemistry is difficult for you to learn as a student? | 38 | (95.0) | 2 | (5.0) | 40 (100) |

Source: (Student-teachers' organic chemistry difficult questionnaire (STOCDQ), 2022)

Data in Table 5 shows that as many as 38 respondents representing 95.0% responded "Yes" whereas only two (2) of them representing 5.0% responded "No". This means that almost all the respondents who took part in this study perceived (thought or believed) that organic chemistry was a difficult subject for them to learn or understand.

For question item (2b) in the STOCDQ in Appendix A, the respondents were asked to list the top five most difficult organic chemistry topics they have encountered. The top five most difficult topics for participants in terms of their numbers (frequency) and the percentages were benzene 38(95.0%), amines 36(87.5%), carbonyl compounds 35(87.5%), polymers and polymerization 34 (85%), and separation and purification of organic compounds 31(77.5%). This means that majority of the respondents (more than half) perceived benzene, amines, carbonyl compounds, polymers and polymerization, and separation and purification of organic compounds as the five topmost difficult topics they have encountered ever since they started learning organic chemistry.

Moreover, to assess the topics in the COE level 200 organic chemistry curriculum that they perceived or viewed to be difficult to learn at the college level, the respondents' responses to question items (3a-p) in the STOCDQ in Appendix A were analysed quantitatively using descriptive statistics and are presented in Table 6.

**Table 6: Mean scores of respondents' views on difficult topics to learn**

| No | Topics in organic chemistry syllabus/curriculum | ND | SD | D | VD | N | Mean (x) | Remark |
|---|---|---|---|---|---|---|---|---|
| a | Introduction to organic chemistry | 32 | 5 | 2 | 1 | 40 | 1.3 | ND |
| b | Bonding and type of hybridization in carbon | 6 | 31 | 1 | 2 | 40 | 1.9 | ND |
| c | Qualitative elemental analysis | 29 | 6 | 3 | 2 | 40 | 1.5 | ND |
| d | Quantitative elemental analysis | 4 | 33 | 2 | 1 | 40 | 2.0 | ND |
| e | Alkanes | 7 | 16 | 12 | 5 | 40 | 2.4 | ND |
| f | Alkenes | 4 | 15 | 14 | 7 | 40 | 2.7 | D |
| g | Alkynes | 2 | 11 | 19 | 8 | 40 | 2.8 | D |
| h | Alkanols (Alcohols) | 3 | 16 | 13 | 8 | 40 | 2.5 | D |
| i | Aldehydes | 3 | 10 | 19 | 7 | 40 | 2.7 | D |
| j | Ketones | 2 | 3 | 29 | 6 | 40 | 2.9 | D |
| k | Alkanoic (Carboxylic) acids | 5 | 16 | 12 | 7 | 40 | 2.5 | D |
| l | Alkanoates (Esters) | 3 | 13 | 16 | 8 | 40 | 2.7 | D |
| m | Acid anhydrides | 4 | 15 | 13 | 8 | 40 | 2.6 | D |
| n | Acid halides | 6 | 17 | 12 | 5 | 40 | 2.2 | ND |
| o | Acid amides | 8 | 16 | 12 | 4 | 40 | 2.3 | ND |
| p | Amines | 3 | 11 | 17 | 9 | 40 | 2.8 | D |

Source: (Student-teachers' organic chemistry difficult questionnaire (STOCDQ), 2022)

Data in Table 6 shows that the mean scores of the topics range from 1.3 to 2.9 respectively. Data in Table 6 shows that nine topics had mean scores of 2.5 and above whereas seven of the topics had mean scores of less than 2.5. This means that the respondents viewed nine topics in their organic chemistry curriculum to be difficult, whiles seven of the topics were not difficult. The nine topics identified by the respondents as difficult to learn were alkenes, alkynes, alkanols, aldehydes, ketones, alkanoic acids, alkanoates, acid anhydrides and amines. Also, the seven topics identified by the same research subjects as not difficult in this study were introduction to organic chemistry, bonding and type of hybridization in carbon, qualitative elemental analysis, quantitative elemental analysis, alkanes, acid halides and acid amides. Ketones had the highest mean score of 2.9, alkanols and alkanoic acids had the average or best mean score of 2.5 each, whereas the introduction to organic chemistry had the lowest mean score of 1.3. This means that the most difficult topic for the research subjects was ketones (alkanones), and the less (not) difficult topic was introduction to organic chemistry.

Again, in order to assess the various aspects in the organic chemistry curriculum that respondents view as difficult to learn at the college level, their responses to question items (4a-j) of Section A in the STOCDQ in Appendix A were analysed using frequency, percentage and mean and are presented in Table 7.

**Table 7: Mean scores of subjects' views on difficult aspects of organic chemistry**

| No | Aspects of organic chemistry curriculum | Not Difficult F (%) | Difficult F (%) | N | Mean (X) | Remarks |
|---|---|---|---|---|---|---|
| a) | IUPAC nomenclature | 9 ( 22.5) | 31 (77.5) | 40 | 1.7 | Difficult |
| b) | Drawing of structures | 26 ( 65.0) | 14 (35.0) | 40 | 1.3 | Not Difficult |
| c) | Isomerism | 17 (42.5 ) | 23 (57.5) | 40 | 1.5 | Difficult |
| d) | Organic reactions | 7 (17.5 ) | 33 (82.5) | 40 | 1.8 | Difficult |
| e) | Structure and properties of organic compounds | 28 (70.0) | 12 (30.0) | 40 | 1.3 | Not Difficult |
| f) | Organic synthesis | 2 (5.0) | 38 (95.0) | 40 | 2.0 | Difficult |
| g) | Functional group identification | 24 (60.0) | 16 (40.0) | 40 | 1.4 | Not Difficult |
| h) | Organic reaction mechanisms | 6 (15.0) | 34 (85.0) | 40 | 1.9 | Difficult |
| i) | Classification of organic compounds | 23 (57.5) | 17 (42.5) | 40 | 1.4 | Not Difficult |
| j) | Preparation of organic compounds | 13 (32.5) | 27 (67.5) | 40 | 1.6 | Difficult |

Source: (Student-teachers' organic chemistry difficult questionnaire (STOCDQ), 2022)

The data in Table 7 shows that the mean scores of the difficult aspects in the organic chemistry curriculum range from 1.3 to 2.0. Data in Table 7 shows clearly that more than half; 20(50%) of the respondents perceived IUPAC nomenclature, isomerism, organic reactions, organic synthesis, organic reaction mechanisms and preparation of organic compounds as the most difficult aspects to learn in their organic chemistry. The most difficult aspect was organic synthesis (2.0 as mean score); isomerism as average (with 1.5 as mean score) whereas structure and properties of organic compounds (with 1.3 as lowest mean score) was not difficult aspect in their organic chemistry curriculum.

The views expressed by the respondents in Table 7 are compared using percentages and are presented pictorially in a bar-chart as shown in Figure 8.

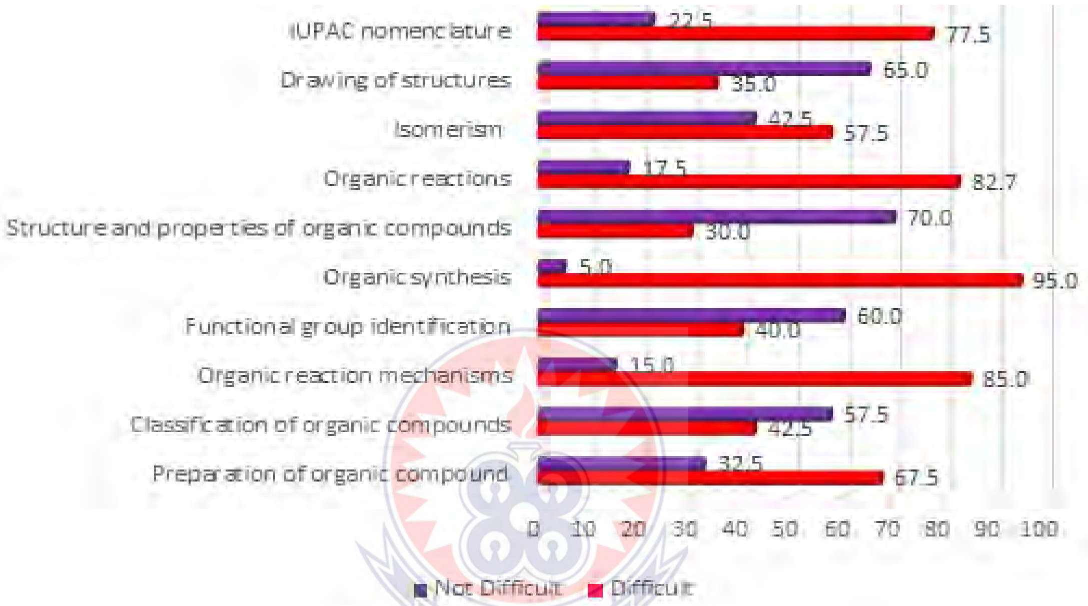



Figure 8: Distribution of subjects' responses on difficult and not-difficult item

Examination of Figure 8 shows that more than half, 20 (50%) of the science student-teachers who took part in this study indicated that IUPAC nomenclature, isomerism, organic reactions, organic synthesis, organic reaction mechanisms and preparation of organic compounds are the six most difficult aspects to learn in their organic chemistry curriculum. The order of difficulty of these six aspects from the highest to the lowest with their percentages are organic synthesis (95.0%), organic reaction mechanisms (85.0%), organic reactions (82.7%), IUPAC nomenclature (77.5%), preparation of organic compounds (67.5) and isomerism (57.5%). Based on data in Figure 8, organic synthesis (95.0%) was identified as the most difficult aspect to learn in their curriculum whiles structure and properties of organic compounds (30.0%) was the not difficult aspects in their curriculum. Majority of them also indicated that structure and properties of organic compounds (70.0%); drawing of structures (65.0%); functional group identification (60.0%) and classification of organic compounds (57.5%) were the four not difficult aspects to learn in their organic chemistry curriculum.

Responses in Tables 4, 5, 6 and 7 and Figure 8 show that science student-teachers in this study encountered learning difficulties in the selected organic chemistry topics.

#### *4.2.2 Research Question 2: What are the possible causes of the COE science student-teachers' conceptual difficulties in learning the selected topics in organic chemistry?*

In answering research question 2, all the 40 research subjects' responses to questions (5a-j) of Section B in the STOCDQ in Appendix A on the possible causes of science student-teachers' conceptual difficulties in learning the selected topics in organic chemistry were analysed quantitatively and are presented in Table 8.

**Table 8: Causes of subjects' conceptual difficulties in learning organic chemistry**

| No | Items on causes of STs' conceptual difficulties in selected organic chemistry topics | Yes (%) | No (%) | Total (%) |
|---|---|---|---|---|
| a) | Organic chemistry syllabus is too broad | 40 (100) | 0 (0.0) | 40 (100) |
| b) | Inadequate time allocated for organic chemistry lessons. | 32 (80.0) | 8 (20.0) | 40 (100) |
| c) | Difficulty in understanding various abstract organic chemistry concepts. | 31 (77.5) | 9 (22.5) | 40 (100) |
| d) | Ineffective teaching methods used by teachers | 29 (72.5) | 11(27.5) | 40(100) |
| e) | Poor attitudes of student-teachers towards organic chemistry. | 27 (67.5) | 13(32.5) | 40(100) |
| f) | Lack of teaching and learning materials (TLMs:- e.g., models, ICT software, etc.) | 38 (95.0) | 2 (5.0) | 40(100) |
| g) | Presence of student-teachers misconceptions | 24 (60.0) | 16(40.0) | 40(100) |
| h) | Inadequate/lack of laboratory practical activities during organic chemistry lessons | 36 (90.0) | 4 (10.0) | 40(100) |
| i) | Inadequate explanations from chemistry tutors | 15 (37.5) | 25 (62.5) | 40(100) |
| j) | Lack of remedial actions by COE tutors for student-teachers due to work overload. | 40 (100) | 0 (0.0) | 40 (100) |

Source: (Student-teachers' organic chemistry difficult questionnaire (STOCDQ), 2022)

Data in Table 8 shows that there are several possible causes of science student-teachers' conceptual difficulties in learning the selected organic chemistry topics. For example, all the 40 (100%) participants unanimously agreed that lack of remedial actions by COE tutors for them due to work overload; and the organic chemistry syllabus was too broad were the two major causes of subjects' conceptual difficulties in learning the selected organic chemistry topics. This means that lack of remedial actions by COE tutors for student-teachers due to work overload; and organic chemistry syllabus was too broad were the two major causes of the subjects' learning difficulties organic chemistry.

Again, as many as 38(95.0%) also indicated that lack of teaching and learning materials (TLMs:- e.g., models, ICT software, etc.) was the possible cause of science student-teachers' conceptual difficulties in learning the selected topics in organic chemistry whiles only two (2) of them representing 5.0% disagreed. This implies that lack of TLMs was another major cause of respondents' conceptual difficulties in learning the selected topics in organic chemistry. Also, majority of them (36 out of 40) representing 90.0% agreed that inadequate/lack of laboratory practical activities during organic chemistry lessons was a possible cause of their conceptual difficulties, whiles 4 (10.0%) disagreed to the same statement. This means that inadequate/lack of laboratory practical activities during organic chemistry lessons was another factor that cause conceptual difficulties of subjects in learning the selected organic chemistry topics.

Again, when asked whether the inadequate time allocated for organic chemistry lessons was a possible cause of their conceptual difficulties in learning organic chemistry, as many as 32 (80.0% ) of the respondents responded " Yes" with a handful of 8 (20.0% ) also responded " No" to the same item. This response means that inadequate time allocated for organic chemistry lessons was a possible cause of subjects' conceptual difficulties in learning selected topics in organic chemistry.

Moreover, majority of the respondents (31 out of 40) representing 77.5% agreed that difficulty in understanding various abstract organic chemistry concepts was the possible cause whiles only nine (9) of them representing 22.5% disagreed to the item. This means that difficulty in understanding various abstract organic chemistry concepts was a major cause of subjects' conceptual difficulties in learning organic chemistry.

When asked whether ineffective teaching methods used by teachers was a possible cause of respondents' conceptual difficulties in learning the selected topics in organic chemistry, as many as 29 of them representing 72.5% indicated "Yes" whiles a handful of 11 respondents representing 27.5% also indicated "No" for same item. This implies that ineffective teaching methods used by teachers was a possible cause of respondents' conceptual difficulties in learning selected topics in organic chemistry.

When asked if poor attitudes of student-teachers towards organic chemistry was one of the possible causes of respondents' difficulties in learning organic chemistry, as many as 27 respondents representing 67.5% responded "Yes" whereas 13 of the same respondents representing 32.5% also responded "No". This means that poor attitudes of research subjects towards organic chemistry was one of the causes of their conceptual difficulties in learning the selected organic chemistry topics.

Also, as many as 24 (60.0%) respondents responded "Yes" for presence of student-teachers misconceptions whiles 16(40.0%) of them responded "No" for the same item. This means that presence of student-teachers misconceptions was one of the causes of their conceptual difficulties.

Moreover, other possible causes of science student-teachers' conceptual difficulties in learning the selected topics in organic chemistry (stated as question item 5b) in the SSTPIS in Appendix B mentioned by the respondents included lack of interests in organic chemistry, poor attitudes of tutors towards the teaching of organic chemistry, difficult language often use by tutors in teaching organic chemistry, improper exposure to organic chemistry laboratory activities, lack of motivation, lack of required textbooks, presence of COE tutors' misconceptions, science student-teachers fear of organic chemistry, chemistry tutors' lack of conceptual understanding in some aspects of organic chemistry and inadequate exposure to problem solving procedures in organic chemistry.

Also, during the focus group interview the respondents' responses on the causes advanced for their difficulties in organic chemistry were analysed qualitatively and presented under four thematic areas as follows:

**1) Broad or bulky nature of the organic chemistry concepts**

Majority of the respondents indicated that the organic chemistry concepts were too wide or broad in nature. They stated that the organic chemistry curriculum had several topics and each topic also had numerous sub-topics. These several topics and their sub-topics made it very difficult to comprehend when studying them. Responses from two of the respondents are illustrated below.

> *"Organic chemistry topics are lengthy and so before I reach the end of all the topics, I will forget what I learnt previously" (SST 4).*

> *"Organic chemistry curriculum are too broad and also has many sub-topics that are related. By the time you study one topic and move to another topic you become confused and don't know what to do. I wish it is not part of my course of study. (SST 13).*

**2) Abstract and difficult nature of the organic chemistry topics**

Another common reason advanced by the respondents were that the topics in organic chemistry were too abstract in nature and that they were difficult to understand. Almost all of them indicated that the nature of the topics and various aspects of organic chemistry such as organic synthesis, reaction mechanisms and IUPAC nomenclature were too abstract and difficult to comprehend. One male science student-teacher said:

*"I don't want to remember the time I took courses in organic chemistry. For me, it was very difficult and too abstract to comprehend. I tried to study hard, but when I came back to solve organic chemistry exercises, really it was a very big challenge. All the efforts I put in the study became nothing. Wow...I don't want to remember it" (SST 29).*

**3). Poor foundation in organic chemistry**

Analysis of the respondents' responses also revealed that most of them were of the view that they had poor foundation in organic chemistry at their previous educational levels. Most of them indicated that they had poor foundation at the senior high school level. Responses from two of the respondents are illustrated below.

*"I didn't get the foundation well at the senior high school level. Right from the beginning because of rumours I had in mind that organic chemistry is difficult; so I have negative attitude towards organic chemistry" (SST 12).*

*"Organic chemistry is always the last topic to be treated at the senior high school level and with this I am unable to get the concept very well since the one who teaches it teach it in hurry to finish" (SST 33).*

**4) Ineffective method used by teachers in teaching organic chemistry**

Most of the respondents indicated that the ineffective or poor teaching methods used by chemistry teachers in teaching organic chemistry concepts to them. Some of them expressed their sentiments that the methods teachers used in teaching them were not attractive and appealing enough to address their difficulties. Typical responses from some of respondents are illustrated below.

*"Organic chemistry is taught in a theory-based fashion rather than practical, understanding organic chemistry becomes difficult if you do not do any practical work" (SST 5).*

*"Organic chemistry teachers teach the organic chemistry using theoretical or lecture methods without any practical activities. They*

*don't even use any teaching and learning resources and this makes the understanding of the organic chemistry very difficult" (SST 40).*

In order to delve deep into their responses on possible causes of their difficulties in organic chemistry, ten of the respondents were randomly selected and one-on-one interactive interview session was conducted for them (as part of day three pre-intervention stage activities). The R and SST stand for researcher and science student-teacher respectively. The interviewed responses from these selected research subjects have been presented verbatim below as follows:

*Researcher (R): What do you think is/are the possible cause(s) of your conceptual difficulties in learning or understanding organic chemistry concepts?*

*SST 1: Sir, in fact the organic chemistry syllabus is too wide. There are several topics and sub-topics in it and we have to learn all of them within the shortest possible time. In most times we do not properly cover the topics in the syllabus and that the topics are too many and confusing too. I wish it is not part of my chemistry course.*

*SST 2: The time or period allocated for the organic chemistry lessons is not enough. We have only 2 hours for theory lessons and 3 hours for the practical lessons each per week. Since the time period allotted for the course is too small and the intended topics to be covered are too much; most often we do not complete the topics.*

*SST 3: Lack of remedial actions by our tutors for "we the slow learners". During chemistry lessons, teaching is often done at a faster pace and also dominated by few fast students leaving those of us slow and middle learners aside; making things very difficult for us in classroom. I wish to plead with chemistry tutors in this college to organize remedial classes for those of us who are "slow learners".*

*SST 4: Lack of good and proper foundation in organic chemistry at the senior high school level. Sir, some of us did not do organic chemistry at all at the SHS level. My elective chemistry teacher did not teach me anything* *"organic" at that level. He said WAEC people often set few questions on them so we should not force ourselves. The little you learn is enough.*

*SST 5: Inadequate explanations from my COE chemistry tutors. Chemistry is a difficult subject which requires specific explanations about concepts, facts, laws and rules. Some teachers usually spend most of their chemistry periods telling stories, showing videos and giving advice to instead of teaching these concepts. How can we learn organic chemistry in the form of video shows without proper explanations?*

*SST 6: Back at the SHS, we lacked chemistry teachers who could teach proper organic chemistry to our understanding. The whole school we had three teachers teaching the subject. They can only teach you during extra classes hours.*

*SST 7: The nature of the chemistry as a subject requires that teachers who teach it motivate 'we' the students to learn. This is not the case with our teachers. They teach it any how; they start with one topic they will no finish and new topic will be introduced.*

*SST 8: I don't actually like organic chemistry at all. Because of the many scare IUPAC nomenclatures, chemical substances, equations and big terminologies I have to learn. However, in this case I have to learn it by-force to pass my exams and forget.*

*SST 9: Poor method of teaching organic chemistry at SHS and even at this level. Most chemistry teachers just read and dictate notes on organic chemistry directly to us from textbooks without proper explanations and activities.*

*SST 10: I have poor foundation in organic chemistry right from my senior high school. At that place we were having only three chemistry teachers and they teach organic at the latter part of form 3, when we are about to write your final exams.*

All these responses from the respondents in this study shows that there are several factors that cause science student-teachers' conceptual difficulties in learning organic chemistry concepts in schools especially at the college of education level.

### *4.2.3 Research Question 3: What conceptions do the science student-teachers possess about the selected organic chemistry topics?*

In answering research question 3, the entire 40 science student-teachers' answers to question items 1(a-j), 2(a & b), 3(a-j), 4(a-c) and (5a) of Section B in science student-teachers' pre-interview schedule (SSTPIS) in Appendix B were analysed quantitatively using descriptive statistics mainly frequency and percentage and are presented in chronological or orderly manner as follows:

For question items 1(a-j), respondents were asked to provide correct IUPAC nomenclature for ten different organic compounds. The respondents' answers were analysed using descriptive statistics mainly frequency and percentages, categorised into three as Correct Answer, C.A; Incorrect Answer, I.A; and No Answer, N.A and are presented in Figure 9.

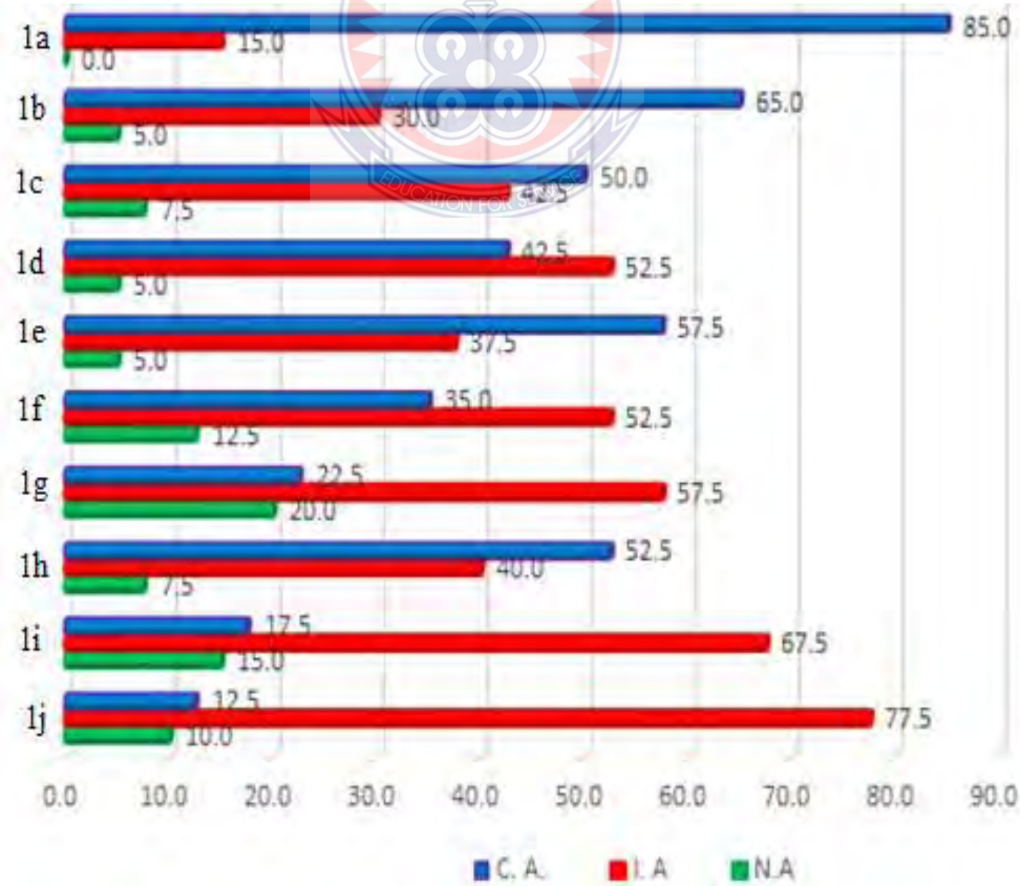



Figure 9: Frequency distribution of respondents' answers on IUPAC nomenclature

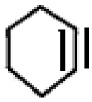
Data in Figure 9 shows clearly that science student-teachers' performance or ability to write correct IUPAC nomenclature for the ten given organic compounds was average. From Figure 9, the participants' performance or ability to write correct IUPAC nomenclature for organic compounds (1a), (1b), (1c), (1e) and (1h) was very good. This is because majority (50% or more) of the participants were able to write the correct IUPAC names for (1a) - alkane without a substituent (85.0%), (1b) - alkane molecule with substituents (65.0%), (1c)-alkene (50.0%), (1e)- alkanol (57.5%), and (1h)- alkanoic (carboxylic) acid (52.5%). This result means that majority of these participants had better conceptual understanding with respect to correct IUPAC nomenclature for five out of the ten given organic compounds.

However, the same participants' performance in correct IUPAC nomenclature for organic compounds (1d), (1f), (1g), (1i) and (1j) was quite poor or not good, with (1j) being the poorest. This is because less than half (50.0%) of these participants gave correct IUPAC nomenclature for these groups of organic compounds. This result invariably means that majority (more than 50.0%) of the participants were not able to write the correct IUPAC nomenclature for these organic compounds (1d)-alkyne molecule with organic substituents (52.5%), (1f)-cycloalkyne (52.5%), (1g)-alkanal or aldehyde (57.5%), (1i)-alkanones or ketone (67.5%), and (1j)- amine (77.5%). From the Figure 9, the compound with the highest correct IUPAC name was (1a) - alkane without a substituent whereas the compound with lowest correct IUPAC name was (1j)- an amine.

The participants' responses in Figure 9 were then categorised into sound understanding, SU; partial understanding, PU; specific misconception, SM; no understanding, NU; and no response, NR in order to assess their conceptual understanding levels on correct IUPAC names for the ten given organic compounds. The frequency and percentage for "correct answer, C.A" was shown as sound understanding

SU, whereas frequency and percentage for “no answer “was shown as “no response NR”. However, the frequency and percentage for “incorrect answers, I.A” were further grouped into three categories as partial understanding, PU; specific misconception, SM; and no understanding, NU. These five categorisation of the participants’ responses in Figure 9 were analysed using descriptive statistics and are presented in Table 9.

**Table 9: Respondents’ understanding levels on correct IUPAC nomenclature**

| No | Given Compound | SU | PU | SM | NU | NR |
|---|---|---|---|---|---|---|
| | | F (%) | F (%) | F (%) | F (%) | F (%) |
| 1a) | $CH_3CH_2CH_2CH_2CH_3$ | 34 (85.0) | 2 (5.0) | 3 (7.5) | 1(2.5 ) | 0 (0.0) |
| 1b) | $CH_3CH_2C(Cl)_2CH_2(C_2H_5)$ | 26 (65.0) | 4(10.0 ) | 5 (12.5) | 3 (7.5 ) | 2 (5.0) |
| 1c) | $(CH_3)_2CHCH_2CH{=}C(Cl)CH_3$ | 20 (50.0) | 9 (22.5) | 6 (15.0) | 2 (5.0 ) | 3 (7.5) |
| 1d) | $CH_3CH_2C(CH_3)_2C{\equiv}CH$ | 17 (42.5) | 7 (17.5) | 13(32.5) | 1 (2.5 ) | 2 (5.0) |
| 1e) | $CH_3CH_2CH(OH)CH_3$ | 23 (57.5) | 8 (20.0) | 5 (12.5) | 2 ( 5.0 ) | 2 (5.0) |
| 1f) |  | 14 (35.0) | 11 (27.5) | 6 (15.0) | 4(10.0) | 5 (12.5) |
| 1g) | $CH_3CHO$ | 9 (22.5) | 6 (15.0) | 12 (30.0) | 5 (12.5) | 8 (20.0) |
| 1h) | $C_2H_5COOH$ | 21 (52.5) | 7 (17.5) | 6 (15.0) | 3 (7.5) | 3 (7.5) |
| 1i) | $CH_3COCH_2CH_3$ | 7 (17.5) | 8 (20.0 ) | 13(32.5) | 6 (15.0) | 6 (15.0) |
| 1j) | $CH_3NH_2$ | 5 (12.5) | 10 (25.0) | 19 (47.5) | 2 (5.0) | 4 (10.0) |

Source: (Science Student-Teachers’ Pre-Interview Schedule (SSTPIS), 2022)

Data in Table 9 shows that the respondents who took part in this study had varied levels of conceptual understanding ranging from sound understanding through specific misconception to no response with respect to IUPAC nomenclature for the different organic compounds. Generally, data in Table 9 shows clearly that respondents had sound conceptual understanding levels on correct IUPAC nomenclature for organic compounds (1a), (1b), (1c), (1e), and (1h). The frequency and percentage for the correct IUPAC nomenclature for these five organic compounds are (1a. $F_{SU}$: 34, 85.0%), (1b. $F_{SU}$: 26, 65.0%), (1c. $F_{SU}$: 20, 50.0%), (1e. $F_{SU}$: 23, 57.5%) and (1h. $F_{SU}$: 21, 52.5%). This result means that organic compound (1a) had the most sound understanding level regarding correct IUPAC nomenclature. However, the respondents had the most difficult understanding level regarding the correct IUPAC nomenclature for (1j. $F_{SU}$: 5, 12.5%).

Items (1a) and (1b) were used to measure respondents' conceptual understanding levels or conceptual difficulties regarding correct IUPAC nomenclature for alkanes. For item (1a), 34 (85.0%) of respondents showed sound understanding. About 2(5.0%) of them showed partial understanding, 3(7.5%) subjects showed specific misconception, 1(2.5%) subject showed no understanding, whereas no response had 0(0%). This means that majority (34, 85.0%) of them gave correct IUPAC name for organic compound (1a), alkane without a substituent. With regards to item (1b), 26 (65.0%) of respondents showed sound understanding. About 4(10.0%) of them showed partial understanding, 5(12.5%) subjects gave specific misconception, 3(7.5%) of them showed no understanding whereas 2(5.0%) of them showed no response. This results means that quite a significant number 26(65.0%) of them gave correct IUPAC name for compound (1b), alkane molecule with substituents. Comparing the research subjects' understanding levels for items (1a) and (1b), majority of them had difficulties in naming (1b)-alkane with substituents than in naming (1a)-alkane without a substituent.

Again, items (1d) and (1f) were used to assess the respondents' conceptual understanding levels for IUPAC nomenclature for alkyne compounds. For item (1d), 17 (42.5%) of respondents showed sound understanding. About 7(17.5%) of them showed partial understanding, 13(32.5%) subjects showed specific misconception, 1(2.5%) subject gave no understanding and 2 (5.0%) of them showed no response. With regards to item (1f), 14 (35.0%) of them showed sound understanding. About 11(27.5%) of them showed partial understanding, 6 (15.0%) of them showed specific misconception, 4 (10.0%) respondents showed no understanding and 5(12.5%) of them also showed no response. Comparing the respondents' conceptual understanding levels for items (1d) and (1f), quite a significant number of them had conceptual difficulties in naming (1f) cycloalkyne than that of (1d) aliphatic alkyne. This result means that giving the correct names for cycloalkynes tended to be difficult for the participants than giving the correct names for straight chain (aliphatic) alkynes.

Additionally, the data in Table 9 shows that majority (50.0% or more) of the respondents had conceptual difficulties with respect to IUPAC nomenclature for five other organic compounds (1d), (1f), (1g), (1i) and (1j); with compound (1j) being the most difficult. This result indicated that the respondents had highest sound conceptual understanding level for compound (1a. Fsu: 34, 85.0%) and demonstrated lowest conceptual understanding level for compound (1j. $F_{SU}$: 5, 2.5%).

Moreover, analysis of data in Figure 9 and Table 9 show that majority of the respondents gave incorrect answers regarding correct IUPAC nomenclature for these five organic compounds (1d), (1f), (1g), (1i), and (1j) and had misconceptions on them. The respondents' wrong names for these five organic compounds identified in this study as misconceptions were analysed and are presented in Tables 10a to 10e.

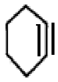
The 21 respondents' incorrect answers regarded as misconceptions for the IUPAC nomenclature of (1d), $CH_3CH_2C(CH_3)_2C{\equiv}CH$ are shown in Table 10a.

**Table 10a: Wrong names of (1d) $CH_3CH_2C(CH_3)_2C{\equiv}CH$ given by 21 respondents**

| No | Wrong names given by some student-teachers | Frequency | Percentage |
|---|---|---|---|
| 1). | 3, 3-methylpent-1-yne | 11 | 52.3 |
| 2). | 3, 3-dimethylpentyne | 4 | 19.0 |
| 3). | 3, 3-ethylpentyne | 3 | 14.3 |
| 4). | 3, 3-dimethyl-2-pentyne | 2 | 9.6 |
| 5). | 3-methylpentyne | 1 | 4.8 |
| | **Total** | **21** | **100** |

Source: (Field work, 2022). Correct name is 3, 3-dimethylpent-1-yne

Again, the 21 respondents' incorrect answers regarded as misconceptions for the IUPAC nomenclature of (1f),  are shown in Table 10b.

**Table 10b: Wrong names of (1f)**  **given by 21 science student-teachers**

| No | Wrong names given by some student-teachers | Frequency | Percentage |
|---|---|---|---|
| 1). | Benzene | 8 | 38.1 |
| 2). | 2-cycloalkyne | 5 | 23.6 |
| 3). | 2-cyclohexyne | 3 | 14.3 |
| 4). | Cyclohexane | 2 | 9.6 |
| 5). | Hexaphenyl | 1 | 4.8 |
| 6). | Cyclohexen | 1 | 4.8 |
| 7). | 6-cyclohexyne | 1 | 4.8 |
| | **Total** | **21** | **100** |

Source: (Field work, 2022). Correct name is cyclohexyne.

Also, the 23 respondents' incorrect answers regarded as misconceptions for the IUPAC nomenclature of (1g), $CH_3CHO$ are shown in Table 10c.

**Table 10c: Wrong names of (1g) $CH_3CHO$ given by 23 research subjects**

| No | Wrong names given by some student-teachers | Frequency | Percentage |
|---|---|---|---|
| 1). | Methanal | 7 | 30.4 |
| 2). | Ethanoate | 5 | 21.8 |
| 3). | Butanoic acid | 4 | 17.4 |
| 4). | 1-oxoethane | 3 | 13.0 |
| 5). | Acetaldehyde | 2 | 8.7 |
| 6). | 1-hydroxideethyne | 2 | 8.7 |
| | **Total** | **23** | **100** |

Source: (Field work, 2022). Correct name is ethanal

Moreover, the 27 respondents' incorrect answers regarded as misconceptions for the IUPAC nomenclature of (1i), $CH_3COCH_2CH_3$ are shown in Table 10d.

**Table 10d: Wrong names of (1i) $CH_3COCH_2CH_3$ given by 27 research subjects**

| No | Wrong names given by some student-teachers | Frequency | Percentage |
|---|---|---|---|
| 1). | Methyl propanone | 13 | 48.2 |
| 2). | Ethyl ethanoate | 6 | 22.2 |
| 3). | Propanal | 4 | 14.8 |
| 4). | Ethyl methanoate | 3 | 11.1 |
| 5). | 3-propanol | 1 | 3.7 |
| | **Total** | **27** | **100** |

Source: (Field work, 2022). Correct name is butanone.

Finally, the 31 research subjects' incorrect answers regarded as misconceptions for the IUPAC nomenclature of (1j), $CH_3NH_2$ are shown in Table 10e.

**Table 10e: Wrong names of (1j) $CH_3NH_2$ given by 31 student-teachers**

| No | Wrong names given by some student-teachers | Frequency | Percentages |
|---|---|---|---|
| 1). | Methyl amino acid | 15 | 48.5 |
| 2). | Methane amine | 7 | 22.6 |
| 3). | Methyl methanamide | 4 | 12.9 |
| 4). | Methyl ammonia | 3 | 9.6 |
| 5). | Butamide | 2 | 6.4 |
| | **Total** | **31** | **100** |

Source: (Field work, 2022). Correct name is aminomethane.

The responses in Tables 10a, 10b, 10c, 10d and 10e showed that science student-teachers who took part in this study had low level of conceptual understanding for IUPAC names with regards to (1d) aliphatic alkyne, (1f) cycloalkyne, (1g) aldehyde, (1i) ketone and (1j) amine and that they possessed several misconceptions on them.

For question item (2) in Section B of the SSTPIS in Appendix B, the entire 40 respondents were asked to draw to illustrate the correct reaction mechanisms for two organic reactions (2a & 2b). The respondents' answers were analysed using frequency and percentage. These were categorised into three as Correct Answer, C.A; Incorrect Answer, I.A; and No Answer, N.A and are presented in Figure 10.

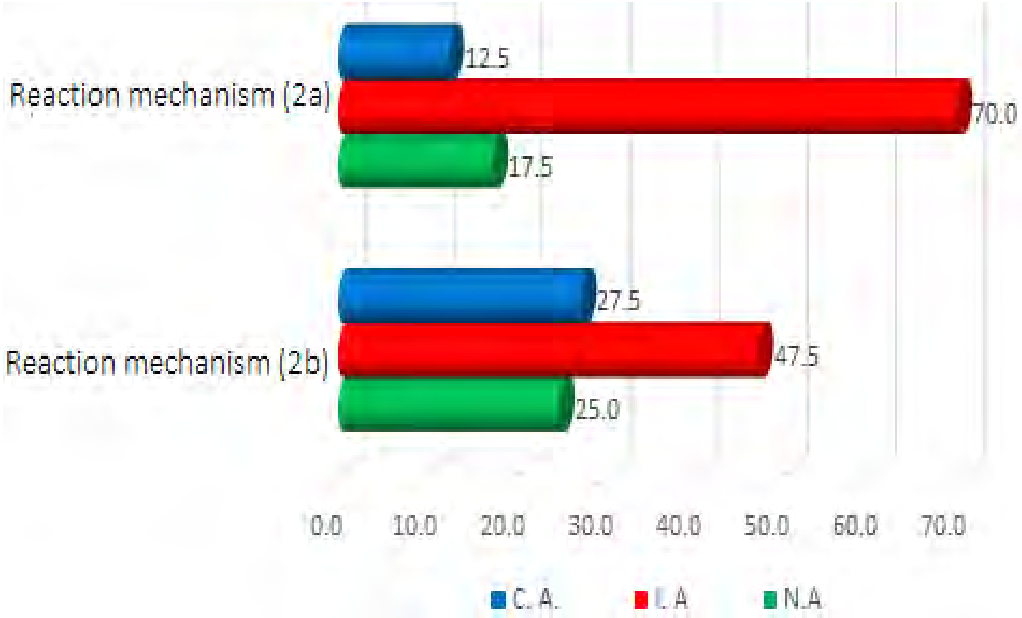



Figure 10: Frequency distribution of respondents' answers on reactions mechanisms

Data in Figure 10 shows that generally, science student-teachers' performance in these two organic reaction mechanisms was quite poor. This is because in both reaction mechanisms, majority (50% or more) of the participants were not able to illustrate correct mechanisms for the two reactions. For example, in item (2a), only 5(12.5%) respondents gave correct answer for reaction mechanism (2a), as many as 28(70.0%) of them gave incorrect answer and 7(17.5%) of them gave no response. For item (2b), quite a significant number (11, 27.5%) of participants gave correct answer, 19 (47.5%) of them gave incorrect answer and 10 (25.0%) of them also gave no answer for the same reaction mechanism. This result shows that although the participants in this study had conceptual difficulties with respect to organic reaction mechanisms, but these participants did quite well in the reaction mechanism (2b) than that of (2a).

The responses in Figure 10 were then categorised into sound understanding, SU; partial understanding, PU; specific misconception, SM; no understanding, NU and no response, NR in order to assess their conceptual understanding levels with respect to illustration of organic reaction mechanisms. The five categories of respondents' responses were analysed and are presented in Figure 11.

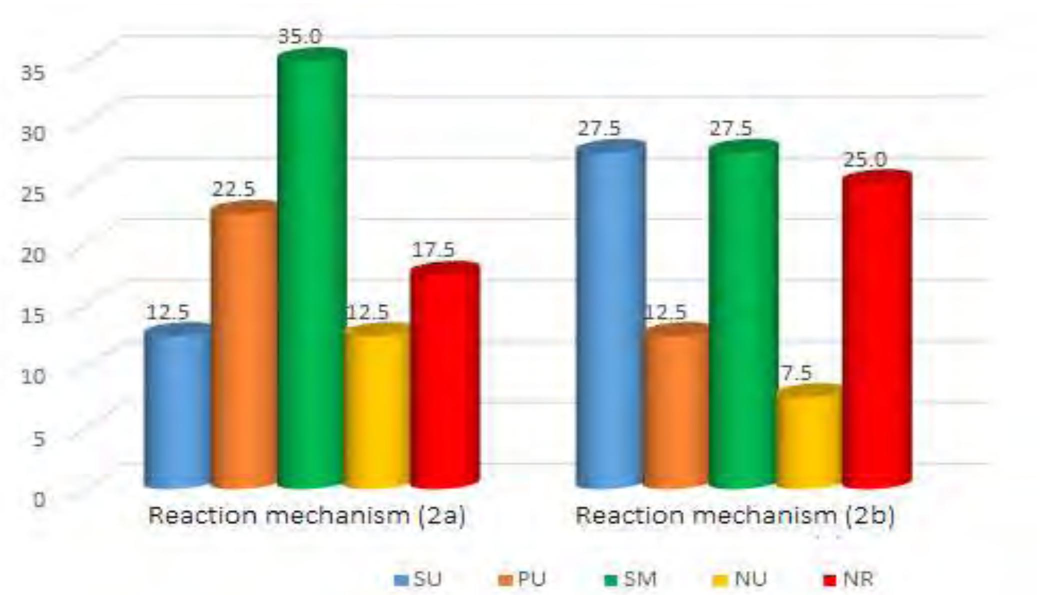



Figure 11: Distribution of subjects' understanding levels on reaction mechanism

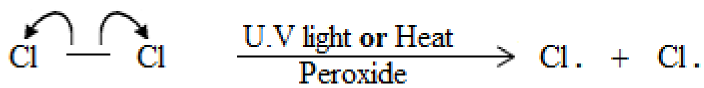
The analyses of data in Figure 11 shows that the science student-teachers in this study had varied levels of conceptions ranging from sound understanding through specific misconceptions to no understanding with respect to reaction mechanisms.

Item (2a) was used to measure the respondents' conceptual understanding in illustrating reaction mechanism of chlorine molecule which undergoes homolysis or homolytic cleavage in the presence of UV light or heat with peroxide as a catalyst to give chlorine free radicals. For item (2a), only 5 (12.5%) of respondents showed sound understanding. About 9(22.5%) of them showed partial understanding, 14(35.0%) of them showed specific misconceptions, 5(12.5%) of them showed no understanding and 7(17.5%) respondents also showed no response.

Also, item (2b) was used to measure the respondents' conceptual understanding in illustrating reaction mechanism involving alkanoic acid reacting with alkanol in the presence of heat and concentrated $H_2SO_4$ as a catalyst to produce ester and water. For item (2b), quite a significant number (11, 27.5%) of them showed sound understanding.

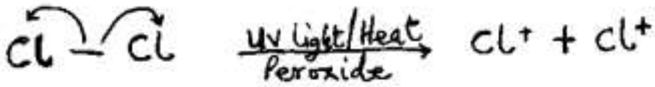
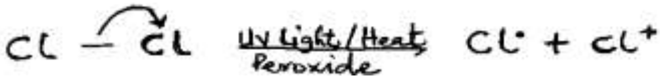
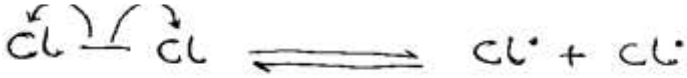
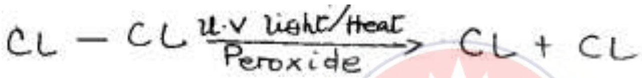
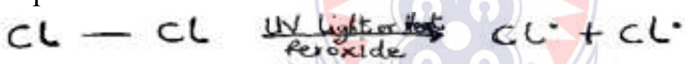
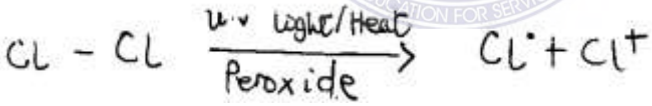
About 5(12.5%) of them showed partial understanding, 11(27.5%) of respondents showed specific misconceptions, 3(7.5%) of them showed no understanding, and 10 (25.5%) respondents also showed no response.

This result shows that although the participants who took part in this study had conceptual difficulties with respect to organic reaction mechanisms, a significant number (11, 27.5%) demonstrated better or sound understanding level for the reaction mechanism (2b) than in reaction mechanism (2a). This result means that the respondents had the most sound understanding for reaction mechanism (2b) with ($F_{SU}$: 11, 27.5%), fewer specific misconceptions ($F_{MS}$: 11, 27.5%), and also significant number of them ($F_{NR}$: 10, 25.0%) did not attempt it at all. This result also indicates that the respondents demonstrated low level of conceptual understanding for reaction mechanism (2a), with ($F_{SU}$: 5, 12.5%), more specific misconceptions ($F_{MS}$: 14, 35.0%) and fewer respondents ($F_{NR}$: 7, 17.5%) did not attempt that question. This result shows that science student-teachers who took part in this study had conceptual difficulties in reaction mechanism (2a) than that of (2b). This might be due to the facts that reaction mechanism (2b) is commonly seen in their textbooks and often used as example in most courses and that they did not have much difficulty in illustrating reaction mechanism (2b) as compared to mechanism (2a) which is uncommon in their textbooks. The correct reaction mechanism for organic reaction (2a) is illustrated below.




However, careful analysis of respondents' responses in Figure 10 above, showed that 28 (70.0%) of them gave incorrect answers for reaction mechanism (2a) which were considered as misconceptions in this study. The 28 respondents' incorrect answers regarded as misconceptions for the reaction mechanism (2a) are shown in Table 11.

**Table 11: Respondents' misconceptions on reaction mechanism illustrated in (2a)**

| No | Misconceptions given by 28 subjects | Frequency | Percentage |
|---|---|---|---|
| 1) | <br>Inability to show correct signs on the products | 7 | 25.0 |
| 2) | <br>Shows only one curved-arrow notation; no reversible sign; wrong notation sign (+) on one of the products | 5 | 17.9 |
| 3) | <br>Inability to show curved-arrow notations; no reversible sign; no reagents and conditions for reaction mechanism | 4 | 14.3 |
| 4) | <br>Inability to show reagents and conditions for mechanism | 4 | 14.3 |
| 5) | <br>Inability to show curved-arrow notations; no reversible sign; inability to show free chlorine radicals as products | 3 | 10.7 |
| 6) | <br>Inability to show curved-arrow notations; and failure to use reversible sign | 3 | 10.7 |
| 7) | <br>Failure to show curved-arrow; no irreversible sign; wrong notation sign (+) on one of the products | 2 | 7.1 |
| | **Total** | **28** | **100** |

Source: (Field work, 2022).

Moreover, the correct reaction mechanism for reaction (2b) is illustrated below.

$$\text{Alkanoic acid} + \text{Alkanol} \underset{\text{Heat}}{\overset{\text{Conc. } H_2SO_4}{\rightleftharpoons}} \text{Ester (Alkanoate)} + \text{Water}$$

However, careful analysis of respondents' responses in Figure 10 above, showed that 19 (47.5%) of them gave incorrect answers for reaction mechanism (2b) which were considered as misconceptions in this study. The 19 respondents' incorrect answers regarded as misconceptions for the reaction mechanism (2b) are shown in Table 12.

**Table 12: Subjects' misconceptions on reaction mechanism illustrated in (2b)**

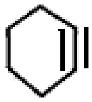
| No | Incorrect answers as misconceptions given by 19 subjects | Frequency | Percentage |
|---|---|---|---|
| 1) | Alkanoic acid + Alkanol $\xrightarrow[Heat]{Conc\ H_2SO_4}$ Ester + Water<br>Inability or failure to show reversible sign. | 5 | 26.3 |
| 2) | Alkanoic acid + alkanol $\rightleftharpoons$ Ester + water<br>Failure to show the reagent and condition for mechanism | 4 | 21.1 |
| 3) | Alkanol + alkanoic acid $\xleftarrow{Conc\ H_2SO_4}$ Ester + water<br>Failure to show condition for the reaction mechanism | 4 | 21.1 |
| 4) | Alkanoic acid + alkanol $\underset{Heat}{\rightleftharpoons}$ Ester + water<br>Inability to show the reagent for the mechanism | 3 | 15.8 |
| 5) | Alkanoic acid + Alkanol $\rightarrow$ Ester + Water<br>Inability to show reagent, condition and reversible sign | 2 | 10.5 |
| 6) | Alkanol + alkanoic acid $\xleftarrow{Conc\ H_2SO_4}$ Ester<br>Inability to show conditions for reaction and correct products. Only one product was written. | 1 | 5.3 |
| | **Total** | **19** | **100** |

Source: (Field work, 2022).

The respondents' responses in Tables 11 and 12 showed that science student-teachers in this study demonstrated low level of conceptual understanding with regards to illustration of organic reaction mechanisms (2a) and (2b) and that they possessed numerous misconceptions on them.

For question item (3) in Section B of SSTPIS in Appendix B, the 40 research subjects were asked to identify functional groups for ten different sets of given organic compounds. The respondents' answers were analysed using frequency and percentages, categorised into Correct Answer, C.A; Incorrect Answer, I.A; and No Answer, N.A and are presented in Table 13.

**Table 13: Science student-teachers' answers on functional group identification**

| No | Organic compound | Functional group identification | | | |
|---|---|---|---|---|---|
| | | C. A. F (%) | I. A F (%) | N.A F (%) | Total (%) |
| 3a) | $CH_3CH_2CH_2CH_2CH_3$ | 37 (92.5) | 3 (7.5) | 0 (0.0) | 40 (100) |
| 3b) | $CH_3CH_2C(Cl)_2CH_2(C_2H_5)$ | 35 (87.5) | 4 (10.0) | 1 (2.5) | 40 (100) |
| 3c) | $(CH_3)_2CHCH_2CH{=}C(Cl)CH_3$ | 33 (82.5) | 5 (12.5) | 2 (5.0) | 40 (100) |
| 3d) | $CH_3CH_2C(CH_3)_2C{\equiv}CH$ | 34 (85.0) | 4 (10.0) | 2 (5.0) | 40 (100) |
| 3e) | $CH_3CH_2CH(OH)CH_3$ | 31 (77.5) | 6 (15.0) | 3 (7.5) | 40 (100) |
| 3f) |  | 15 (37.5) | 18 (45.0) | 7 (17.5) | 40 (100) |
| 3g) | $CH_3CHO$ | 11 (27.5) | 17 (42.5) | 12 (30.0) | 40 (100) |
| 3h) | $C_2H_5COOH$ | 23 (57.5) | 15 (37.5) | 2 (5.0) | 40 (100) |
| 3i) | $CH_3COCH_2CH_3$ | 8 (20.0) | 19 (47.5) | 13 (32.5) | 40 (100) |
| 3j) | $CH_3NH_2$ | 5 (12.5) | 21 (52.5) | 14 (35.0) | 40 (100) |

Source: (Field work, 2022).

The data in Table 13 shows that generally, science student-teachers' performance in functional group identification was quite good. The research subjects' performance in (3a), (3b), (3c), (3d), (3e) and (3h) was very good, with (3a) being the highest. This is because more than half, 20(50.0%) of the respondents gave the correct functional groups for these compounds. This result means that majority of the respondents had better conceptual understanding on functional group identification for six out of the ten given organic compounds.

However, the respondents' performance on correct functional group identification for organic compounds (3f), (3g), (3i) and (3j) was quite poor; with (3j) being the poorest. This is because less than half (50.0%) of the respondents gave correct identification for these groups of organic compounds. This result means that majority (50.0% or more) of the respondents were not able to identify these organic compounds (3f), (3g), (3i) and (3j) with their correct functional groups. Out of the ten given organic compounds, the organic compound (3j) was the most difficult among the respondents and the order of difficult was (3j)- amine, (3i)-ketone, (3g)-aldehyde and (3f)-alkene.

Items (3d) and (3f) were used to measure respondents' knowledge on the alkyne functional group identification. For item (3d), majority (34, 85.0%) gave the correct answers, 4 (10.0%) gave incorrect answers and 2(5.0%) of them did not response. With regards to item (3f), only 15(37.5%) gave the correct answer, 18 (45.0%) gave incorrect answer, with quite a handful (7, 5.0%) of them did not response. This result means that higher proportions of the respondents had better knowledge regarding functional group identification for aliphatic alkyne than that of the cycloalkyne.

The respondents' responses in Table 13 were then categorised into sound understanding, SU; partial understanding, PU; specific misconception, SM; no understanding, NU; and no response, NR in order to assess their conceptual understanding levels. These five categorisation of the responses were analysed using frequency and percentage and are presented in Table 14.

**Table 14: Respondents' understanding levels on functional group identification**

| No | Given Compound | SU | PU | SM | NU | NR |
|---|---|---|---|---|---|---|
| | | F (%) | F (%) | F (%) | F (%) | F (%) |
| 3a) | $CH_3CH_2CH_2CH_2CH_3$ | 37 (92.5) | 2 (5.0) | 1 (2.5) | 0 (0.0) | 0 (0.0) |
| 3b) | $CH_3CH_2C(Cl)_2CH_2(C_2H_5)$ | 35 (87.5) | 1 (2.5) | 2 (5.0) | 1 (2.5) | 1 (2.5) |
| 3c) | $(CH_3)_2CHCH_2CH{=}C(Cl)CH_3$ | 33 (82.5) | 2 (5.0) | 1 (2.5) | 2 (5.0) | 2 (5.0) |
| 3d) | $CH_3CH_2C(CH_3)_2C{\equiv}CH$ | 34 (85.0) | 1 (2.5) | 2 (5.0) | 1 (2.5) | 2 (5.0) |
| 3e) | $CH_3CH_2CH(OH)CH_3$ | 31 (77.5) | 2 (5.0) | 3 (7.5) | 1 (2.5) | 3 (7.5) |
| 3f) |  | 15 (37.5) | 5 (12.5) | 10 (25.0) | 3 (7.5) | 7 (17.5) |
| 3g) | $CH_3CHO$ | 11 (27.5) | 8 (20.0) | 6 (15.0) | 3 (7.5) | 12 (30.0) |
| 3h) | $C_2H_5COOH$ | 23 (57.5) | 4 (10.0) | 10 (25.0) | 1 (2.5) | 2 (5.0) |
| 3i) | $CH_3COCH_2CH_3$ | 8 (20.0) | 9 (22.5) | 6 (15.0) | 4 (10.0) | 13 (32.5) |
| 3j) | $CH_3NH_2$ | 5 (12.5) | 6 (15.0) | 11 (27.5) | 4 (10.0) | 14 (35.0) |

Source: (Field work, 2022).

The analysis of the data in Table 14 shows that the respondents who took part in this study possessed varied degrees of conceptions or conceptual understanding levels ranging from sound understanding through specific misconception to no response on functional group identification. The data in Table 14 shows that the respondents had better conceptual understanding level regarding functional group identification for organic compounds (3a)-alkane (without substituent), (3b)-alkane (with substituents), (3c)-alkene, (3d)-alkyne (aliphatic), (3e)-alkanol, and (3h)-alkanoic (carboxylic) acid. The frequency and percentage with respect to their sound conceptual understanding level for these compounds are as follows (3a. $F_{SU:}$ 37, 92.5%), (3b. $F_{SU}$ 35, 87.5%), (3c. $F_{SU:}$ 33, 82.5%), (3d. $F_{SU}$ 34, 85.0%), (3e. $F_{SU:}$ 31, 77.5%) and (3h. $F_{SU:}$ 23, 57.5%). This result shows that compound (3a) was the easiest organic compound identified by most of the respondents with respect to its functional group identification. This means that respondents had the most sound understanding level with respect to the functional group identification for organic compound (3a)-alkane (without a substituent).

However, the data in Table 14 shows that the majority (50% or more) of the respondents had conceptual difficulties regarding four organic compounds (3f)-alkyne (in cyclic form), (3g)-aldehyde, (3i)-ketone, and (3j)-amine, with compound (3j) an amine ($NH_2$) being the most difficult to identify its functional group. This result means that these research subjects had conceptual difficulties in identifying alkyne (in cyclic form), aldehyde, ketone and amine functional groups. Analysis of data in Table 14 shows that majority of the respondents gave incorrect answers to functional group identification for these compounds (3f), (3g), (3i), and (3j) and that these respondents had several misconceptions about them. The respondents' incorrect answers for these four organic compounds (3f), (3g), (3i) and (3j) identified as misconceptions were analysed using frequency and percentages and are presented in Tables 14a, 14b, 14c and 14d.

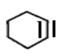
The 18 respondents' incorrect answers regarded as misconceptions for functional group identification for (3f),  are shown in Table 14a.

**Table 14a: Wrong functional groups of (3f)**  **given by 18 respondents**

| No | Wrong functional group given by some subjects | Frequency | Percentage |
|---|---|---|---|
| 1). | Benzene | 11 | 61.1 |
| 2). | Cyclic alkyne | 4 | 22.2 |
| 3). | Benzyl | 2 | 11.1 |
| 5). | Phenyl | 1 | 5.6 |
| | **Total** | **18** | **100** |

Source: (Field work, 2022). Correct functional group is Alkyne

Again, the 17 respondents' incorrect answers regarded as misconceptions for functional group identification for (3g), $CH_3CHO$ are shown in Table 14b.

**Table 14b: Wrong functional groups of (3g) $CH_3CHO$ given by 17 respondents**

| No | Wrong functional group given by some subjects | Frequency | Percentage |
|---|---|---|---|
| 1). | Alkanol | 10 | 58.7 |
| 2). | Ketone | 3 | 17.7 |
| 3). | Alkanoic acid | 3 | 17.7 |
| 4). | Acetal | 1 | 5.9 |
| | **Total** | **17** | **100** |

Source: (Field work, 2022). Correct functional group is carbonyl (aldehyde)

Moreover, the 19 subjects' incorrect answers regarded as misconceptions for functional group identification for (3i), $CH_3COCH_2CH_3$ are shown in Table 14c.

**Table 14c: Wrong functional groups for (3i) $CH_3COCH_2CH_3$ given by 19 subjects**

| No | Wrong functional group given by some subjects | Frequency | Percentage |
|---|---|---|---|
| 1). | Ester (Alkanoate) | 9 | 47.4 |
| 2). | Carboxylic (Alkanoic) acid | 4 | 21.1 |
| 3). | Acid amide | 3 | 15.7 |
| 4). | Alkanol (Alcohol) | 2 | 10.5 |
| 5). | Acid anhydride | 1 | 5.3 |
| | **Total** | **19** | **100** |

Source: (Field work, 2022). Correct functional group is carbonyl (ketone)

Finally, the 21 subjects' incorrect answers regarded as misconceptions for functional group identification for (3j), $CH_3NH_2$ are shown in Table 14d.

**Table 14d: Wrong functional groups for (3j) $CH_3NH_2$ given by 21 respondents**

| No | Wrong functional group given by some subjects | Frequency | Percentage |
|---|---|---|---|
| 1). | Amide | 10 | 47.5 |
| 2). | Acid amide | 4 | 19.1 |
| 3). | Aldehyde | 3 | 14.3 |
| 4). | Acid anhydride | 3 | 14.3 |
| 5). | Ammonia | 1 | 4.8 |
| | **Total** | **21** | **100** |

Source: (Field work, 2022). Correct functional group is amine

Data in Tables 14a, 14b, 14c and 14d shows that science student-teachers who participated in this study demonstrated low conceptual understanding levels with respect to (3f)-cycloalkyne, (3g)-aldehyde, (3i)-ketone and (3j)-amine and therefore, had several misconceptions on them.

For question items (4a-c) in the SSTPIS in Appendix B, the entire 40 respondents were asked to balance three complete but unbalanced equations involving combustion of hydrocarbons and were expected to balance each equation by putting correct stoichiometric coefficient in the spaces provided. The respondents' answers were analysed, categorised into three as Correct Answer, C.A; Incorrect Answer I.A; and No Answer N.A and are presented in Figure 12.

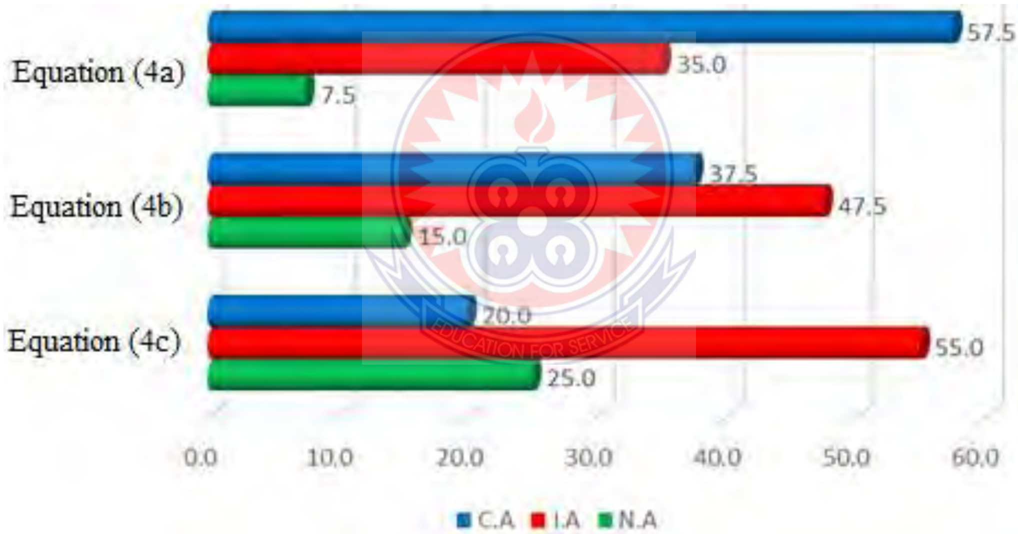



Figure 12: Frequency distribution of respondents' answers on balancing of equations

Data in Figure 12 shows that science student-teachers' performance in balancing these three complete but unbalanced equations involving combustion of hydrocarbons was unsatisfactory. The performance of the respondents on equation (4a) was quite good. For equation (4a), out of the 40 respondents, as many as 23(57.5%) of them were able to balance it correctly. The expected answer for the equation (4a) was $CH_{4\,(g)} + 2O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2H_2O_{(l)}$. This implies that majority (more than 50.0%) of them were able to write the correct balanced equation involving combustion of alkane (methane).

However, their performance in equations (4b) and (4c) were quite poor. This is because majority (50.0% or more) of them were not able to write the correct balanced equations for these two reactions. For example, in equation (4b), only 15(37.5%) were able to balance this equation correctly, 47.5% gave incorrect answer and 15.0% gave no response. The expected answer for equation (4b) was $C_2H_{4\,(g)} + 3O_{2\,(g)} \rightarrow 2CO_{2\,(g)} + 2H_2O_{(l)}$. Also, for equation (4c), only 8(20.0%) of them gave correct answer, 55.0% gave incorrect answer and 25.0% gave no response. The expected answer for equation (4c) was $C_2H_{2\,(g)} + 2.5O_{2\,(g)} \rightarrow 2CO_{2\,(g)} + H_2O_{(l)}$. This results implies that higher percentage (50.0% or more) of the respondents were not able to write the correct balanced equation for (4b) involving combustion reaction of ethene and that of equation (4c), ethyne.

The respondents' responses in Figure 12 were then categorised into sound understanding, SU; partial understanding, PU; specific misconception, SM; no understanding, NU; and no response, NR in order to assess their conceptual understanding levels. These five categorisation of respondents' responses were analysed carefully using frequency and percentage and are presented in Figure 13.

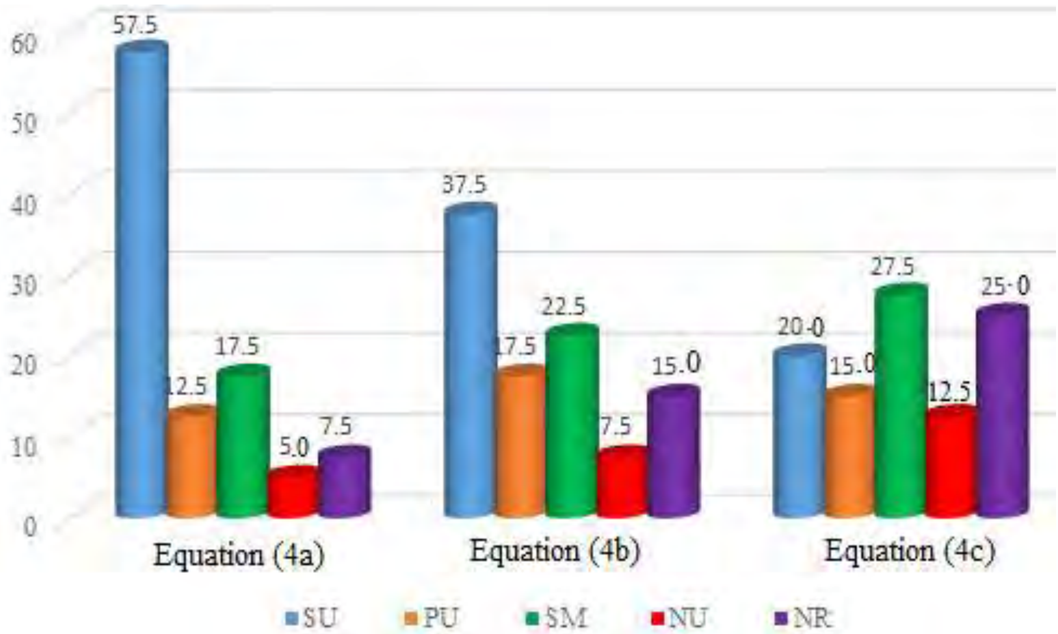



Figure 13: Frequency distribution of subjects' understanding levels on equations

The analysis of Figure 13 shows that the science student-teachers who took part in this study showed varied degrees of conceptions ranging from sound understanding through specific misconception to no response with respect to balancing organic equations involving combustion reaction of hydrocarbons. Data in Figure 13 shows that the respondents had better or sound conceptual understanding level ($F_{SU}$: 57.5%) with respect to correct equation (4a) i.e. correct balancing of combustion equation of alkanes.

Figure 13 however, also shows that the respondents demonstrated low levels of conceptual understanding with respect to equation (4b) and (4c). For example, in equation (4b), 37.5% showed sound understanding, 17.5% showed partial understanding, 22.5% showed specific misconceptions, 7.5% showed no understanding and 15.0% showed no response. Also, for equation (4c), only 20.0% showed sound understanding, 15.0% showed partial understanding, 27.5% showed specific misconceptions, 12.5% showed no understanding and 25.0% showed no response. Comparing the respondents' conceptions with regards to equation (4b) and (4c), data in Figure 13 shows that the respondents demonstrated quite satisfactory conceptual understanding level ($F_{SU}$: 37.5%) with fewer specific misconceptions ($F_{SM}$: 22.5%) for equation (4b) than that of equation (4c) of low conceptual understanding level ($F_{SU}$: 20.0%) with many specific misconceptions ($F_{SM}$: 27.5%). This result means that majority (50% or more) showed low level of conceptual understanding in equation (4b), correct balancing of equation involving combustion reaction of alkene and that of equation (4c). The most difficult equation for the respondents was equation (4c), that is the correct balancing of combustion equation involving alkyne.

The participants or respondents' misconceptions identified with regards to correct balancing these three combustion reactions equations involving alkane, alkene and alkyne were analysed qualitatively and presented in Table 15.

**Table 15: Subjects' misconceptions on balancing of chemical equations**

| No | Subjects' misconceptions in balancing combustion equations of hydrocarbons |
|---|---|
| 1). | Changing the formulae of compound by changing the position of subscripts.<br>Example, $2CH_{4\,(g)} + 2O_{2\,(g)} \rightarrow 2(CO)_{2\,(g)} + 4H_2O_{\,(l)}$ |
| 2). | Multiplying through both reactants and products by a common coefficient.<br>Examples, $2CH_{4\,(g)} + 2O_{2\,(g)} \rightarrow 2CO_{2\,(g)} + 2H_2O_{\,(l)}$<br>$4C_2H_{4\,(g)} + 4O_{2\,(g)} \rightarrow 4CO_{2\,(g)} + 4H_2O_{\,(l)}$ |
| 3). | Failing to realize that balancing of one element in a formula may affect the elements in other formulae in the equation.<br>Examples, $2CH_{4\,(g)} + 4O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2H_2O_{\,(l)}$<br>$C_2H_{4\,(g)} + O_{2\,(g)} \rightarrow 2CO_{2\,(g)} + 2H_2O_{\,(l)}$ |
| 4). | Failing to reduce coefficients of the chemical species to the lowest terms.<br>Examples, $2CH_{4\,(g)} + 4O_{2\,(g)} \rightarrow 2CO_{2\,(g)} + 4H_2O_{\,(l)}$<br>$2C_2H_{4\,(g)} + 8O_{2\,(g)} \rightarrow 4CO_{2\,(g)} + 4H_2O_{\,(l)}$<br>$3C_2H_{2\,(g)} + 6O_{2\,(g)} \rightarrow 6CO_{2\,(g)} + 3H_2O_{\,(l)}$ |
| 5). | Changing some subscripts of the reactants into coefficients of the products.<br>Examples, $CH_{4\,(g)} + O_{2\,(g)} \rightarrow 2CO_{2\,(g)} + 2H_2O_{\,(l)}$<br>$C_2H_{4\,(g)} + O_{2\,(g)} \rightarrow 2CO_{2\,(g)} + 4H_2O_{\,(l)}$ |
| 6). | Putting fractions in front of both atoms and molecules instead of molecules.<br>Examples, $\frac{1}{2}CH_{4\,(g)} + \frac{1}{2}O_{2\,(g)} \rightarrow \frac{1}{2}CO_{2\,(g)} + \frac{1}{2}H_2O_{\,(l)}$<br>$\frac{1}{2}C_2H_{4\,(g)} + \frac{1}{2}O_{2\,(g)} \rightarrow \frac{1}{2}CO_{2\,(g)} + \frac{1}{2}H_2O_{\,(l)}$ |
| 7). | Changing formulae of compounds by introducing parenthesis in the formula.<br>Examples, $CH_{4\,(g)} + \frac{1}{2}(O)_{2\,(g)} \rightarrow \frac{1}{2}CO_{2\,(g)} + 2H_2O_{\,(l)}$<br>$2CH_{4\,(g)} + 2O_{2\,(g)} \rightarrow 2(CO)_{2\,(g)} + 4H_2O_{\,(l)}$ |
| 8). | Incoherent / inconsistent approaches to balancing of chemical equations.<br>Examples, $3CH_{4\,(g)} + 2O_{2\,(g)} \rightarrow 4CO_{2\,(g)} + 2H_2O_{\,(l)}$<br>$2C_2H_{4\,(g)} + 8O_{2\,(g)} \rightarrow 2CO_{2\,(g)} + 12H_2O_{\,(l)}$<br>$3C_2H_{2\,(g)} + 2O_{2\,(g)} \rightarrow 6CO_{2\,(g)} + 3H_2O_{\,(l)}$ |
| 9). | Placing a coefficient in the middle of a formula<br>Example, $C_2H_{2\,(g)} + O_{2\,(g)} \rightarrow C_2O_{2\,(g)} + 2H_2O_{\,(l)}$ |
| 10). | Adding subscripts of reactants and changing them into coefficient of products<br>Examples, $CH_{4\,(g)} + O_{2\,(g)} \rightarrow 6CO_{2\,(g)} + 6H_2O_{\,(l)}$<br>$C_2H_{4\,(g)} + O_{2\,(g)} \rightarrow 8CO_{2\,(g)} + 8H_2O_{\,(l)}$ |

Source: (Field work, 2022).

The data in the Table 15 shows that the science student-teachers had several misconceptions with regards to the correct balancing of equations involving combustion of hydrocarbons (alkane, alkene and alkyne) respectively. From Table 15, ten common patterns of misconceptions were identified in this study among the respondents' responses to balancing of the three given combustion of hydrocarbon equations. Some common patterns of misconceptions identified in this study among the research subjects included changing the formulae of compound by changing the position of subscripts; multiplying through both reactants and products by a common coefficient; failing to realize that balancing of one element in a formula may affect the elements in other formulae in the equation; failing to reduce coefficients of the chemical species to the lowest terms; incoherent/ inconsistent approaches to balancing of chemical equation; placing a coefficient in the middle of a formula and many others as shown in Table 15. The presence of these varied misconceptions indicated that science student-teachers who participated in this study had not developed appropriate and better conceptual understanding with respect to the balancing equations involving combustion reaction of hydrocarbons (alkane, alkene and alkyne). Data in Table 15 shows the ten common patterns of misconceptions identified among the respondents in this study.

Moreover, the respondents were asked to indicate their perceived difficulties regarding the four given questions (stated as question item 5b) in the SSTPIS in Appendix B. They indicated that item (2) was the most very difficult, followed by item (4), the next was item (1) and then finally, item (1) respectively.

### *4.2.4 Research Question 4: What are the effects of the POEIA on the science student-teachers' performance in the selected organic chemistry topics?*

In answering research question 4, science student-teachers' tests scores in both pre-intervention test and post-intervention test (in Appendix C & D respectively) were analysed quantitatively, compared and are presented in Tables 16 and 17.

**Table 16: Comparing respondents' pre- and post-intervention test scores**

| | Pre-test Scores | | Post-test Scores | |
|---|---|---|---|---|
| Marks | Frequency | Percentage | Frequency | Percentage |
| 0 | 1 | 2.5 | 0 | 0.0 |
| 1 | 1 | 2.5 | 0 | 0.0 |
| 2 | 1 | 2.5 | 0 | 0.0 |
| 3 | 2 | 5.0 | 0 | 0.0 |
| 4 | 3 | 7.5 | 1 | 2.5 |
| 5 | 1 | 2.5 | 2 | 5.0 |
| 6 | 4 | 10.0 | 1 | 2.5 |
| 7 | 2 | 5.0 | 0 | 0.0 |
| 8 | 3 | 7.5 | 1 | 2.5 |
| 9 | 2 | 5.0 | 0 | 0.0 |
| 10 | 4 | 10.0 | 0 | 0.0 |
| 11 | 1 | 2.5 | 1 | 2.5 |
| 12 | 2 | 5.0 | 0 | 0.0 |
| 13 | 2 | 5.0 | 1 | 2.5 |
| 14 | 2 | 5.0 | 0 | 0.0 |
| 15 | 3 | 7.5 | 4 | 10.0 |
| 16 | 2 | 5.0 | 3 | 7.5 |
| 17 | 1 | 2.5 | 4 | 10.0 |
| 18 | 2 | 5.0 | 2 | 5.0 |
| 19 | 1 | 2.5 | 1 | 2.5 |
| 20 | 0 | 0.0 | 3 | 7.5 |
| 21 | 0 | 0.0 | 3 | 7.5 |
| 22 | 0 | 0.0 | 2 | 5.0 |
| 23 | 0 | 0.0 | 1 | 2.5 |
| 24 | 0 | 0.0 | 3 | 7.5 |
| 25 | 0 | 0.0 | 2 | 5.0 |
| 26 | 0 | 0.0 | 1 | 2.5 |
| 27 | 0 | 0.0 | 2 | 5.0 |
| 28 | 0 | 0.0 | 2 | 5.0 |
| 29 | 0 | 0.0 | 0 | 0.0 |
| 30 | 0 | 0.0 | 0 | 0.0 |
| **Total** | **40** | **100** | **40** | **100** |

Source: (Field work, 2022)

Data in Table 16 shows that the respondents' pre-intervention test scores ranged from 0 to 19 marks, and none of them had scores of 20 marks and above. Since the total score marks of the test was 30 marks, then respondents with the total score of 0 - 14 marks were considered to have failed the test whiles those with total marks of 15-30 were considered to have pass the test. Based on these statistics, it could be seen that only 9

(22.5%) science student-teachers passed the pre-intervention test whiles as many as 31 of them representing 77.5% failed the same pre-intervention test. The pre-intervention test scores of the 40 science student-teachers in Table 16 have been presented pictorially in a pie-chart as shown in Figure 14.

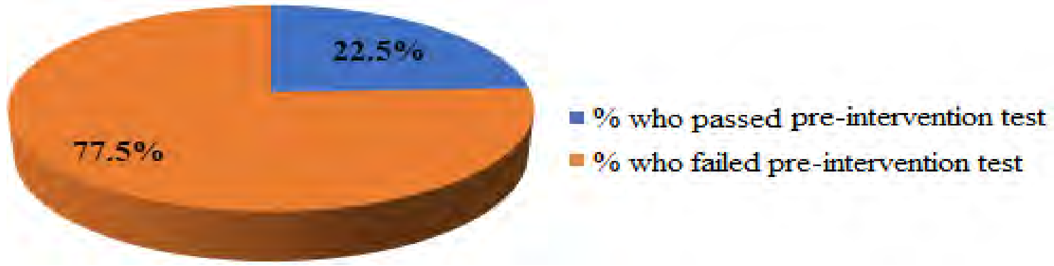



Figure 14: Percentage of the respondents who passed and failed pre-intervention test

The analysis of data in Figure 14 shows that generally, the performance of the entire 40 respondents in the pre-intervention test were not the best and that majority (31 out of 40) of them representing 77.5% failed the test. Thus, their performance was poor.

On the other hand, data in Table 16 shows that science student-teachers' post-intervention test scores ranged from 4 to 28 marks. This result means that the highest score in this post-intervention test was 28 marks and the least score was 4. None of them had a score of 0 to 3 marks as well as 29 and 30 marks. Based on the data in Table 16 above, it could be seen that 33 respondents representing 82.5% passed the post-test by having scores between 15-28 marks whiles only 7 of them representing 17.5% failed the same post-intervention test. The post-intervention test scores of the 40 research subjects' in Table 16 have been presented pictorially in a pie-chart as shown in Figure 15.


Figure 15: Percentage of the respondents who passed and failed post-intervention test

The analysis of data in Figure 15 shows that generally, the performance of the entire 40 respondents in the post-intervention test was very good and that majority (33 out of 40) of them representing 82.5% passed the test. Thus, they performed very well in this test. In order to compare the respondents' performance in each of the tests, the entire 40 science student-teachers' pre-intervention test and post-intervention test scores in Table 16 were further analysed using frequency and percentage; compared and are presented pictorially in a bar-chart as shown in Figure 16.

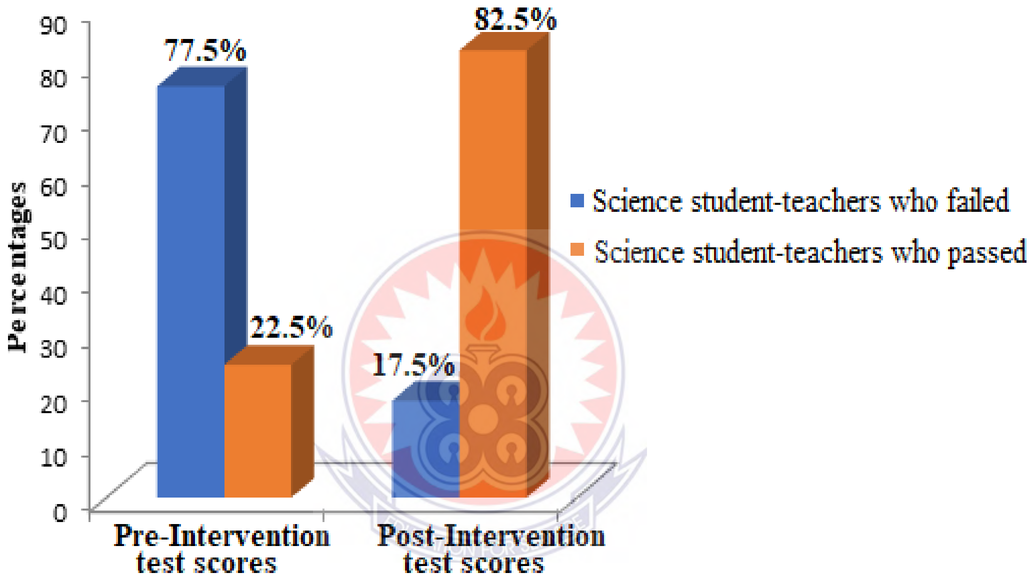



Figure 16: Comparing subjects' pre- and post-intervention tests scores in percentage

The analyses of data in Table 16 and Figure 16 show that science student-teachers performed better in the post-intervention test scores after the implementation of the POE Instructional Approach (POEIA) activities than in the pre-intervention test scores (i.e., before implementation of the POEIA intervention activities). This tremendous improved performance of the research subjects might be attributed to the POEIA intervention activities used in the teaching and learning of the selected organic chemistry topics in the college for the past ten weeks.

In order to ascertain whether significant difference existed between the pre-intervention test and post- intervention test means scores, the entire 40 respondents were analysed, compared using inferential statistics (t-test) and are presented in Table 17.

**Table 17: Independent sample t-test on pre-and post-intervention tests mean scores**

| Type of Test | N | Mean (X) | Standard Deviation | Std. Error Difference | t-Value | F | p-Value |
|---|---|---|---|---|---|---|---|
| Pre-intervention test | 40 | 9.6000 | 5.13809 | 1.30668 | - 6.639 | 1.048 | .000* |
| Post-intervention test | 40 | 18.2750 | 6.47277 | | | | |

Source: (Field work, 2022). * = Significant; $p < 0.05$.

As the data in Table 17 shows, the independent sample t-test analysis of the pre-intervention test and post-intervention test mean scores of the participants was found to be statistically significant ($t = -6.639$; $p < 0.05$) (see Appendix J). It was concluded that there was statistically significant difference between the pre-intervention test and post-intervention test mean scores of the participants. This result means that the POE instructional approach intervention activities implemented for the ten weeks period was very effective in the teaching and learning of the selected topics. This means that the POEIA treatment had positive effects on the science student-teachers' performance.

### *4.2.5 Research Question 5: What is the impact of the POEIA on the science student-teachers' attitudes towards the selected organic chemistry topics?*

In answering research question 5, respondents were made to respond to five point Likert scale type questionnaire, which had five levels of responses ranging from strongly agree through uncertain to strongly disagree. On analysis, this scale was further rescaled into three categories, agree to uncertain to disagree for the sake of convenience. The strongly agree and agree were clustered as agree, while strongly disagree and disagree were clustered as disagree. The 40 respondents' responses for each of the 14 items in the Science Student-Teachers' Attitude Scale Questionnaire (STASQ) in Appendix E were analysed quantitatively and are presented in Table 18.

**Table 18: Research subjects' responses on attitudes towards organic chemistry**

| No | Attitude scale questionnaire items | A (%) | U (%) | D (%) | Total (%) |
|---|---|---|---|---|---|
| 1) | Organic chemistry was difficult for me before POEIA intervention activities | 37 (92.5) | 1 (2.5) | 2 (5.0) | 40 (100) |
| 2) | I enjoyed learning organic chemistry concepts taught through activities based on the POEIA. | 34 (85.0) | 2 (5.0) | 4 (10.0) | 40 (100) |
| 3) | I still dislike organic chemistry concepts after the exposure to POEIA intervention | 3 (7.5) | 3 (7.5) | 34 (85.0) | 40 (100) |
| 4) | The POEIA gave me more time to perform more practical activities on the organic chemistry concepts taught. | 36 (90.0) | 1 (2.5) | 3 (7.5) | 40 (100) |
| 5) | The POEIA did not give me enough opportunities to have collaborative interactions with my mates. | 2 (5.0) | 1 (2.5) | 37 (92.5) | 40 (100) |
| 6) | The use of POEIA increases my motivation to learn and also gave me more confident in the concepts taught. | 33 (82.5) | 2 (5.0) | 5 (12.5) | 40 (100) |
| 7) | I did not like the way POEIA was used to teach organic chemistry concepts. | 3 (7.5) | 2 (5.0) | 35 (87.5) | 40 (100) |
| 8) | The POEIA is more engaging during teaching and learning processes of the concepts taught than usual traditional expository/lecture instructions. | 37 (92.5) | 1 (2.5) | 2 (5.0) | 40 (100) |
| 9) | The POEIA did not give me enough opportunities to develop my ability to think critically and independently. | 4 (10.0) | 2 (5.0) | 34(85.0) | 40 (100) |
| 10) | The POEIA has helped me to improve my performance and had higher morale in organic chemistry concepts taught. | 35 (87.5) | 1 (2.5) | 4(10.0) | 40 (100) |
| 11) | POEIA did not help me to get deeper understanding of the concepts taught | 4 (10.0) | 1 (2.5) | 35(87.5) | 40 (100) |
| 12) | The POEIA has helped me to develop systematic approach to the learning of organic chemistry concepts taught. | 31 (77.5) | 4(10.0) | 5 (12.5) | 40 (100) |
| 13) | POEIA used to teach organic chemistry concepts was demanding and did not want it to be continued in the college. | 5 (12.5) | 3 (7.5) | 32 (80.0) | 40 (100) |
| 14) | The POEIA has helped me to develop positive attitude towards the learning of organic chemistry concepts taught. | 36 (90.0) | 2 (5.0) | 2 (5.0) | 40 (100) |

Source: (Science Student-Teachers' Attitude Scale Questionnaire (STASQ), 2022)

The data or responses in Table 18 shows that the respondents who participated in this study had different perspectives regarding the impact of POEIA on science student-teachers' attitudes towards the selected topics in the organic chemistry. For example, as many as 37 respondents representing 92.5% vehemently agreed that organic chemistry was difficult for them before the POEIA intervention activities; only 1(2.5%) of them was uncertain, with 2(5.0%) disagreed to the same statement item. This implies that organic chemistry was difficult for majority of the respondents before the implementation of the POEIA intervention activities.

Again, majority of the respondents (34 out of 40) representing 85.0% agreed that they enjoyed learning organic chemistry concepts taught through activities based on the POEIA, with 2(5.0%) of them were uncertain whiles 4 (10.0%) of them disagreed to the same item. This means that the respondents enjoyed learning organic chemistry concepts taught through activities based on the POEIA intervention activities.

On the issue of whether the POEIA gave more time to perform more practical activities on the organic chemistry concepts taught, as many as 36 (90.0%) agreed to this statement, 1(2.5%) of them was uncertain, whiles 3 (7.5%) of them also disagreed to the same item. This implies that majority of them agreed that the POEIA gave them more time to perform more practical activities on the organic chemistry concepts taught.

When asked if the use of POEIA increased motivation to learn and also gave me more confident in the concepts taught, as many as 33 (82.5%) agreed to it, 2 (5.0%) of them were uncertain, and a handful of them 5(12.5%) disagreed to the same item. This means that majority of the subjects agreed that the use of POEIA increased their motivation to learn and also gave them more confidence in the concepts taught.

On the issue of whether the POEIA was more engaging during teaching and learning processes of the concepts taught than the usual traditional expository/lecture instructions, as many as 37(92.5%) respondents vehemently agreed to the item, only 1(2.5%) of them was uncertain, with 2 (5.0%) of them disagreed to the same item. This implies that the POEIA engaged them more during the teaching and learning processes of the concepts taught than the usual traditional expository/lecture instructions.

Again, when asked if the POEIA helped to improve performance and higher morale in the organic chemistry concepts taught, as many as 35 of them representing 87.5% agreed to this item, with 1(2.5%) was uncertain, whiles 4 (10.0%) of them disagreed to the same statement item. This implies that majority of the respondents agreed that the POEIA helped them to improve their performance and also had higher morale in the organic chemistry concepts taught.

On the issue of whether the POEIA helped to develop systematic approach to the learning of organic chemistry concepts taught; as many as 31 of them representing 77.5% agreed to this statement item, 4 (10.0%) were uncertain, whiles 5 (12.5%) of them also disagreed to this statement item. This implies that majority of the science student-teachers agreed that the POEIA helped them to develop systematic approach to the learning of organic chemistry concepts taught.

On the issue of whether the POEIA helped to develop positive attitude towards the learning of organic chemistry concept taught (stated as item 14), as many as 36 (90.0%) agreed to the statement; 2(5.0%) of them were uncertain, whiles 2 (5.0%) disagreed to the same statement item. This implies that almost all of the respondents agreed that the POEIA helped them to develop their positive attitudes towards the learning of organic chemistry concepts taught.

When asked if they still disliked organic chemistry concepts after the exposure to POEIA intervention (as stated in item 3), only 3 (7.5%) of them agreed, another 3(7.5%) of them were uncertain, whereas as many as 34 (85.0%) of them disagreed to the same statement item. This response invariably means that majority of the respondents now liked organic chemistry concepts after the exposure to POEIA intervention. Again, when asked if they did not like the way POEIA was used to teach organic chemistry concepts (stated as item 7), only 3 (7.5%) respondents agreed to this statement, 2 (5.0%) of them were uncertain, whereas as many as 35(87.5%) disagreed to the same statement item. This negative response implies that majority of the respondents agreed that they liked the way POEIA was used to teach organic chemistry concepts.

On the issue of whether the POEIA used to teach organic chemistry concepts was demanding and did not want it to be continued in the college (stated as 13), only 5 (12.5%) of them agreed to this item, 3 (7.5%) were uncertain, and 32 (80.0%) of them disagreed. This response invariably implies that the POEIA used to teach organic chemistry was though demanding, yet they still wanted it to be continued in the college.

When asked if the POEIA did not give enough opportunities to develop their ability to think critically and independently (stated as 9), only 4 (10.0%) agreed, 2(5.0%) were uncertain, whiles as many as 34 (85.0%) disagreed to same statement item. This negative response invariably implies that the POEIA gave them enough opportunities to develop their ability to think critically and independently.

The responses provided by the respondents in Table 18 show that the POE instructional approach (POEIA) had positive impact on the science student-teachers' attitudes towards the selected topics in the organic chemistry.

#### *4.2.6 Research Question 6: What module can be designed to enhance the teaching and learning of the selected organic chemistry topics in the target institution?*

The teaching and learning of the organic chemistry concept, like any other concept is expected to be learner-centered approach, incorporating hands-on and minds-on activities and also the one that would promote lifelong learning. This study adopted a

POE instructional approach rooted in learner-centered approach to the teaching and learning of the selected organic chemistry topics at Foso College of Education. In addition, eight lesson plans and their corresponding worksheets and activity guides based on the POE instructional approach in the form of a module was carefully developed by the researcher and used for this study.

Each lesson plan had a preamble, course learning outcome and indicators, instructional resources and detailed notes on each of the selected organic chemistry topics. Each lesson plan had seven steps and headed by six units, ending with individual assignments. The designed worksheets were based on the step 4 (predict-P), step 5 (observe - O), and step 6 (explain-E) aspects of the lesson plan respectively. The designed activity guides on the other hand, were based on only the step 5 (observe - O) aspect of the lesson plan. The components of the module are as follows:

Unit 1: The alkanes.

Unit 2: The alkenes.

Unit 3: The alkynes.

Unit 4: The alkanols (alcohols).

Unit 5: The carbonyl compounds.

Unit 6: The alkanoic (carboxylic) acids.

Unit 7: The alkanoic acid derivative: Alkanoates/esters.

Unit 8: The amines.

Additional data were collected through interviews using question items in the POEIA Post-Interview Schedule (POEPIS) in Appendix F. Ten of the research subjects were selected using Patton's (1990) maximum variety sampling techniques to constitute a small focus group and interviewed in-depth. The following excerpts from a typical interview session exemplifies this notion (R and SSTs stand for researcher and science student-teachers respectively). The responses from the 10 selected research subjects have been transcribed and presented verbatim under seven thematic areas as follows:

*Researcher: What can you say about the POEIA used in teaching you organic chemistry concepts in your class?*

*SSTs*: *Please sir, the POEIA lessons were very good. It makes you think thoroughly through especially when predicting about an event or phenomenon. At first we were scared or afraid of predicting or expressing our views in writing; what if we wrote a wrong answer and predictions because our mates could laugh at us, but later we became okay. We were amazed about the way organic chemistry concepts were taught in this class. The POEIA provided opportunity for us to learn by engaging in active learning process where we become responsible for our own learning, and also for self-assessment of our performance, attitudes and progress of work through the use of designed POE activity guides and worksheets. The designed POE activity guides and worksheets provided us with an alternative source of exercises for trial after class sessions. We want more of such lessons. In fact, we like the POEIA lessons because it was very fun.*

*Researcher: How have POEIA lessons been different from the normal chemistry class?*

*SSTs*: *Please sir, in our normal class hours, most at times we used to sit alone and listen to chalk and talking from our chemistry tutors making us get confused sometimes. In most situations, organic chemistry is taught using lecture method. This, therefore, affects our' conceptual understanding of the concept as we learn by memorizing, (or by rote learning). But in these POEIA lessons we were actively involved in the teaching and learning processes making us have better conceptual understanding of the organic chemistry concepts taught than in our normal class. This way of teaching has been different from our normal way of teaching and learning processes. We like the approach.*

*Researcher: Did you have hard time in doing different POE instructional approach activities?*

*SSTs*: *Almost all of the interviewees expressed their views that the POEIA based organic chemistry lessons were very good but challenging. in fact, the POEIA based activities engaged us in critical thinking with regards to our predictions and explanations. Some of the statements that illustrate these responses are that "the activities involved much use of us to use our the brains"; it made us think critically, perform hands-on and minds-on activities, analyse our results and discuss the concept we learnt thoroughly among ourselves.*

*Researcher: Were the POEIA materials useful for teaching you concepts understudy?*

*SSTs*: *Yes sir. In general, the POE instructional materials were very good, very positive and very appropriate to use. The POE materials (POE worksheets, activity guides, etc) and the POEIA lessons instructions were very clear, appropriate for our level of learning and they presented the concepts understudy in simple and logical sequence, which made it easy for us to follow and understand better. In fact, the POE materials were very useful to us.*

*Researcher: Has the POEIA intervention activities help you to improve on your performance and attitudes towards selected topics in the organic chemistry?*

*SSTs*: *Yes please. In fact we are 100% sure. The POEIA intervention activities has helped us to improve our performance and also developed positive attitudes towards organic chemistry concepts taught. The approach is simple and easy to use and understand. In this POEIA, the lessons are too practical as you predict an event, you perform experiment on it and discuss your findings with others in a cooperative manner. This approach involved the use of more of our senses in learning; and that the more we used our senses to learn the better we understand the concept better. In a nutshell, we say the POEIA has helped us very much in learning the organic chemistry concepts very well.*

*Researcher: Are you in favour of using POE instructional approach in teaching you organic chemistry; and that do you want it to be continued in your college?*

*SSTs*: *Ooh yes please. We like the conducive learning environment associated with the POE instructional approach and the way we learn in a collaborative manner from each other. In fact we would be very much happy if learning of chemistry continues this way until we write our final examination. We are in support of this unique instructional approach and we wanted it to be continued in this college especially in the teaching and learning of sciences.*

*Researcher: Do you have any comments, suggestions or other things you would like to say which you think might be useful?*

*SSTs*: *We loved this method of teaching. In fact, we were more than the word convinced. The approach was very good because it created good learning environment and better cooperation among us; our tutor and other facilitators. We want our COE chemistry tutors and tutors of other disciplines to use the POE instructional approach in their teaching. This would make their teaching very effective, interesting and fun. The POEIA strategy provides us with analogical situation for the teaching and learning abstract concept such as organic chemistry concepts.*

These responses and the data in Table 18 shows that science student-teachers who took part in this study had positive impressions with respect to the POEIA module used in the teaching and learning of the selected organic chemistry topics.

### 4.3 Discussion of the Results

The result of the present study indicated that the science student-teachers who took part in this study had difficulties in learning the selected topics in organic chemistry. At the beginning of the study, it was observed that all the 40 respondents had done organic chemistry before, and that they were expected to have better conceptions or conceptual understanding in the organic chemistry topics understudied. However, it was noticed that although all the participants had undertaken organic chemistry before, yet their performance in the pre-intervention test and in the pre-interview schedule (SSTPIS) before the POEIA intervention activities was not the best. It was observed that almost all the science student-teachers (38 out of 40) representing 95.0% indicated that organic chemistry was a difficult subject for them. This finding implies that the college of education science student-teachers in this study perceived organic chemistry to be very difficult to learn. This finding is in agreement with the results of other researchers (Wasacz, 2010; O'Dwyer & Childs, 2010; Hanson, 2017). These researchers reported that organic chemistry concepts were difficult for many students to learn, as its very fundamental concepts were insufficiently understood by these students.

Moreover, it was revealed that majority (50.0% or more) of the participants indicated that benzene, amines; carbonyl compounds, polymers and polymerization, and separation and purification of organic compounds were the five topmost difficult organic chemistry topics they had encountered ever since they started learning organic chemistry. The frequency and percentages of these five topmost difficult organic topics were benzene 38(95.0%), amines 36(87.5%), carbonyl compounds 35(87.5%), polymers and polymerization 34 (85%), and separation and purification of organic compounds 31(77.5%). This finding means that the research subjects in this study perceived or viewed benzene, amines, carbonyl compounds, polymers and polymerization and separation and purification of organic compounds as the five topmost difficult topics they had encountered ever since they started learning organic chemistry from their senior high school days. This finding means that the participants' learning difficulties could be traced or might be pre-dated from their senior high school days. This finding is in consonance with the results of Nartey and Hanson (2021) that polymers and polymerization (69%), structure and stability of benzene (65%), reactions of benzene (60%), naming of alkanes and structural isomerism (56%), and petroleum (54%) were the five topmost difficult topics among the selected senior high school students used for their study.

Also, it was observed that majority of the respondents indicated that alkenes, alkynes, alkanols, aldehydes, ketones, alkanoic acids, alkanoates, acid anhydrides and amines were the nine most difficult topics to learn in their COE organic chemistry curriculum. These nine identified difficult topics had mean score of 2.5 and above. Also, seven topics namely introduction to organic chemistry, bonding and type of hybridization in carbon, qualitative elemental analysis, quantitative elemental analysis, alkanes, acid halides and acid amides were identified as less or not difficult topics to learn in their COE organic chemistry curriculum (with mean score of less than 2.5). Ketones with the highest mean score of 2.9 was perceived to be the most difficult topic to learn, alkanols and alkanoic acids had the best mean score of 2.5 each, whereas introduction to organic chemistry had the lowest mean score of 1.3 and was perceived as the easiest topic to learn in their COE organic chemistry curriculum. This finding implies that out of the 16 organic chemistry topics in their curriculum, these science student-teachers had learning difficulties with nine of them. Based on this finding, it can be concluded that science student-teachers who took part in this study encountered or had learning difficulties with most of the topics in their COE organic chemistry curriculum.

Again, it was found out that majority of the participants (with their percentage scores) indicated that organic synthesis (95.0%); organic reaction mechanisms (85.0%); organic reactions (82.7%), IUPAC nomenclature (77.5%), preparation of organic compounds (67.5) and isomerism (57.5%) were the most difficult aspects to learn in their COE organic chemistry curriculum. This finding means that the research subjects perceived organic synthesis, organic reaction mechanisms, organic reactions, IUPAC nomenclature, preparation of organic compounds and isomerism as the six most difficult aspects to learn in their COE organic chemistry curriculum. This finding is consistent with the results of Eticha and Ochonogor (2017) that majority of the students had conceptual difficulties in learning organic chemistry concepts including IUPAC nomenclature; stereochemistry, organic reactions and reaction mechanisms. Also, it was revealed that majority of these participants indicated that structure and properties of organic compounds (70.0%), drawing of structures (65.0%), functional group identification (60.0%) and classification of organic compounds (57.5) were the four aspects in their organic chemistry curriculum that were not difficult to learn. Moreover, the most difficult aspect to learn was organic synthesis, with isomerism as average/moderately difficult, whereas structure and properties of organic compounds was the less difficult aspect to learn in their curriculum. This finding implies that out of the ten aspects of organic chemistry to be studied in their curriculum, these research subjects had learning difficulties with six of them. Based on this finding, it can be concluded that science student-teachers in this study encountered learning difficulties with respect to some aspects in their COE organic chemistry curriculum. This finding is in agreement with the results of other researchers (McClary & Bretz, 2012; Graulich, 2015; Nartey & Hanson, 2021; Anim-Eduful & Adu-Gyamfi, 2022), who found that students encountered conceptual difficulties in learning organic chemistry at all levels of education including colleges of education.

The result of this study also revealed that there were several possible causes of the COE science student-teachers' conceptual difficulties in learning the selected topics in organic chemistry. It was observed that all the 40 participants representing 100% unanimously agreed that the organic chemistry syllabus was too broad. There was also no remedial action by the COE tutors for the student-teachers due to their work overload. It appears that these two concerns were the major causes of the science student-teachers' conceptual difficulties in learning the selected topics. Thus, it can be concluded that organic chemistry syllabus was too broad, and lack of remedial action by COE tutors for science student-teachers due to their work overload were the two major causes of research subjects' conceptual difficulties in learning the selected organic chemistry topics. This finding supports the assertion made by Taber (2002a) that the major causes of students' difficulties in learning organic chemistry were the broad and abstract nature of the organic chemistry topics in their syllabus. The finding is similar to that made by Tilahun and Tirfu (2016). These researchers attributed the causes of students' difficulties in learning organic chemistry to the chemistry teachers' inability to organise or conduct remedial action for their students when teaching organic chemistry lessons in schools.

Other possible causes of the research subjects' conceptual difficulties in learning the selected topics in organic chemistry identified in this study were lack of teaching and learning materials (TLMs:- e.g., models, ICT software, etc.), inadequate/lack of laboratory practical activities, inadequate time allocated for organic chemistry lessons, difficulty in understanding various abstract organic chemistry topics, ineffective teaching methods used by teachers, science student-teachers' poor attitudes towards organic chemistry, presence of student-teachers misconceptions, lack of interests in organic chemistry, difficult language often use by teachers in teaching organic chemistry, lack of motivation, lack of required textbooks, presence of COE tutors' misconceptions in organic chemistry, science student-teachers fear of organic chemistry, abstract and difficult nature of the organic chemistry topics and poor foundation in organic chemistry. This finding shows that there were several factors that cause science student-teachers' conceptual difficulties in learning the selected topics in organic chemistry. This finding is in consonance with the results of several researchers (Yara, 2009; Hand & Choi, 2010;

O'Dwyer & Childs, 2014; Afadil & Diah, 2018). These researchers noted that there were several causes of students' learning difficulties in organic chemistry.

The results of this study also showed that most of the science student-teachers in this study possessed different levels of conceptual understanding. These levels ranged from sound understanding through specific misconception to no response with respect to IUPAC nomenclature, organic reaction mechanisms, functional group identification and balancing of organic equations involving combustion of hydrocarbons (alkanes, alkenes and alkynes). It was observed that majority of these research subjects had average conceptual understanding levels with respect to IUPAC nomenclature of organic compounds. Majority of them showed better performance in writing correct IUPAC nomenclature for five out of the ten given organic compounds, and these compounds were alkane molecule without a substituent, alkane molecule with substituents, alkene, alkanol, and alkanoic acid with few misconceptions about them. Based on this finding, it can be concluded that majority of the research subjects had better conceptual understanding with respect to correct IUPAC nomenclature for alkane molecule without a substituent, alkane molecule with substituents, alkene, alkanol and alkanoic acids. This finding contradicts the results of Sendur (2012) that only few 22(31.4%) prospective science teachers showed good conceptual understanding in naming organic compounds and that majority of them 48(68.6%) had difficulties in naming organic compounds.

However, it was found out that most of these research subjects demonstrated low level of conceptual understanding in terms of correct IUPAC nomenclature for alkyne molecule with substituents, cycloalkyne, aldehyde, ketone and amine, and they had several misconceptions on these five organic compounds as outlined in Tables 10a to 10e of this study. The organic compound $CH_3CH_2CH_2CH_2CH_3$, with IUPAC name of pentane or n-pentane had highest conceptual understanding level of 34 (85.0%), whereas the compound $CH_3NH_2$, with correct IUPAC name of aminomethane had the lowest conceptual understanding level of 5(12.5%) among the respondents.

Moreover, a shocking observation made in this study was that majority of the participants had conceptual difficulties in writing correct IUPAC nomenclature for alkane molecule with substituents, $CH_3CH_2C(Cl)_2CH_2(C_2H_5)$ than in writing correct IUPAC name for an alkane molecule without a substituent, $CH_3CH_2CH_2CH_2CH_3$. This finding implies that naming alkane molecule with organic substituents tended to be very difficult for the participants than naming an alkane without substituents. Based on this finding, it can be concluded that participants had difficulties in naming alkane molecule with substituents, and these difficulties might be attributed to their inability to identify the correct number of carbon atoms in parent chain, to identify substituents present and their correct positions, and to identify the functional group present in the organic molecule. This finding is consistent with the results of other researchers (Sendur, 2012; Adu-Gyamfi et al., 2017). These researchers found that students had learning difficulties in naming structural formulae of branched-and substituted-chains of alkanes and alkenes and unbranched alkynes; and that most of them had misconceptions on these topics.

Another shocking revelation observed in this study was that quite a significant number of the participants had conceptual difficulties in giving the correct IUPAC name for cycloalkyne than that of aliphatic alkyne. This finding implies that writing the correct IUPAC name for a cycloalkyne tended to be more difficult for them, and that they had some misconceptions on it as outlined in Table 10b than giving the correct IUPAC name for aliphatic alkyne. Most of them wrote benzene instead of cyclohexyne or cyclohex-1-yne. This finding is in support with the results of Şendur (2012) that students had difficulties in writing correct IUPAC names for certain cycloalkynes.

It was also revealed that almost all the science student-teachers in this study demonstrated low conceptual understanding regarding organic reaction mechanisms, and therefore, they had some misconceptions on reaction mechanisms as outlined in Tables 11 and 12. It was observed that although the participants had conceptual difficulties with respect to organic reaction mechanisms however, quite a significant number of them (11, 27.5%) demonstrated better conceptual understanding for the reaction mechanism (2b) involving alkanoic acid reacting with alkanol in the presence of heat and concentrated $H_2SO_4$ as a catalyst to produce ester and water than that of 5(12.5%) of reaction mechanism (2a) involving chlorine molecule which undergoes homolysis or homolytic cleavage in the presence of UV light or heat with peroxide as a catalyst to give chlorine free radicals. This finding shows that the respondents had conceptual difficulties in illustrating reaction mechanism (2a) than that of (2b). This might be due to the facts that reaction mechanism (2b) is commonly seen in most of their textbooks and also often used as example by tutors when teaching and that most of them did not have much difficulty with respect to reaction mechanism (2b). Moreover, the study also revealed that less than half, 20(50.0%) of these research subjects were able to illustrate each of these reaction mechanisms correctly. Based on this finding, it can be concluded that only few science student-teachers showed good conceptual understanding and performed well in both reaction mechanisms with majority of them having misconceptions on these two reaction mechanisms. Further analysis of the research subjects' SSTPIS answer sheets (in Appendix B) showed that they possessed several misconceptions on these two organic reaction mechanisms, and some of their misconceptions identified in this study were:

1) Inability to show correct signs or symbols on the products.
2) Shows only one curved-arrow notation and wrong notation sign (+) on only one of the products.

3) Inability to show both curved-arrow notations and reversible signs.
4) Inability to show full curved-arrow notations and failure to use reversible sign.
5) Failure to show the reagent and condition for the reaction mechanisms.

Based on these findings, it can be concluded that science student-teachers in this study demonstrated low conceptual understanding levels with respect to organic reaction mechanisms. These findings are consistent with the results of other researchers (Bhattacharyya & Bodner, 2005; Eticha & Ochonogor, 2017). These researchers reported that majority of students had misconceptions regarding organic reaction mechanism and that only few students showed good conceptual understanding and did well in the illustrations of the organic reaction mechanisms.

It was also observed that majority of the science student-teachers demonstrated very good conceptual understanding in relation to functional group identification and therefore, they possessed fewer misconceptions. Majority of them performed better in six out of the ten given organic compounds namely alkane molecule without a substituent, alkane molecule with substituents, alkene, alkyne (aliphatic), alkanol and alkanoic acid. Again, it was observed that majority of them had conceptual difficulties in four remaining organic compounds namely alkyne (in cyclic form), aldehyde, ketone and amine, with amine ($NH_2$) being the most difficult functional group to be identified by the respondents. It was found out that most of these participants had some misconceptions on these four perceived difficult organic chemistry compounds as outlined in Tables 14(a) to 14(d). The organic compound $CH_3NH_2$, with amine or $NH_2$ functional group had the lowest conceptual understanding of 5(12.5%) among the respondents, whereas the compound $CH_3CH_2CH_2CH_2CH_3$, with an/the alkane (C-C) functional group had the highest conceptual understanding of 37(92.5%) with respect to functional group identification. This means that the performance of the respondents in the functional group identification was quite good for six compounds and poor for the other four organic compounds. Based on this finding, it can be concluded that the respondents' performance in functional group identification was quite good. This finding contradicts the results of Akkuzu and Uyulgan (2016) that most students had difficulties in learning functional groups identification including the physical properties of the functional groups.

However, a shocking observation made in this study was that quite a significant number of the science student-teachers (37, 92.5%) were able to identify the functional group for alkane molecule without a substituent correctly than the number of respondents (35, 87.5%) who identified the functional group for an alkane molecule with substituents. Another shocking revelation was that majority (34, 85.0%) of the science student-teachers were able to identify functional group for alkyne (aliphatic or straight-chain alkyne) but only a handful of them (15, 37.5%) were able to identify the functional group for alkyne (cycloalkyne) with most of them identified it as the benzene functional group. This finding indicated that although some (few) of the research subjects had conceptual difficulties giving correct functional group identification for four of the ten given organic compounds generally, most of them had better conceptual understanding with respect to functional group identification for most (six out of ten) of these organic compounds. This finding contradicts the results of Akkuzu and Uyulgan (2016) that only few students generally had better understanding and that majority of them had conceptual difficulties and misconceptions with respect to the functional group identification.

It was also revealed that science student-teachers in this study had conceptual difficulties in relation to correct balancing of organic equations involving combustion reaction of hydrocarbons and therefore, possessed some misconceptions on them as outlined in Table 15. Out of the three complete but unbalanced equations involving combustion of hydrocarbons (alkane-methane; alkene-ethene; and alkyne-ethyne), majority of them (23 out of 40) representing 57.5% performed better in equation (4a) by given the correct balanced equation involving combustion of alkane (methane). Again, it was observed that majority of them (25 out of 40) representing 62.5% had conceptual difficulties, with only 15 (37.5%) of them showed better conceptual understanding and performed well with respect to equation (4b) involving correct balanced equation for combustion of alkene (ethene). Also, it was revealed that majority of them (32 out of 40) representing 62.5% had conceptual difficulties, with only 8(20.0%) showed good conceptual understanding and did well with respect to equation (4c) involving correct balanced equation for combustion of alkyne (ethyne). This finding implies that majority of science student-teachers had better conceptual understanding in relation to correct equation balancing of the combustion of alkane (methane), but almost all of them demonstrated low conceptual understanding in providing the correct combustion equation balancing of alkene (ethene) and that of alkyne (ethyne). This means that correct balancing of equation involving combustion of alkyne (ethyne) tended to be much difficult for them than that of the correct balancing of equations involving combustion of alkene (ethene). This finding means that although majority of the research subjects were able to balance equation involving combustion of alkane (methane) correctly. Generally, their performance with respect to the balancing of equations involving combustion reaction of alkene (ethene) and that of alkyne (ethyne) were quite poor and problematic. Therefore, it can be concluded that these research subjects had conceptual difficulties with respect to balancing equations involving combustion reaction of hydrocarbons and that they had misconceptions on these concepts. This finding is in consonance with that of Baah and Ghartey (2012), who observed that out of 334 students only 71(21.3%) of the students were able to balance equations of combustion reactions involving hydrocarbons correctly. The study concluded that less than one quarter had good conceptual understanding in correct balancing of equations of combustion reactions of hydrocarbons, with as many as 263(78.7%) had misconceptions in relation to correct balancing of combustion equations of the hydrocarbons.

The study also revealed that science student-teachers' performance in the post-intervention test was far better than that of the pre-intervention test. This means that these participants' performance had improved greatly after they have been exposed to "predict-observe-explain instructional approach" (POEIA) intervention activities. This improved performance of the science student-teachers might be attributed to the POEIA intervention activities used in teaching and learning of the selected topics in organic chemistry including hydrocarbons, alkanols, carbonyl compounds, alkanoic acids, esters and amines. The POEIA intervention activities helped to organise the science student-teachers' conceptual structures in a particular way to aid in better understanding of these topics. This finding is in agreement with the results of several researchers (Yavuz & Celik, 2013; Hilario, 2015; Ojo & Owolabi, 2021; Özcan & Uyanık, 2022; Harman & Yenikalayci, 2022). These scholars reported that the POE instructional approach (POEIA) was very effective in improving students' performance in any scientific concepts than the traditional lecture/expository methods of teaching.

Moreover, the study showed that there was a statistically significant improvement in science student-teachers' performance with respect to their mean pre-intervention test and that of their post-intervention test score. In fact, the POE instructional approach had been found to contribute significantly to students' performance or achievement at all grades levels, in different subject areas and in different geographical locations. Similar findings have been reported by other researchers (Vadapally, 2014; Hilario, 2015; Özcan & Uyanık, 2022; Harman & Yenikalayci, 2022). These researchers found that students who took part in the POE instructional approach based-lessons had statistically significant improved performance in their studies.

The results of this study also showed that science student-teachers had positive attitudes towards the use of POEIA intervention activities in the teaching and learning of the selected topics in organic chemistry. For example, almost all of them (37 out of 40) representing 92.5% strongly agreed that the POEIA was more engaging during teaching and learning processes of the concepts taught than usual traditional expository/lecture instructions, with only 1(2.5%) of them was uncertain whereas 2 (5.0%) of them disagreed to the same statement. This finding means that the POEIA intervention activities engaged them better than traditional lecture method often used by tutors. Again, almost all of them (36 out of 40) representing 90.0% vehemently agreed that the POEIA helped them to develop their positive attitudes towards the learning of organic chemistry topics taught, 2(5.0%) of them were uncertain, whiles another 2 (5.0%) of them disagreed to the same statement item. This finding implies that almost all the science student-teachers agreed that the POEIA had helped them to develop their attitudes positively towards the learning of organic chemistry topics taught. Also, it was observed that majority of the research subjects indicated that the POEIA gave them enough time to perform more practical activities on the organic chemistry topics taught, had increased their motivation to learn and also gave them more confidence in the topics taught and had helped them to develop systematic approach to the learning of organic chemistry topics taught. It was revealed that majority of them (35 out of 40) representing 87.5% indicated that the POEIA has helped them to improve on their performance and also had higher morale in the organic chemistry concepts taught, with only 1 (2.5%) was uncertain, whereas 4 (10.0%) disagreed to the same item. Again, overwhelming majority of them (34 out of 40) representing 85.0% indicated that they enjoyed learning organic chemistry concepts taught through activities based on the POEIA, 2 (5.0%) of them were uncertain whereas 4 (10.0%) of them disagreed to the same statement. This finding means that majority of respondents vehemently agreed that they enjoyed learning organic chemistry topics taught through activities based on the POEIA. The higher positive attitudes scores of the science student-teachers in this study might be attributed to the motivation, enjoyment and interests derived by these subjects from the POEIA intervention activities on a prolonged basis. The POEIA intervention activities served as effective teaching and learning aids which aroused their interests and helped them to develop positive attitudes towards the selected organic chemistry topics. Hence, a higher percentage of them expressed their view that they enjoyed learning organic chemistry topics taught through activities based on the POEIA. These findings imply that the use of POEIA intervention activities had impacted positively on their attitudes towards the selected organic chemistry topics. Based on these findings, it can be concluded that the research subjects had positive attitudes towards the use of POEIA in the teaching and learning of the selected organic chemistry topics. This finding is consistent with the results of other researchers (Koseoglu et al., 2004; Ayvaci, 2013; Muna, 2017). These researchers found out that POE instructional approaches could be used to develop students' positive attitudes towards the teaching and learning of the sciences, particularly in organic chemistry.

The study also showed that the designed module could be used to enhance the teaching and learning of the selected organic chemistry topics in the target institutions. The various components of the designed module for the teaching and learning of the selected organic chemistry topics in the target institutions (COE) are discussed below.

**Unit 1: The alkanes**: The learning of alkanes requires learners to have prior knowledge of aspects of alkanes at their senior high school and general chemistry I at the

COE level. This unit involves the introduction to alkanes, sources of alkanes, isomersism, isomerism in alkanes, physical and chemical properties of alkanes and uses of alkanes. It also discussed the laboratory preparation of a named alkane (methane gas), gave summary notes and individual assignments on alkanes. The first unit of the module would assist COE tutors and their leaners in comprehending fully the knowledge on alkanes.

**Unit 2: Alkenes:** This unit involves the learners' RPK, introduction to alkenes, sources of alkenes, isomerism in alkenes, physical and chemical properties of alkenes, test of alkenes and uses of alkenes. It also looked at the laboratory preparation of alkene (ethene gas), provided summary notes and individual assignment on alkenes. The second unit of the module would assists tutors and their learners in the teaching and learning of alkenes at the college level.

**Unit 3: The alkynes:** This unit comprises the learners' RPK, introduction to alkynes, sources, isomerism, physical and chemical properties, test and uses of alkynes. It also looked at the laboratory preparation of a named alkyne (ethyne gas), gave summary notes and individual assignment on alkynes. It was observed in their pre-interview schedule, worksheets and the pre-intervention test that majority of them had learning difficulties about this topic. Thus, the third unit of the module would assist tutors and their leaners with respect to the teaching and learning of alkynes at the college level.

**Unit 4: Alkanols (alcohols):** This unit presents the learners' RPK on alkanols, introduction to alkanols, sources, isomerism, physical and chemical properties, test and uses of alkanols. It also looked at the laboratory preparation of a named alkanol (ethanol), provided summary notes and individual assignments on alkanols. The fourth unit of the module would enhance the teaching and learning of alkanols at the college level.

**Unit 5: Carbonyl compounds:** This unit presents the learners' RPK on carbonyl compounds, introduction to carbonyl compounds, isomerism, physical and chemical properties, test and uses of carbonyl compounds. It also looked at the laboratory preparation of a named carbonyl compound (ethanal, an aldehyde), gave summary notes and individual assignments on carbonyl compounds. The fifth unit of the module would enhance the teaching and learning of carbonyl compounds at the college level.

**Unit 6: The alkanoic (carboxylic) acids:** This unit involves the learners' RPK on alkanoic acids, introduction to alkanoic acids, isomerism in alkanoic acids, physical and chemical properties of alkanoic acids, test and the uses of alkanoic acids. It also looked at the laboratory preparation of a named alkanoic acid (ethanoic acid), provided summary notes and assignments on alkanoic acids. The sixth unit of the module would enhance the teaching and learning of alkanoic acids at the college level.

**Unit 7: Alkanoic acid derivative: Alkanoates (Esters)**: This unit involves the learners' RPK on alkanoates, introduction to alkanoates, sources of alkanoates, physical properties alkanoates, chemical properties and uses of alkanoates. It also discussed the laboratory preparation of a named alkanoate (ethylethanoate), gave summary notes and assignments on alkanoates. The seventh unit of the module would enhance the teaching and learning of alkanoates among tutors and their learners at the college level.

**Unit 8: Amines:** This unit involves the learners' RPK on amines, introduction to amines, sources of amines, isomerism in amines, physical properties of amines, chemical properties of amines, test for amines and uses of amines. It also discussed the laboratory preparation of a named amine (ethylamine/ethanamine), provided summary notes and assignments on amines. The eighth unit of the module would enhance the teaching and learning of amines among tutors and their learners at the college level.

Moreover, an interesting dimension was provided by the interview conducted for the ten selected research subjects which constituted the small focus group used in the study. Almost all of them seemed content with the POE instructional approach they used to learn the selected organic chemistry topics. This might be attributed to the fact that these science student-teachers made significant gains in their performance and also developed positive attitudes after the POE instructional approach intervention activities. Reflections of the science student-teachers' responses from the small focus group interview illustrate several opportunities that arise when using the POE instructional approach in the teaching and learning of the selected organic chemistry topics.

The first opportunity for learning using POEIA was provided by visualisation and conceptualisation of the abstract organic topics taught through making hypothesis in the form of predication, manipulating of physical objects (experimentation in observe stage), viewing the results and seeking casual explanations in the form of discussion. The POE materials in the form of modules were designed such that in the course of using them, they served as aids that allowed these science student-teachers to involve themselves actively in the teaching and learning processes. Moreover, the POE instructional approach provided opportunity for learning by engaging them in active learning process and for self-assessment of their performance through the designed POE activity guides and worksheets. Most of them reported that the activity guides and worksheets served as alternative source of exercises after class sessions.

Reflections of the research subjects' responses from the interviews also showed that their opinions or views on the POE instructional approach were positive. They were of the view that the module/materials for this approach were very clear, appropriate for their level and also presented the organic chemistry topics in simple and logical sequence. Some of the interviewees indicated that they were first scared to express their views in writing in the form of prediction, what if they wrote wrong predictions but the strategy helped them to overcome their fears. This result means that the science student-teachers had positive perceptions about the POE instructional approach used in the teaching and learning process. This finding is in consonance with the results of Hilario (2015) that the experimental group leaders had positive perceptions of the POE based lessons and that some of them indicated that they were first scared to express their views in writing, but the strategy helped them to overcome their fears.

The science student-teachers also acknowledged and appreciated the conducive learning environment associated with the POE instructional approach. Majority of them stated categorically that they were in support of this unique instructional approach and that they wanted this approach to be continued in their college especially in the teaching and learning of sciences even after the study. Most of them indicated that they would be very much happy if the teaching and learning of chemistry continued this way until they wrote their final examinations. This means that POE based lessons tended to provide conducive learning environments for the science student-teachers in learning the selected organic chemistry topics. This finding is consistent with the results of Hudson (2010; 2012) that students who took part in POE tasks based instructions noted that the use of POE learning strategies created positive learning environments for them to learn.

Finally, these expressions made by the science student-teachers demonstrated that they had positive impressions and perceptions with respect to the POE instructional approach (POEIA) intervention activities used in the teaching and learning of the selected organic chemistry topics. This finding is consistent with the results of other researchers (Vadapally, 2014; Sutopo et al., 2016; Demircioğlu, 2017) that students at various levels of education including university have positive views and perceptions regarding POE instructional approach in both the classroom and laboratory settings.

# CHAPTER FIVE

## SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

### 5.0 Overview of the Study

This chapter covers the summary of the study, key findings, conclusions, recommendations, educational implications and suggestions for further studies. Also, included are the contributions of the study to science education and the contributions of the study to knowledge.

### 5.1 Summary of the Study

The study sought to assess the effects of predict-observe-explain instructional approach (POEIA) on Foso College of Education science student-teachers' performance and attitudes towards selected organic chemistry topics. Specifically, the objectives of the study were:

1) To find out the COE science student-teachers' difficulties in learning the selected topics in organic chemistry.
2) To identify the possible causes of the COE science student-teachers' conceptual difficulties in learning the selected topics in organic chemistry.
3) To explore the science student-teachers' conceptions of the selected topics in organic chemistry.
4) To evaluate the effects of POEIA on the science student-teachers' performance in the selected topics in organic chemistry.
5) To assess the impact of POEIA on the science student-teachers' attitudes towards the selected topics in organic chemistry.
6) To design a module that could be used to enhance the teaching and learning of the selected organic chemistry topics in the target institution.

An action research was the design employed for the study. A total sample size of forty (40), 2021-2022 second year science student-teachers pursuing organic chemistry (as part of General Chemistry Theory II) participated in the study. The 40 science student-teachers were made up of 32 (80.0%) males and 8 (20.0%) of them being females. The ages of the participants ranged between 20 and 34 years, with an average age of 23 years. Per the Ghana's 1992 constitution, they were considered as matured and adults. Thus, their responses were considered to come from matured science student-teachers. A purposive sampling technique of the non-probability sampling procedure was used to select the 40 research subjects in an intact class for the study.

These research subjects were selected because all of them in that class offered chemistry as an elective course. Again, the use of the level 200 or second year science student-teachers was dictated by two factors. Firstly, the organic chemistry featured prominently in the level 200 General Chemistry Theory II curriculum or course outline (Unit 3; pp. 6 -10) and these science student-teachers were studying it at the time of conducting this study. Secondly, almost all of them in that class had difficulties in learning some topics in organic chemistry. The whole class was used for the study because the study was incorporated into the normal teaching period without disrupting the academic calendar of the College. Interview, test and questionnaire were the three instruments used to collect data for the study. In addition, written documents such as daily observational notes, document analysis and audiotapes were made to augment data that were obtained from the main instruments. The combination of these approaches ensured triangulation of the collected data. Data obtained from the study were analysed using both quantitative and qualitative data analysis methods. Statistical Package for Social Science (SPSS) version 21.0 for window was used for data analysis and Microsoft excel program was used to present the data pictorially into Tables and charts (pie-charts and bar charts).

## 5.2 Key Findings

The key findings of the study are:

1. All the 40 (100%) science student-teachers unanimously agreed that they had studied organic chemistry before; and that they were expected to have better conceptual understanding and performed very well in the selected organic chemistry topics at the beginning of the study.
2. Almost all the science student-teachers (38 out of 40) representing 95.0% perceived organic chemistry to be very difficult to learn and comprehend.
3. Benzene, amines, polymers and polymerization, separation and purification of organic compounds and carbonyl compounds were identified as the five topmost difficult organic chemistry topics they had ever encountered since they started learning organic chemistry from their SHS level.
4. Alkenes, alkynes, alkanols, aldehydes, ketones, alkanoic acids, alkanoates, acid anhydrides and amines were identified as the nine difficult topics to learn; with ketones being the most difficult topic.
5. Introduction to organic chemistry, bonding and type of hybridization in carbon, qualitative elemental analysis, quantitative elemental analysis, alkanes, acid halides and acid amides were identified as less (not) difficult topics, with introduction to organic chemistry being the less difficult topic to learn in their COE organic chemistry curriculum.
6. Majority of them perceived organic synthesis, organic reaction mechanisms, organic reactions, IUPAC nomenclature, preparation of organic compounds and isomerism as the six most difficult aspects to learn in their COE organic chemistry

curriculum; whiles structure and properties of organic compounds, drawing of structures, functional group identification and classification of organic compounds were the four not (less) difficult aspects to learn at college level.

7. All the 40 (100%) research subjects unanimously agreed that the organic chemistry syllabus was too broad, and lack of remedial actions by COE tutors for science student-teachers due to their work overload were the two major causes of their conceptual difficulties in learning the selected organic chemistry topics.
8. Lack of teaching and learning materials (e.g., models, ICT software, etc.), inadequate/lack of laboratory practical activities, inadequate time allocated for organic chemistry lessons, ineffective teaching methods used by tutors, science student-teachers' poor attitudes towards organic chemistry, presence of student-teachers misconceptions and poor foundation in organic chemistry were the other possible causes of the research subjects' conceptual difficulties in learning the selected organic chemistry topics.
9. Majority of the science student-teachers possessed varied degrees of conceptions ranging from sound understanding through specific misconception to no response with respect to IUPAC nomenclature, organic reaction mechanisms, functional group identification and correct balancing of combustion equations involving hydrocarbons (alkanes, alkenes and alkynes).
10. Majority of the respondents had average conceptual understanding with respect to IUPAC nomenclature of ten organic compounds, by exhibited sound conceptual understanding for correct IUPAC nomenclature of five compounds namely alkane molecule without a substituent, alkane molecule with substituents, alkene, alkanol, and carboxylic acid, but also demonstrated low level of conceptual understanding for other five other organic compounds namely alkyne

molecule with substituents, cycloalkyne, aldehyde, ketone and amine, and they had several misconceptions on these organic compounds.

11. A shocking observation made in this study was that majority of the subjects had conceptual difficulties in writing correct IUPAC nomenclature for alkane molecule with substituents $CH_3CH_2C(Cl)_2CH_2(C_2H_5)$ than in writing correct IUPAC nomenclature for an alkane without a substituent $CH_3CH_2CH_2CH_2CH_3$.
12. Quite a significant number of science student-teachers had conceptual difficulties in writing the correct IUPAC nomenclature for a cycloalkyne than providing the correct IUPAC name for an aliphatic alkyne.
13. Majority of the respondents demonstrated sound conceptual understanding with respect to functional group identification; with fewer misconceptions; but almost all them demonstrated low conceptual understanding in relation to organic reaction mechanisms, and correct balancing of equations involving combustion of hydrocarbons and thus, they had several misconceptions on these concepts.
14. Another shocking revelation was that majority (34, 85.0%) of the respondents were able to identify functional group for straight-chain alkyne, but only handful of them (15, 37.5%) were able to identify functional group for cycloalkyne with most of them identified cycloalkyne as benzene functional group.
15. Science student-teachers' performance in the selected organic chemistry topics had improved significantly after they had been exposed to the POEIA intervention activities.
16. Science student-teachers had higher positive attitudes towards the POEIA used in the teaching and learning of the selected organic chemistry topics.
17. The views of the science student-teachers on the POEIA module were very positive. They indicated the POEIA was very effective and the POE materials

used were very clear, appropriate and presented the topics understudied in simple and logical sequence. They stated categorically that the designed module could be used to enhance the teaching and learning of the selected organic chemistry topics at the COE level.

18. Finally, several opportunities that arose when science student-teachers use the POEIA in learning scientific concepts were revealed. They were provided with the opportunity for a private dialogue with the teacher and among themselves to share their views and uncover their misconceptions. They indicated that the POEIA was fun and very helpful in engaging them actively in the teaching and learning process; improved their performance and attitudes towards the selected organic chemistry topics taught; and that they wanted it to be continued in the college for the teaching and learning of the other science courses.

## 5.3 Conclusions

This research drew its motivation from the reported impact and efficacy of the POE instructional approach (POEIA) in the teaching and learning of the selected topics in organic chemistry in different cultural contexts (Bilen & Aydogdu, 2010; Hilario, 2015; Çalış & Özkan, 2022) and thus, an action research was conducted to evaluate its effectiveness on second year science student-teachers in a typical science-based college of education studying organic chemistry in a typical African context of Ghana.

The study revealed that almost all the science student-teachers (38 out of 40) representing 95.0% perceived organic chemistry to be difficult for them to learn at the beginning of this study, although all of them had studied organic chemistry before. Also, since they had done organic chemistry before, they were expected to have better understanding in the topics understudied. However, it was noticed that their performance before the start of the POEIA intervention activities was not the best. Moreover, they indicated that benzene, amines, polymers and polymerization, separation and purification of organic compounds and carbonyl compounds were the five topmost difficult organic chemistry topics they had encountered ever since they started learning organic chemistry from their senior high school level to date. A higher proportion of them were of the view that alkenes, alkynes, alkanols, aldehydes, ketones, alkanoic acids, alkanoates, acid anhydrides and amines were the nine most difficult topics to learn in their COE organic chemistry curriculum. Again, most of them perceived organic synthesis, organic reaction mechanisms, organic reactions, IUPAC nomenclature, preparation of organic compounds and isomerism as the six most difficult aspects to learn in their curriculum.

The study also concluded that organic chemistry syllabus being too broad, and lack of remedial action by COE tutors for them were identified among all the respondents as the two major possible causes of their conceptual difficulties in learning the selected organic chemistry topics. Moreover, lack of teaching and learning materials, inadequate/lack of laboratory practical activities, ineffective teaching methods used by teachers, science student-teachers' poor attitudes towards organic chemistry, and poor foundation in organic chemistry were the other causes of their difficulties in learning the selected topics. Thus, it can be concluded that there were several causes of the respondents' conceptual difficulties in learning the selected organic chemistry topics.

Again, the results of the study also indicated that COE science student-teachers used in this study had better conceptual knowledge with respect to functional group identification, but had low conceptual understanding levels for IUPAC nomenclature, organic reaction mechanisms, and correct balancing of equations involving combustion of hydrocarbons and therefore, had misconceptions on these concepts. It was found that majority of them (34, 85.0%) were able to identify functional group for straight-chain alkyne, but most of them were not able to identify functional group for cycloalkyne. Only a handful of them (15, 37.5%) were able to give correct functional group for cycloalkyne (cyclohexyne) with most of them indicated that it belongs to benzene functional group.

The results of the study also indicated that science student-teachers who were exposed to the POEIA intervention activities performed better in their post-intervention test scores than that of their pre-intervention test scores. The result also showed statistical significant difference in performance existed between the research subjects' post-intervention test mean scores and that of their pre-intervention test. A significant increase in performance was seen to occur in the research subjects exposed to POE instructional approach. Therefore, it can be concluded that science student-teachers exposed to POEIA retained significantly the selected organic chemistry topics taught better in their class.

The study also revealed that science student-teachers who were taught using the POEIA intervention activities had higher positive attitudes towards the selected topics in the organic chemistry. This important finding was that the use of the POEIA intervention activities to learn these topics, helped stimulated their interests and also developed their attitudes positively towards the selected topics in the organic chemistry.  Thus, it can be concluded that the POEIA intervention activities had impacted positively on the attitudes of the research subjects towards the selected topics in organic chemistry.

The study observed that the research subjects' views or opinions of the POEIA module used in the teaching and learning organic chemistry topics were very positive. They indicated the POEIA was very effective and the POE materials used were very clear, appropriate at their level and presented the topics studied in simple and logical sequence. They also indicated that the designed module could be used to enhance the teaching and learning of the selected organic chemistry topics at the college level.  Also, the POEIA provided the participants with the opportunity to predict with reason, perform experiment (observation), compare their predictions with observation by reconcile any differences and explain their findings in the form of discussions. The approach provided them with opportunity for a private dialogue with the tutor, among themselves and to uncover their misconceptions. They indicated categorically that POEIA was very helpful in engaging them actively in the teaching and learning process, stimulated their interests, improved their performance and developed their attitudes in the selected topics taught. There was general unanimity for the continuation of the POEIA intervention activities by the participants. The study therefore yielding considerable argument in favour of the use of the POEIA for the COE science student-teachers.

In conclusion, the findings of the present study lend credence to the results of several researchers (Bilen & Aydogdu, 2010; Vadapally, 2014; Hilario, 2015; Harman & Yenikalayci, 2022; Çalış & Özkan, 2022). These researchers found that students exposed to POEIA intervention activities showed better performance and a more favourable attitudes towards the scientific concepts taught. Therefore, chemistry tutors in the Ghanaian COE should be encouraged to use the POE instructional approach in the teaching and learning of organic chemistry topics for their science student-teachers to understand meaningfully and thereby, demystify the learning of organic chemistry topics/concepts better in their colleges of education.

## 5.4 Recommendations

Based on the findings of this study, it is recommended that:

1) COE chemistry tutors should adopt innovative teaching strategies such the POEIA so as to help COE science student-teachers to learn abstract organic chemistry topics such hydrocarbons, alkanols, carbonyls, alkanoic acids, esters and amines better at the college level.
2) Stakeholders in COE chemistry education should equip all the Ghanaian COE laboratories with the requisite resources in the form of instructional materials and

reagents/chemicals, computers and softwares, models, etc so as to help in the teaching and learning of the selected organic chemistry topics to them through the use of POEIA activities and thereby demystify chemistry at the colleges.

3) Ministry of Education (MOE) in collaboration with mentoring universities should organized in-service training on the use of the POE instructional approach for the COE chemistry tutors to sharpen their pedagogical content knowledge (PCK) in teaching these abstract organic chemistry topics so that COE tutors can in turn teach these topics better to their science student-teachers.
4) COE chemistry tutors should do well to illicit science student-teachers' misconceptions in various organic chemistry concepts understudied and adopt innovative and effective instructional strategies such as POEIA to help address such misconceptions among their learners during teaching and learning process.
5) COE chemistry tutors should guide and counsel their science student-teachers to develop positive attitudes towards abstract and difficult chemical concepts such hydrocarbons, alkanols, carbonyl compounds, alkanoic acids, esters and amines.
6) Course experts at the various mentoring universities and other stakeholders should take advantage of the on-going review of educational reforms at the COE level to inject some new teaching strategies such as the POEIA into the science programme so that tutors could adopt this approach to improve their student-teachers' performance and attitudes in organic chemistry.
7) COE chemistry tutors should be encouraged to use real life examples and analogies in teaching abstract chemical concepts. POEIA intervention activities and module in the form of POE lesson plans, activity guides and worksheets could help improve science student-teachers' performance and attitudes towards the

learning of organic chemistry concepts and help them to conceptualize whatever concept is taught better or meaningfully.

8) COE chemistry tutors should understand their science student-teachers' learning difficulties in organic chemistry and design appropriate instructional approach such as POE instructional approach for them with relevant hands-on and minds-on activities and also interjections wherever applicable so as to deal with their learning difficulties.
9) COE chemistry tutors should do well to organise remedial action for their science student-teachers so as to help them learn organic chemistry well in the colleges.
10) COE science student-teachers should be empowered to become responsible for their own learning. This can be done when tutors use more innovative teaching methods such as POEIA activities to empower them to learn. This can be done for instance, if a problem is raised or an idea introduced and the tutor supervises the activity or intellectual discussion, where they predict and assign reasons for their predictions, make observations through experiments, compare their earlier predictions with observation in order to address any conflicts.
11) COE chemistry tutors should adopt and use effective teaching methods (e.g. POEIA, activity-oriented methods, etc) so as to help enhance the science student-teachers' conceptual understanding, improve their performance and also develop their positive attitudes towards the selected topics at the college level.

## 5.5 Educational Implications of the Study

The present study was intended to assess the effects of predict-observe-explain instructional approach (POEIA) intervention activities on Foso College of Education science student-teachers' performance and attitudes towards the selected organic chemistry topics. From the discussions and findings, the investigator arrived at the conclusion that POEIA can be employed at the colleges of education lecture halls and/or laboratories to improve science student-teachers' interests, performance and attitudes towards the selected organic chemistry topics.

From the present study, it is proved beyond doubt that POEIA can be applied at the COE level as the investigator could see that the research subjects were seen more active and motivated to learn organic chemistry lessons systematically. But the existing methods used in teaching chemistry at the college level are not helpful in providing enough knowledge as visualized in this approach. Hence, in this study, POE module in the form of lesson plans, their corresponding activity guides and worksheets could that be used to enhance the teaching and learning of the eight selected organic chemistry topics at the college level had been designed. Thus, chemistry tutors would gain enough idea to handle the class easily as shown by this innovative approach.

It is therefore, recommended that the POEIA intervention activities be used by COE chemistry tutors to teach abstract organic chemistry topics at the college level. Moreover, the findings of this present study proved beyond doubt that the application of POE instructional approach is beneficial and hence, it is suggested while framing organic chemistry curriculum at the college level, priority should be given to the POE instructional approach so as to help enhance science student-teachers' predictory-observational-explanatory skills, improved their performance and their attitudes towards chemistry concepts particularly in the selected organic chemistry topics.

## 5.6 Suggestions for Further Studies

The educational implications of the findings of this study calls for further research or studies in the area of using POE instructional approach (POEIA) in improving COE science student-teachers' performance and attitudes towards the selected organic chemistry topics. The following suggestions have been made for further studies. It is suggested that:

1) The study should be replicated for level 200 science student-teachers in COE in other regions of Ghana using lager samples. This would provide a basis for more generalization of conclusions to be arrived at about the effectiveness of POE instructional approach in improving COE science student-teachers' performance in the selected organic chemistry topics.
2) Similar study should be conducted for the second year science student-teachers in the COE in other regions of Ghana using lager samples so that generalisations could be made about the effectiveness of POEIA in developing COE science student-teachers' attitudes towards the various selected organic chemistry topics.
3) Similar study should be conducted with larger samples of male and female science student-teachers in different college settings to find out the differences in performance and attitudes of the males and females towards the selected organic chemistry topics using the POE instructional approach.
4) A similar study should be conducted in COE in other part of Ghana using quasi experimental research design so as to assess the effectiveness of POEIA in improving participants' performance and attitudes in selected organic chemistry topics at college level by comparing it with their control group counterpart.
5) Lastly, it is suggested that more developmental researches should be undertaken, by devising POE teaching methods in the area of technology where POEIA based softwares on various organic chemistry topics can be developed so that science student-teachers can learn these abstract topics/concepts by just the click of button of their laptops and mobile phones.

## 5.7 Contributions of the Study to Science Education

Despite its limitations, the strength of the study lies on its contribution to science education in Ghana. It is envisaged that the success of science education depends mainly on the methodologies used by the science teachers and curriculum developers to enhance understanding, performance and attitudes towards various scientific concepts. Adewuyi (2001) noted that the method of teaching employed by teacher is a potent factor in motivating learners to learn and thereby improve upon their performance and attitudes towards chemistry topics specifically in the organic chemistry. The perennial methods of teaching science through listening, looking and memorising facts have not been successful. If anything, it has resulted in making college of education science student-teachers dislike organic chemistry and also perform poor in organic chemistry. Therefore, reflecting on the challenges Ghanaian colleges of education chemistry tutors and their science student-teachers face in the teaching and learning of the selected organic chemistry topics, the designed POE instructional approach and the materials developed in the form of module are intended to help COE chemistry tutors and their leaners with the teaching and learning of these topics in terms of lesson presentation, group work and assessment of their science student-teachers' learning. The designed POE module (mainly lesson plans, activity guides and worksheets) used in this study could be useful to COE chemistry tutors and their science student-teachers with respect to the teaching and learning of the selected organic chemistry topics.

Curriculum planners and developers as well as course experts would gain vital information from this study that would guide them in designing POE teaching methods and learning activities in the COE chemistry curriculum. They would be better placed to develop, inculcate interesting and innovative POEIA activities that are meant to bring tutors and their learners closer leading to the improvement of the performance and the development of more favourable and purposeful science student-teachers' attitudes towards organic chemistry in the Colleges of Education. In addition, they would be better placed in making certain structural changes in the fields of chemistry education in colleges to encourage the use of predict-observe-explain instructional approach (POEIA) in the teaching and learning of sciences particularly chemistry for that matter organic chemistry in the Ghanaian Colleges of Education.

## 5.8 Contributions of the Study to Knowledge

This study has contributed to knowledge by highlighting the science-based college of education science student-teachers' learning difficulties with respect to the selected topics and some aspects of organic chemistry in their level 200 organic chemistry curriculum. Also, it has outline the possible causes or factors responsible for the science student-teachers' conceptual difficulties in learning the selected organic chemistry topics in relation to Ghanaian COE context. Again, it has contributed to knowledge by revealing science student-teachers' sound conceptions and their specific misconceptions in relation to IUPAC nomenclature, organic reaction mechanisms, functional group identification and balancing of equations involving combustion reactions of hydrocarbons (alkanes, alkenes and alkynes).

Moreover, this study has contributed to knowledge immensely by proving the efficacy or effectiveness of the POE instructional approach thereby providing COE chemistry tutors and other chemistry teachers with effective approach for teaching the selected organic chemistry topics at the college/school levels. This is evident in this study as the science student-teachers' performance was found to be significantly enhanced and their attitudes towards the selected organic chemistry topics were positively impacted by the use of POE instructional approach. This indicates that the use of POEIA could help identify COE student-teachers' misconceptions on the various selected organic chemistry topics/concepts and also help them to improve their performance as well as their attitudes towards the selected organic chemistry topics.

Most importantly, this study has contributed to knowledge by designing a module in the form of POE lesson plans and their corresponding worksheets and activity guides that could be used to enhance the teaching and learning of the selected organic chemistry topics at the College of Education level.

Finally, this present study has also contributed to knowledge by adding to the existing pool of empirical studies with respect to the effectiveness of the POE instructional approach (POEIA) in improving science student-teachers' performance in and their attitudes towards the selected organic chemistry topics at the college level.

# REFERENCES


Acar-Sesen, B. (2013). Diagnosing pre-service science teachers' understanding of chemistry concepts by using computer-mediated predict-observe-explain tasks. *Chemistry Education Research and Practice, 14* (3), 239 - 246.

Acar-Seşen, B., & Mutlu, A. (2016). Predict-observe-explain tasks in chemistry laboratory: Pre-service elementary teachers' understanding and attitudes. *Sakarya University Journal of Education, 6* (2), 184 - 208.

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

Adesanya, L. A. (2009). Education and learner autonomy. In U. M. O. Ivowi, K. Nwufo, C. Nwagbara, J. Ukwungwu, I. E. Emah, G. Uya (Eds.), *Curriculum theory and practice*. (Pp. 123-130). Top Goddy Limited.

Adesoji, F. A., & Raimi, S. M. (2004). Effects of enhanced laboratory instructional technique on senior secondary student's attitude toward chemistry in Oyo township. *Journal of Science Education and Technology, 3*(5), 377- 385.

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

Adom, D., Hussein, E. K., & Agyem, J. A. (2018). Theoretical and conceptual framework: Mandatory ingredients of a quality research. *International Journal of Scientific Research, 7* (1), 438 - 441.

Adu-Gyamfi, K., Ampiah, J. G., & Appiah, J. Y. (2017). Students' difficulties in IUPAC naming of organic compounds. *Journal of Science and Mathematics Education, 6* (2), 77 - 106.

Afadil, A. W., & Diah, M. (2018). *Effectiveness of learning materials with science-philosophy oriented to reduce misconception of students on chemistry*. Dan Press. DOI: 10.2991/ice-17.2018.43 Corpus ID: 186966729.

Agiande, D. U., Wiliams, J. W., Dunnamah, A. Y., & Tumba, D. P. (2015). Conceptual change theory as teaching strategy in environmental education. *European Scientific Journal, 11* (35), 395 - 408.

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.

Ajayi, O. V. (2019). *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.* [PhD Thesis]. Benue State University.

Akgün, A., Tokur, F., & Özkara, D. (2013). Investigation of the effect of poe strategy on teaching pressure. *Amas University Journal of Education Faculty, 2*(2), 348-369.

Akinade, E. A., & Owolabi, T (2009). *Research methods: A pragmatic approach for social, behavioural sciences and education*. Connell Publications.

Akkuzu, N., & Uyulgan, M. A. (2016). An epistemological inquiry into organic chemistry education: Exploration of students' conceptual understanding of functional groups. *Chemistry Education Research and Practice, 17*(1), 36 -57.

Akpan, V. I., Igwe, U. A., Mpamah, I. B. I., & Okoro, C. O. (2020). Social constructivism: Implications on teaching and learning. *British Journal of Education, 8* (8), 49 - 56.

Alfiyanti, I. F., Jatmiko, B., & Wasis, T. (2020). The effectiveness of predict observe explain (POE) model with PhET to improve critical thinking skills of senior high school students. *Studies in Learning and Teaching, 1*(2), 76 - 85.

Anane, E., & Anyanful, V. K. (2016). *Guide for writing and presenting project work.* Institute of Education. University of Cape Coast.

Anderson, T. L., & Bodner, G. M. (2008). What can we do about 'Parker'? A case study of a good student who didn't 'get' organic chemistry. *Chemistry Education Research and Practice, 9* (2), 93-101.

Anim-Eduful, B., & Adu-Gyamfi, K. (2022). Chemistry students' conceptual understanding of organic qualitative analysis. *Pedagogical Research, 7*(4), 1-17.

Anisa, D. N., Masykuri, M., & Yamtinah, S. (2013). Pengaruh model pembelajaran poe (predict-observe and explain) dan sikap ilmiah terhadap prestasi belajar siswa pada materi asam. *Jurnal Pendidikan Kimia (JPK), 2* (2), 16 - 23.

Antwi, S. K., & Hamza, K. (2015). Qualitative and quantitative research paradigms in business research: A philosophical reflection. *European Journal of Business and Managemen*, *7* (3), 217- 226.

Arslan, M., & Emre, I. (2020). The effect of predict-observe-explain strategy on students' academic achievement, scientific process skills and attitude towards science. *Inonu University Journal of the Graduate School of Education, 7*(14), 81- 89.

Astiti, T. D., Ibrahim, M., & Hariyono, E. (2020). Application of poe learning strategies to reduce students' misconceptions in science subjects in elementary school. *Journal of Innovative Science and Research Technology, 5*(7), 437- 445.

Ausubel, D. P. (1968). *Educational psychology: A cognitive view*. Holt, Rinehart and Winston Press.

Ausubel, D. P. (2000). *The acquisition and retention of knowledge*. Kluwer Press.

Awalia, V., Sitompul, S. S., & Hamdani, H. (2016). Remediasi miskonsepsi peserta didik smp tentang cermin datar menggunakan strategi prediction, observation, and explanation. *Jurnal Pendidikan dan Pembelajaran Khatulistiwa, 5*(6), 1 - 14.

Aydın, A. (2010). *Yaşadığımız dünya*. Pegem Akademi.

Ayvaci, H. S. (2013). Investigating the effectiveness of predict-observe-explain strategy on teaching photo electricity. *Journal of Science Education. 12* (5), 548-564.

Baah, R., & Ghartey, J. (2012). *Senior high school students' understanding and difficulties with chemical equations*. Retrieved from https://www.google.com/search?q=Baah+%2526+Ghartey%252C+2012).

Bain, K., & Towns, M. H. (2018). Investigation of undergraduate and graduate chemistry students' understanding of thermodynamic driving forces in chemical reactions and dissolution. *Journal of Chemical Education, 95*(4), 512 - 520.

Bain, K., Rodriguez, J. M. G., Moon, A., & Towns, M. A. (2018). The characterization of cognitive processes involved in chemical kinetics using a blended processing framework. *Chemistry Education Research and Practice*, *19* (2), 617- 628.

Bajah, S. T., (2003*). Sciencing with children: A solid foundation for our future scientists innovative*. Faculty of Education lecture series. Unilag Series.

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.

Banawi, A., Sopandi, W., Kadarohman, A., & Solehuddin, M. (2019). Prospective primary school teachers' conception change on states of matter and their changes through predict-observe-explain strategy. *International Journal of Instruction, 12* (3), 359 - 374.

Bao, L., & Koenig, K. (2019). Physics education research for 21st century learning. *Disciplinary and Interdisciplinary Science Education Research, 1*(1), 2 - 11.

Bassey, M. (1998) Action research for improving practice. In R. Halsall (Ed.) *Teacher research and school improvement: Opening doors from the inside*. Open University Press.

Bhattacharyya, G., & Bodner, G. M. (2005). "It gets me to the product": How students propose organic mechanisms. *Journal of Chemical Education, 82* (9), 1402-1406.

Bilen, K., & Aydogdu, M. (2010). Using the predict-observe-explain strategy to teach of concepts photosynthesis and respiration in plants. *Mustafa Kemal University Journal of Social Sciences Institute, 7*(14), 179 - 194.

Bilgin, A. K., Yurukel, F. N., & Yigit, N. (2017). The effect of a developed react strategy on the conceptual understanding of students: Particulate nature of matter. *Journal of Turkish Science Education, 14* (2), 65 - 81.

Bodner, G. M., & Domin, D. S. (2000). Mental models: The role of representations in problem solving in chemistry. *University Chemistry Education, 4*(1), 24 - 30.

Borg, W. R., Gall, J. P., & Gall, M. D. (1993). *Applying educational research: A practical guide.* Longman Publishing Group.

British Educational Research Association (BERA), (2011). A summary of ethical guidelines for educational research. Wickford teaching school alliance. Pp 1- 6.

Brown, B. L (1997). *New learning strategies for generation*. Eric Digest No. 184.

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.

Burkam, D. T., Lee, V. E., & Smerdon, B. A. (1997). Gender and science learning early in high school: Subject matter and laboratory experiences. *American Educational Research Journal, 34*(2), 297-331.

Cabaroglu, N. (2014). Professional development through action research: Impact on self-efficacy. *System*, *44*, 79 - 88.

Çalış, S., & Özkan, M. (2022). The effect of science teaching based on poe strategy on the academic achievement and attitudes of fifth-grade students in the distance education process. *Mimbar Sekolah Dasar, 9* (3), 381-395.

Camp, W. G. (2001). Formulating and evaluating theoretical frameworks for career and technical education. *Career and Technical Education Research, 26*(1), 4 - 25.

Capistrano, J. R. (2000). *The use of improvised apparatus in teaching physics via POE approach*. [Unpublished Master Thesis]. Technical University Practice, Manila.

Carballo, A. K. G. (2009). *Education: Analysing the status of math and science education*. Retrieved from http://growthrevolutionmag/edu.

Cardellini, L. (2012). *Chemistry: Why the subject is difficult*. Educquím publicado en línea el 242. Universidad nacional autónoma de México. DOI. ISSNE 18708404.

Carey, F. A., & Sundberg, R. J. (2007). *Advanced organic chemistry: Structure and mechanisms*. Springer.

Cartrette, D. P., & Mayo, P. M. (2011). Students' understanding of acids/ bases in organic chemistry contexts. *Chemical Educational Research Practice, 12* (1), 29 - 39.

Champagne, A., Klopfer, L., & Anderson J. (1979). *Factors influencing learning of classical mechanics*. Paper presented at A.E.R.A. meeting. Pp. 1 - 7.

Chen, Y. L., Pan, P. R., Sung, Y. T., & Chang, K. E. (2013). Correcting misconceptions on electronics: Effects of a simulation-based learning environment backed by a conceptual change model. *Educational Technology and Society*, *16* (2), 212-227.

Childs, P. E., & Sheehan, M. (2009). What's difficult about chemistry?: An Irish perspective, chemistry education. *Research and Practice, 10*(6), 204-218.

Childs, P. E., Markic, S., & Ryan, M. C. (2015). The role of language in teaching and learning chemistry. In J. Garcia-Martinez & E. Serrano-Torregrossa (2nd ed.). *Chemistry education: Best practices, opportunities and trends*. Pp. 421- 445.

Chiliang, J. (2011). Using poe to promote young children's understanding of the properties of air. *Journal of Research in Early Childhood Education, 5*(1), 45-68.

Chiu, M. H., (2007). A national survey of students' conceptions of chemistry in Taiwan. *International Journal of Science Education, 29* (8), 421- 452.

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

Cicognani, A. (2011). *Vee heuristic as a collaborative tool for enhanced online learning*. Retrieved from http://www.ebiblioteka/map/uzsienio.

Cinici, A., & Demir, Y. (2015). Teaching through cooperative POE task: A path to conceptual change. *Journal of Educational Strategies and Ideas, 86* (1), 1 - 10.

Clark, J. S., Porath, S., Thiele, J., & Jobe, M. (2020). *Action research*. Kansas State University Libraries. New Prairie Press.

Cohen, L., Manion, L., & Morrison, K. (2013). *Research methods in education*. Routledge.

Coll, R. (2014). *Investigating first year chemistry learning difficulties in South Pacific*. Retrieved from http://www.wisese/what-is-organic-chemistry?

Cooper, M., Underwood, S. M., & Williams, L. C. (2015). Student understanding of intermolecular forces: A multimodal study. *Journal of Chemical Education, 92(8),* 12 - 23.

Copeland, R. (1984). *How children learn mathematics: Teaching implications of Piaget's Research* (4th ed.). Macmillan.

Costu, B., Ayas, A., & Niaz, M. (2010). Promoting conceptual change in students' understanding of evaporation. *Chemistry Education: Research and Practice, 11*(3), 5-16.

Coştu, B., Ayas, A., & Niaz, M. (2012). Investigating the effectiveness of a POE-based teaching activity on students' understanding of condensation. *Instructional Science, 40* (1), 47-67.

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Dahar, R. W. (2011). *Teori-teori belajar dan pembelajaran*. Erlangga.

Dalziel, J. (2010). *Practical teaching strategies for predict-observe-explain problem-based learning and role plays*. LAMS International Press.

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B. J., & Osher, D. (2019). Implications for educational practice of the science of learning and development. *Applied Developmental Science, 24* (2), 97-140.

Decocq, V., & Bhattacharyya, G. (2019). TMI (too much information): Effects of given information on organic chemistry students' approaches to solving mechanism tasks. *Chemistry Education Research and Practice, 20*(4), 213-228.

Demircioğlu, H. (2017). Effect of PDEODE teaching strategy on Turkish students' conceptual understanding: Particulate nature of matter. *Journal of Education and Training Studies 5*(7), 78 - 90.

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

Dewantoro, R. S., Subandi, S., & Fajaroh, F. (2017). Misconception identification using two-tier test and poe strategy to improve mass balance topic mastery in industrial chemistry in vocational high school. *Journal Pendidikan, 5*(4), 27 - 34.

Donkoh, S. (2017). Very difficult senior high school organic chemistry topics: Students and teachers perception. *IJCRT 5*(4), 2746 - 2752.

Ealy, J. B., & Hermanson, J. (2006). Molecular images in organic chemistry: Assessment of understanding in aromaticity, symmetry, spectroscopy and shielding. *Journal of Science Education and Technology, 15*(1), 59 - 65.

Elliott, S. N., Kratochwill, T. R., Littlefield, C. J., & Travers, J. (2000). *Educational psychology: Effective teaching and learning.* McGraw-Hill Press.

Ellis, R. (1994). *The study of second language acquisition*. Oxford University Press. Retrieved from https://www.scirp.org/ (S(351jmbn).

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

Eticha, A. T., & Ochonogor, C. (2017). *Assessment of undergraduate chemistry students' difficulties in organic chemistry*. Retrieved from http://uir.unisa.ac.za/handle/10.

Ferguson, R., & Bodner, G. M. (2008). Making sense of the arrow-pushing formalism among chemistry majors enrolled in organic chemistry. *Chemistry Education Research and Practice, 9*(2), 102 - 113.

Ferk, V., Vrtacnik, M., Blejec, A., & Gril, A., (2003). Students' understanding of molecular structure representations. *Journal Science Education, 5*(6), 27- 45.

Fernando, S. Y., & Marikar, F. M. (2017). Constructivist teaching/learning theory and teaching methods. *Journal of Curriculum and Teaching*, *6*(1), 110 -122.

Ferty, Z. N., Wilujeng, J. I., & Kuswanto, H. (2019). Enhancing 11th grade students' critical thinking skills through physics education technology poe simulation assisted of scaffolding. *Journal of Physics: Conference Series 12*(33), 1-11.

Friesen, S., & Scott, D. (2013). *Inquiry-based learning: A review of the research literature*. Retrieved from https://galileo.org/focus-on-inqu.

Furqani, D., Feranie, S., & Winarno, N. (2018). The effect of predict-observe-explain (POE) strategy on students' conceptual mastery and critical thinking in learning vibration and wave. *Journal of Science Learning, 2* (1), 11-19.

Gafoor, K. A., & Shilna, V. (2013). *Perceived difficulty of chemistry units in std IX for students in Kerala stream calls for further innovations*. UGC sponsored national seminar on innovations in pedagogy and curriculum. Thalassery. Pp 1-7.

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 from http://www.diginle.lib.fsu.edu/cgi.

Garg, N. K. (2019). How organic chemistry became one of UCLA's most popular classes. *Journal of Biological Chemistry, 294* (46), 176 - 183.

Garnett, P. J., & Treagust, D. F. (1992). Conceptual difficulties experienced by senior high school students of electrochemistry: Electric circuits and oxidation-reduction equations. *Journal of Research in Science Teaching, 29*(2), 121-142.

Gernale, J., Aranes, F., & Duad, D. (2015). The effects of predict-observe-explain (POE) approach on the students' achievement and attitudes towards science. *The Normal Lights, 9*(2), 1 - 23.

Gilbert, J. K. (2005). *Visualization: A metacognitive skill in science and science education.* Springer. Retrieved from https://doi.org/10.1007/1.

Grant, C., & Osanloo, A. (2014). Understanding, selecting, and integrating a theoretical framework in dissertation research: Creating the blueprint for your "house". *Administrative Issues Journal Education Practice and Research*, *4*(2), 12-26.

Graulich, N. (2015). The tip of the iceberg in organic chemistry classes: How do students deal with invisible?. *Chemistry Education Research and Practice, 16*(1), 9-21.

Grove, N. P., & Bretz, S. L. (2010). Perry's scheme of intellectual and epistemological development as a framework for describing student difficulties in learning organic chemistry. *Chemistry Education Research and Practice, 11*(3), 207-211.

Grubern, H., & Vone'che, J. (1977). *The essential Piaget*. Routledge and Kegan.

Gunstone, R., & White, R. (1981). Understanding of gravity. *Science Education, 65*(3), 291- 299.

Gurel, D. K., Eryılmaz, A., & McDermott, L. C. (2015). A review and comparison of diagnostic instruments to identify students' misconceptions in science. *Eurasia Journal of Mathematics, Science and Technology Education, 11*(5), *989-1008.*

Haidar, A., & Abraham, M. (1991). A comparison of applied and theoretical knowledge of concepts based on the particulate nature of matter. *Journal of Research in Science Teaching*, *28* (5), 919 - 938.

Hanani, N. (2020). Meaningful learning reconstruction for millennial: Facing competition in the information technology era. *IOP Conference Series: Earth and Environmental Science, 4*(1), 10 - 17.

Hand, B., & Choi, A. (2010). Examining the impact of student use of multiple modal representations in constructing arguments in organic chemistry laboratory classes. *Research in Science Education, 40* (1), 29 - 44.

Hanson, R. (2017). Enhancing students' performance in organic chemistry through context-based learning and micro activities: A case study. *European Journal of Research and Reflection in Educational Sciences, 5(6),* 7 – 20.

Hanson, R., Sam, A., & Antwi, V. (2012). Misconceptions of undergraduate chemistry teachers about hybridisation. *African Journal of Educational Studies in Mathematics and Sciences, 10* (4), 15 - 21.

Harman, G., & Yenikalayci, N. (2022). The effect of prediction-observation-explanation (POE) method on learning of image formation by a plane mirror and pre-service teachers' opinions. *Journal of Educational Research and Practice, 12*(4), 1-17.

Hartanto, T. J., Dinata, P. A. C., Azizah, N., Qadariah, A., & Pratama, A. (2023). Students' science process skills and understanding on Ohm's law and direct current circuit through virtual laboratory based poe model. Jurnal Pendidikan Sains Indonesia. *Indonesian Journal of Science Education, 11*(1), 113 -128.

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. T. (2002). *POE approach and students' achievement in general chemistry laboratory*. [Master Thesis] Technological University of Philippines, Manila.

Hilario, J. S. (2015). The use of predict-observe-explain-explore as a new teaching strategy in general chemistry-laboratory. *International Journal of Education and Research, 3*(2), 37- 48.

Hogg, M., & Vaughan, G. (2005). *Social psychology* (4th ed.). Prentice-Hall.

Hudson, R. D. (2010). *Didactical desain research for teaching as a desaign profession, dalam teacher education policy in Europe: A voice of higher Education Institutions*. University of Umea, Umea.

Hudson, R. D. (2012). Is there a relationship between chemistry performance and question type and gender?. *Science Education Research, 23*(1), 56 - 83.

Ibe, A, W., & Umoren, F. S. (2009). *Misconceptions in chemistry: Its identification and remedial measures*. Retrieved from https://www.google.com.

Ivie, S. D. (1998). Ausubel's learning theory: An approach to teaching higher order thinking skills. *The High School Journal, 82*(1), 35 - 42.

Johnstone, A. H. (1991). Why science is difficult to learn?: Things are seldom what they seem". *Journal of Computer Assisted Learning*, *2*(2), 175 - 181.

Johnstone, A. H. (1993). The development of chemistry teaching: A change response to changing demand. *Journal of Chemical Education*, *70* (5), 701- 705.

Juniati, M. (2009). Penerapan strategi pembelajaran probex untuk meningkatkan motivasi dan Hasil belajar peserta didik SMP Negeri 3 purworejo, jawa tengah tahun pelajaran 2007/2008 pada konsep kalor. *Edukasi, 1*(2), 13 - 19.

Kane, E. (1996). *Research handbook for girls' education in Africa*. EDI learning resource series. The international bank for reconstruction and development. Pp. 1-12

Kanno, T. N. (2018). Guided discovery teaching method. In T. N. Kanno & U. M. Nzewi (3rd ed.), *Issues in curriculum development and implementation in Nigeria*. Pp. 7-14. Foremost Educational Services Limited.

Karamustafaoğlu, S., & 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.

Kay, C. C., & Yiin, H. K. (2010). *Misconceptions in the teaching of chemistry in secondary schools in Singapore and Malaysia*. Proceedings of the sunway academic conference 2010/1. Sunway College Johor Bahru. Pp. 1-14.

Kearney, M. (2003). *Classroom use of multimedia-supported predict-observe-explain tasks to elicit and promote discussion about students' physics concepts*. [Unpublished Doctoral Dissertation]. Curt University of Technology.

Kelly, J. (2012). *Learning theories*. Retrieved from http://thepeakperformancecenter.

Khald, K. (2017). Quantitative, qualitative or mixed research: Which research paradigm to use ?. *Journal of Educational and Social Research, 7*(2), 15 - 24.

Khoo, G., & Koh, T. (1998). Using visualization and simulation tools in tertiary science education. *Journal of Computer in Mathematics and Science Teaching, 7*, 10-20.

Kibirige, I., Osodo, J., & Tlala, K. M. (2014). The effect of predict-observe-explain strategy on learners' misconceptions about dissolved salts. *Mediterranean Journal of Social Sciences, 5* (4), 30 - 37.

Klangmanee, R., & Sumranwanich, W. (2011). *The development of grade 5 Thai students' metacognitive strategies in learning about force and pressure through poe.* Retrieved from http://www.fedu.met.edu.tr/grade5-students.

Koosimile, A. T. (2005). Induction of pupils into secondary school science in Botswana. *African Journal of Research in Mathematics, Science and Technology Education, 9* (1), 39 - 48.

Köseoğlu, F., Tümay, H., & Kavak, V. N. (2004). *An effective teaching method based on constructivist learning theory: Guess-observe-explain-"can the water be boiled with ice?.* Retrieved on May 3, 2021 from http://www.fedu.metu.edu.tr/.

Kubiatko, M. (2013). *Postoje žiakov druhého stupňa základných škôl k prírodovedným predmetom*. Habilitačná práca. Masarykova Univerzita.

Kubiatko, M. (2007). *Postoje druhého stupňa základných škôl k prírodovedným predmetom*. Habilitačná práca. Masarykova Univerzita.

Kumi, B. C., Olimpo, J. T., Bartlett, F., & Dixon, B. L. (2013). Evaluating the effectiveness of organic chemistry textbooks in promoting representational fluency and understanding of 2D-3D diagrammatic relationships. *Chemistry Education Research and Practice, 14*(2), 177-187.

Lamas, A. H. (2015). School performance. *Propósitosy representaciones, 3*(1), 313-386. Retrieved from http://dx.doi.org/10.20511/pyr.

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

Liew, C. W. (1995). A predict-observe-explain teaching sequence for learning about students' ideas of heat. *Australian Science Teachers Journal, 41*(1), 68 - 72.

Liew, C., & Treagust, D. F. (1995). A predict-observe-explain learning about student' understanding of heat anti expansion of liquids. *Science Fence Teachers Journal, 41*(1), 68 -71.

Liew, C., & Treagust, D. F. (1998). *The effectiveness of predict- observe-explain tasks in diagnosing students understanding of science and in identifying their levels of achievement*. Paper presented at the annual meeting of American Educational Research Association. Pp. 1- 8.

Lucilo, R. (2010). *Metacognitive awareness and performance level in biological science of non-science students of Universidad de Sta.* [Masters Thesis]. Sta. Universidad

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.

Marek, E. (1986). *Science misconceptions of students in senior high school.* Paper presented at the national social science association conference. Pp. 1- 5.

Martí, E. (2003). *Representar el mundo externamente: La construcción infantil de los sistemas externos de representación*. Machado. Pp. 1- 11.

Martínez-Otero, V. (2007). *Los adolescentes ante el estudio. Causas y consecuencias del rendimiento académico*. Madrid: Fundamentos. Retrieved from http://digitalcommons.uncfsu.edu/jri.

Maturana, H. R., & Varela, F. J. (1992). *The tree of knowledge: The biological roots of human understanding (revised edition).* Shambhala.

McClary, M. L., & Bretz, L. B. (2012). Development and assessment of a diagnostic tool to identify organic chemistry students' alternative conceptions related to acid strength. *International Journal of Science Education, 34*(15), 2317-2341.

McCormick, R., & Li, N. (2006). An evaluation of European learning objects in use. *Learning, Media and Technology, 31*(3), 213 - 231.

McDermott, L., (1984). Research on conceptual understanding in mechanics. *Physics Today, 3*(7), *4 -32*.

McGregor, L., & Hargrave, C. (2008). The use of "predict-observe-explain" with on-line discussion boards to promote conceptual change in the science laboratory learning environment. In K. McFerrin et al. (2nd ed.), *proceedings of society for information technology & teacher education international conference 2008*. Pp. 4735-4740.

McLeod, S. (2019). *Constructivism as a theory for teaching and learning*. Retrieved from https://www.simplypsychology.org/constructivism.html.

Mertler, C. A. (2017). *Action research communities: Professional learning, empowerment, and improvement through collaborative action research*. Milton Park. Routledge.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sources book* (2nd ed). Newbury Park. Sage.

Millar, R., (1991). *A means to an end: The role of process in science education*. Practical science. Open University Press.

Misra, P. K. (2020). Implications of constructivist approaches in the classrooms: The role of the teachers. *Asian Journal of Education and Social Studies*, *1*(7), 17-25

Mistry, N., Singh, R., & Ridley, J. (2020). A web-based stereochemistry tool to improve students' ability to draw Newman projections and chair conformations and assign R/S labels. *Journal of Chemical Education, 97*(4), 1157-1161

Mosca, C. L. (2007). *Relative effectiveness of the poe teaching strategy*. [Master Thesis]. EARIST, Manila.

Muna, I. A. (2017). Model pembelajaran poe (Predict-observe-explain) dalam meningkatkan pemahaman konsep dan keterampilan proses IPA. *Jurnal Studi Agama, 5*(1), 233-248.

Nartey, E., & Hanson, R. (2021). The perceptions of senior high school students and teachers about organic chemistry: A Ghanaian perspective. *Science Education International 32*(4), 331-342.

National Research Council, (2006). *America's laboratory report: Investigations in high school science*. National Academy Press.

National Research Council, (1996). *National science education standards.* National Academy Press.

Nja, O. C., Orim, E. R., Neji, A. H., Ukwetang, J. O., Uwe, U. E., & Ideba, M. A. (2022). *Students' attitudes and academic achievement in a flipped classroom*. Electronic journal. Retrieved on May 16, 2021 from https://www.researchgate.net.

Novak, J. D. (2002). Meaningful learning: The essential factor for conceptual change in limited or inappropriate propositional hierarchies leading to empowerment of learners. *Science Education, 86* (4), 548 -571.

Nwagbo, C. (2001). The relative effect of guided discovery and expository on the achievement in biology of students of different level of scientific literacy. *Journal of the Science Teachers Association of Nigeria, 36* (2), 43 - 51.

O'Dwyer, A., (2012). *Identification of the difficulties in teaching and learning of introductory organic chemistry in Ireland and the development of a second-level intervention programme to address these*. Dissertation submitted to University of Limerick for the degree of Doctor of Philosophy.

O'Dwyer, A., & Childs, P. E., (2017). Who says organic chemistry is difficult? Exploring perspectives and perceptions. *EURASIA Journal of Mathematics Science and Technology Education, 13*(7), 3599 - 3620.

O' Dwyer, A, & Childs, P. (2015). Organic chemistry in action: What is the reaction?. *Journal of Chemical Education, 92*(7), 1159 -1170.

O'Dwyer, A., & Childs, P. (2014). Organic chemistry in action! Developing an intervention program for introductory organic chemistry to improve learners' understanding, and attitudes. *Journal of Chemical Education, 91*(7), 987- 993.

O'Dwyer, A., & Childs, P. (2010). *Second level Irish pupils' and teachers' view of difficulties in organic chemistry*. IOSTE Mini-Symposium June 2011, 19-21.

Ogunniyi, M. B. (2002). *Curriculum development in science, technology and mathematics education challenges of the 21st Century*. Science, Technology and Mathematics Education in Africa 2-12. University of Botswana.

Ojo, M. O., & Owolabi, O. T. (2021). Effects of predict-explain instructional strategy on students' learning outcomes in physics practical in secondary schools. *European Journal of Education Studies, 8*(2), 32- 44.

Omwirhiren, E. M., & Ubanwa, O. A. (2016). An analysis of misconceptions in organic chemistry among selected senior secondary school students in Zaria local government area of Kaduna state, Nigeria. *International Journal of Education and Research, 4*(7), 247- 266.

Orleans, A. V. (2007). The condition of secondary school physics education in the Philippines: Recent developments and remaining challenges for substantive improvements. *The Australian Educational Researcher, 34*(1), 33 -54.

Özcan, G. E., & Uyanık, G. (2022). The effects of the "Predict-Observe-Explain (POE)" strategy on academic achievement, attitude and retention in science learning. *Journal of Pedagogical Research, 6*(3), 103-111.

Özdemir, G., & Clark, D. B. (2007). An overview of conceptual change theories. *Eurasia Journal of Mathematics, Science and Technology Education 3*(4), 351-361

Özmen, H., Ayas, A., & Coştu, B. (2002). Determination of the science student teachers' understanding level and misunderstandings about the particulate nature of the matter. *Educational Sciences: Theory and Practice, 2*(2), 507-529.

Phanphech, P. P., & Tanitteerapan, T. (2017). Using predict-do-observe-explain strategy to enhance conceptual understanding of electric circuits for vocational learners. In O. N. Akfirat, D. F. Staub & G. Yavas (Eds.), *Current Debates in Education, 5*(3), 383-394. IJOPEC Publication Limited.

Phanphech, P. P., Tanitteerapan, T., & Murphy, E. (2019). Explaining and enacting for conceptual understanding in secondary school physics. *Issues in Educational Research, 29*(1), 180-204.

Posner, G., Strike, K., Hewson, P., & Gertzog, W. (1982). Accommodation of a scientific conception: Toward a conceptual change. *Science Education, 66*(8), 211-227.

Prabawati, R., Nugrahaningsih, W. H., & Alimah, S. (2020). The influence of predict observe explain (POE) learning model on student learning outcomes. *Journal of Biology Education, 9*(1), 57- 63.

Rahi, S. (2017). Research design and methods: A systematic review of research paradigms, sampling issues and instruments development. *International Journal of Economics and Management Sciences, 6*(2), 11- 19.

Raj, R. A., Sreerekha, S., & Sanka, S. (2016). Effect of poe strategy on achievement in chemistry of secondary school students. *International Journal of Education and Teaching Analytics*, *1*(2), 1 - 5.

Ravitch, S., & Carl, N. M. (2016). *Qualitative research: Bridging the conceptual, theoretical, and methodological*. Thousand Oaks. Sage Publications.

Renner, J., Brumby, M., & Shephered, D. (1981). Why are there no dinosaurs in Oklahoma? *The Science Teacher, 48*(6), 135-145.

Renz, S. M., Carrington, J. M., & Badger, T. A. (2018). Two strategies for qualitative content analysis: An intramethod approach. *Qualitative research*, *28*(5), 824-831.

Rosdianto, H. (2017). Implementasi model pembelajaran POE (predict observe explain) untuk meningkatkan pemahaman konsep siswa pada Materi Hukum Newton. *Jurnal Pendidikan Fisika, 6*(1)*,* 55-57.

Safdar, M., Hussain, A., Shah, I., & Rifat, Q. (2012). Concept maps: An instructional tool to facilitate meaningful learning. *European Journal of Educational Research, 1*(1), 55-64.

Salame, I. I., & Samson, D. (2019). Examining the implementation of PhET simulations into general chemistry laboratory. *International Journal of Environmental and Science Education, 14*(4)*,* 207-217.

Salamea, D. E., Casinoa, P., & Hodges, N. (2020). Examining challenges that students face in learning organic chemistry synthesis. *International Journal of Chemistry Education Research, 4*(1)*,* 1- 9.

Salta, K., & Tzougraki, C. (2004). Attitudes toward chemistry among 11$^{th}$ grade students in high schools in Greece. *Science Education Periodicals, 88*(4), 535-547.

Samsudin, A., Suhandi, A., Rusdiana, D., Kaniawati, I., & Costu, B. (2017). Promoting conceptual understanding on magnetic field concepts through interactive conceptual instruction (ICI) with PDEODEE Tasks. *Journal of Computational and Theoretical Nanoscience 23*(2), 1205-1209. DOI:10.1166/asl.2017.7539.

Sarita, P. (2017). Constructivism: A new paradigm in teaching and learning. *International Journal of Academic Research and Development*, *2*(4)*,* 183-186.

Schmidt, H. J., Kaufmann, B., & Treagust, D. F. (2009). Students' understanding of boiling points and intermolecular forces. *Chemistry Education Research and Practice, 10*(4)*,* 265 - 272.

Sejčová, Ľ. (2006). *Pohľad na kvalitu života dospievajúcich*. Album Press.

Şendur, G. (2012). Prospective science teachers' misconceptions in organic chemistry: The case of alkenes. *Journal of Turkish science education, 9*(3), 186-191.

Sendur, G., & Toprak, M. (2013). The role of conceptual change texts to improve students' understanding of alkenes. *Chemistry and Practice, 14*(8), 431- 449.

Senese, B. A. (2013). Diagnosing pre-service teachers' understanding of chemistry concepts by using computer-mediated poe tasks. *Chemistry Education Research and Practice, 14*(9), 239 - 246.

Sharkey, M., & Gash, H. (2020). Teachers' constructivist and ethical beliefs. *Behavioural Sciences*, *10*(6), 96 -104.

Sharma, A. K., & DeCicco, R. C. (2018). Discovering isomerism: A guided-inquiry computational exercise for organic chemistry. *Chemical Educator, 23*(7), 39-41.

Sibomana, A., Karegeya, C., & Sentongo, J. (2021). Students' conceptual understanding of organic chemistry and classroom implications in the Rwandan perspectives: A literature. *Educational Studies in Mathematics and Sciences, 16*(2), 13 - 32.

Siddique, M., Ahmed, M., Feroz, M., Shoukat, W., & Jabeen, S. (2022). Attitude towards learning chemistry: A case of secondary school students in Pakistan. *Journal of Positive School Psychology, 6*(12), 1031-1055.

Simsek, U. (2009). The effect of animation and cooperative learning on chemistry students' academic achievement and conceptual understanding about aqueous solution. *World Applied Science Journal, 7* (1), 23-33.

Sirhan, G. (2007). Learning difficulties in chemistry: An overview. *Journal of Turkish Science Education, 4*(2), 2-20.

Sreerekha, S., Arun Raj, R., & Swapna S. (2016). Effect of predict-observe-explain strategy on achievement in chemistry of secondary school students. *International Journal of Education & Teaching Analytics, 1*(1), 2 - 7.

Stieff, G. (2007). Turkish secondary students' conception of introductory chemistry concepts. *Journal of Chemical Education, 74*(5), 518 - 521.

Suparno, P. (2005). *Metodologi pembelajaran fisika: konstruktivistik dan menyenangkan*. Universitas Sanata Dharma Press.

Supriatna, U., Samsudin, A., & Efendi, R. (2019). Teaching solar system topic through Predict Observe-Explain-Apply (POEA) strategy: A path to students' conceptual change. *TADRIS: Jurnal Keguruan dan Ilmu Tarbiyah, 4*(1), 1-15.

Sutopo, S., Berek, F. X., & Munzil, M. (2016). Concept enhancement of junior high school students in hydrostatic pressure and Archimedes law by predict-observe-explain strategy. Jurnal Pendidikan IPA Indonesia. *JPII 5* (2), 230 - 238.

Syuhendri, F. (2017). A learning process based on conceptual change approach to foster conceptual change in mechanics. *Baltic Science Education, 16*(2), 228 - 240.

Taagepera, M., & Noori, S. (2000). Mapping students' thinking patterns in learning organic chemistry. *Journal of Chemical Education, 77*(9), 1224 -1229.

Taber, K. S. (2014). Constructing active learning in chemistry: Concepts, cognition and conceptions. In I. Devetak & S. A. Glažar (Eds.), *Learning with understanding in the chemistry classroom.* (Pp. 5-23). Springer.

Taber, K. S. (2009). *Learning at the symbolic level: In multiple representations in chemical education*. (Pp. 75-105). Springer.

Taber, K. S. (2002a). *Alternative conceptions in chemistry: Prevention, diagnosis and treat*. The Royal Society of Chemistry.

Taber, K. S. (2002b). Compounding: Probing the frontiers of student understanding of molecular orbitals. *Education Research and Practice, 3*(2), 159-173.

Taber, K. S. (2001). Building the structural concepts of chemistry: Some considerations from educational research. *Education Research and Practice, 2*(2), 123-158.

Takawira C. K., & Admire, M. (2012). Student performance in A-level chemistry examinations in Makoni District. *Physics and Chemistry Education, 4*(1), 2 - 29.

Tam, M. (2000). Constructivism, instructional design and technology: Implications for transform distance learning. *Educational Technology and Society, 3*(2), 50 - 60.

Tan, C. T. (2006). *Understanding and applying the acid-base concept of daily life among form four science students.* [Master's Thesis]. Universiti Teknologi.

Taqwa, M. R. A., & Putra, G. S. (2017). *Kajian efektifitas penggunaan model POE berintegrasi PhET pada.* Seminar Nasional Pendidikan "NaNoDik". Pp. 42-52.

Tenaw, Y. A. (2015). Effective strategies for teaching chemistry. *International Journal of Education Research and Reviews, 3*(3), 78 - 84.

Tilahun, K., & Tirfu, M. (2016). Common difficulties experienced by grade 12 students in learning chemistry in Ebinat preparatory school. *AJCE, 6*(2), 16 - 32.

Topal, G., Oral, B., & Ozden, M. (2007). University and secondary school students' misconceptions about the concept of "aromaticity" in organic chemistry. *International Journal of Environmental & Science Education, 2*(4), 135 - 143.

Torres, L. E., & Rodríguez, N. Y. (2006). Rendimiento académico y contexto familiar en estudiantes universitario. *Teaching and Research in Psychology, 11* (2), 255-270.

Treagust, D. F., Chittleborough, G. D., & Mamiala, T. L. (2004). Students' understanding of the descriptive and predictive nature of teaching models in organic chemistry. *Research in Science Education, 3*(4), 1-20.

Ubi, J. (2015). Relative effectiveness of poe and lecture methods of teaching basic science. *International Journal of Science Teaching, 3*(7), 13-19.

Uchegbu, R. I., Ahuchaogu, A. A., & Amanze, K. O. (2017). Tertiary institution students' perception of difficult topics in organic chemistry curriculum in Imo State. *American Association for Science-Technology Journal of Education, 3*(2), 9-15.

Ünal, S., Coştu, B., & Ayas, A. (2010). Secondary school students' misconceptions of covalent bonding. *Journal of Turkish Science Education, 7*(2), 3 - 29.

Uyulgan, M. A., & Akkuzu, N. (2016). An insight towards conceptual understanding: Looking into the molecular structures of compounds. *Journal of Research in Science Teaching, 9*(4), 2-23.

Vadapally, P. (2014). *Exploring students' perceptions and performance on predict-observe-explain tasks in high school chemistry lab*. [A Dissertation]. Pp 1-173.

Von-Glasersfeld, E. (1990). A constructivist approach to teaching. In L. P. Steffe & J. Gale, (Eds.) *Constructivism in education*. (Pp. 3-16). Erlbaum.

Vosniadou, S., & Verschaffel, L. (2004). Extending the conceptual change approach to mathematics learning and teaching. *Learning and Instruction, 14*(5), 445–451.

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

Wahyuni, E. W. (2013). Pembelajaran biologi model POE (prediction, observation, explanation) Melalui laboratorium. *Jurnal Inkuiri, 2*(3), 269 -278.

Wasacz, J. T. (2010). *Organic chemistry preconceptions and their correlation to student success.* [PhD Dissertation]. University of Northern Colorado.

Webber, D. M., & Flynn, A. B. (2018). Students' learning difficulties in functional groups, stereochemistry and spectroscopy. *Chemical Education, 95*(9)*,* 451-467.

Widhiyanti, T. (2016). *Curriculum evaluation and predict-observe-explain implementation: A case study on developing chemistry teachers' understanding of particulate nature of matter*. [PhD Thesis]. Curtin University.

Willcox, M. del R. (2011). Factores de riesgo y protección para el rendimiento académico. *Revista Iberoamericana de Educación, 55*(1), 1- 9.

Wu, H. K., Krajcik, J. S., & Soloway, E. (2001). Promoting understanding of chemical representations. *Journal of Research in Science Teaching, 38*(7)*,* 821-842.

Yaayin, B., Oppong, E. K., & Hanson, R. (2022). Efficacy of jigsaw model in improving pre-service teachers' performance in selected functional group organic compounds. *Science Education International, 32* (3)*,* 191 - 196.

Yara, P. O. (2009). Students' attitudes towards science in some selected secondary schools. *European Journal of Scientific Study, 36* (3)*,* 336-341.

Yavuz, S., & Celik, G. (2013). The effect of poe technique on the misconceptions of elementary teachers about the gases. *Journal of Educational Sciences, 1*(1)*, 1-20.*

Yusuf, T. A., Onifade, C. A., & Bello, S. O. (2016). Impact of class size on learning, behaviour and general attitudes of students in secondary schools in Abeokuta, Ogun State, Nigeria. *Journal of Research Initiatives, 2*(1)*,* 3 - 9.

Zoller, U., (1990). Students' misunderstandings and misconceptions in college freshman chemistry. *Journal of Research in Science Teaching, 27*(10)*,* 1053-1065.

# APPENDIX A

## UNIVERSITY OF EDUCATION, WINNEBA

## Science Student-Teachers' Organic Chemistry Difficult Questionnaire (STOCDQ)

**Instruction:-**Dear Respondent, your responses provided in this questionnaire are specifically intended for academic purpose **only**. Kindly indicate your honest response to each item in the spaces provided. Your responses will be kept **confidential**. Thanks

### Section A: Difficulties in Learning Organic Chemistry Topics

1). Have you ever studied organic chemistry before?

Yes: [ ] No: [ ]

2a) Do you think organic chemistry is difficult for you to learn as a student-teacher?

Yes: [ ] No: [ ]

2b) List the top five most difficult organic chemistry topics you have encountered ever since you started learning organic chemistry:……………………………………...

……………………………………………………………………………………………

……………………………………………………………………………………………

3). What topics in your COE organic chemistry curriculum do you see it to be difficult to learn at the college level? **Use these keys: - [ND]-** Not Difficult; **[SD]**- Slightly Difficult; **[D]**-Difficult; **[VD]**-Very Difficult.

| No | Difficult topics in organic chemistry curriculum | [ND] | [SD] | [ D ] | [ VD ] |
|---|---|---|---|---|---|
| a) | Introduction to organic chemistry | | | | |
| b) | Bonding and type of hybridization in carbon | | | | |
| c) | Qualitative elemental analysis | | | | |
| d) | Quantitative elemental analysis | | | | |
| e) | Alkanes | | | | |
| f) | Alkenes | | | | |
| g) | Alkynes | | | | |
| h) | Alkanols (Alcohols) | | | | |
| i) | Aldehydes | | | | |
| j) | Ketones | | | | |
| k) | Alkanoic (Carboxylic) acids | | | | |
| l) | Alkanoates (Esters) | | | | |
| m) | Acid anhydrides | | | | |
| n) | Acid halides | | | | |
| o) | Acid amides | | | | |
| p) | Amines | | | | |

4) Which aspect(s) of organic chemistry concepts is/are difficult for you to learn at the college level?. **Use these keys**: - Not Difficult - [ ND]; Difficult - [ D ]

| No | Difficult organic chemistry aspects | Not Difficult (ND) | Difficult (D) |
|---|---|---|---|
| a) | IUPAC nomenclature | [ ] | [ ] |
| b) | Drawing of structures | [ ] | [ ] |
| c) | Isomerism | [ ] | [ ] |
| d) | Organic reactions | [ ] | [ ] |
| e) | Structure and properties of organic compounds | [ ] | [ ] |
| f) | Organic synthesis | [ ] | [ ] |
| g) | Functional group identification | [ ] | [ ] |
| h) | Organic reaction mechanisms | [ ] | [ ] |
| i) | Classification of organic compounds | [ ] | [ ] |
| j) | Preparation of organic compounds | [ ] | [ ] |

**Section B: Causes of Difficulties in Learning Organic Chemistry**

5) What are the possible causes of your conceptual difficulties in learning organic chemistry?

| **No** | **Items on causes of SSTs' conceptual difficulties** | **Yes** | **No** |
|---|---|---|---|
| a) | Organic chemistry syllabus is too broad. | [ ] | [ ] |
| b) | Inadequate time allocated for organic chemistry lessons. | [ ] | [ ] |
| c) | Difficulty in understanding various abstract organic chemistry concepts. | [ ] | [ ] |
| d) | Ineffective teaching methods used by teachers | [ ] | [ ] |
| e) | Poor attitudes of student-teachers towards organic chemistry. | [ ] | [ ] |
| f) | Lack of teaching and learning materials (TLMs:- e.g., models, ICT software, etc.) | [ ] | [ ] |
| g) | Presence of student-teachers misconceptions | [ ] | [ ] |
| h) | Inadequate/lack of laboratory practical activities during organic chemistry lessons | [ ] | [ ] |
| i) | Inadequate explanations from chemistry tutors | [ ] | [ ] |
| j) | Lack of remedial actions by COE tutors for student-teachers due to work overload. | [ ] | [ ] |

Thank you for your co-operation

# APPENDIX B

## UNIVERSITY OF EDUCATION, WINNEBA

### Science Student-Teachers' Pre-Interview Schedule (SSTPIS)

**Instruction: -** Dear Respondent, your responses provided in this interview schedule are specifically intended for academic purpose **only**. Kindly indicate your honest response to each question item in the spaces provided. Your responses will be kept **confidential**. Thank you very much.

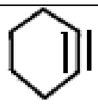
### Section A: - Bio-data of the Respondent

Please, tick your sex and write your code, and the date in the spaces provided below.

**SST's Code:-**.......................... **Sex:-** Male: [ ] Female: [ ] **Date:-**....................

### Section B: - Items in the Pre-Interview Schedule

1) Give the correct IUPAC names or nomenclature for these compounds and also indicate the names of their functional groups in the spaces provided.

| No | Organic compound | IUPAC Nomenclature |
|---|---|---|
| a) | $CH_3CH_2CH_2CH_2CH_3$ | |
| b) | $CH_3CH_2C(Cl)_2CH_2(C_2H_5)$ | |
| c) | $(CH_3)_2CHCH_2CH{=}C(Cl)CH_3$ | |
| d) | $CH_3CH_2C(CH_3)_2C\equiv CH$ | |
| e) | $CH_3CH_2CH(OH)CH_3$ | |
| f) |  | |
| g) | $CH_3CHO$ | |
| h) | $C_2H_5COOH$ | |
| i) | $CH_3COCH_2CH_3$ | |
| j) | $CH_3NH_2$ | |

2). Draw in the spaces provided to illustrate the correct mechanisms for these reactions:-

a) Chlorine molecule undergoes homolysis or homolytic cleavage in the presence of UV light or heat with peroxide as a catalyst to give chlorine free radicals.

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b) Alkanoic acid reacts with alkanol in the presence of heat with concentrated $H_2SO_4$ as a catalyst to produce ester and water.

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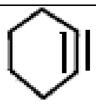
3) For each of these compounds, indicate their functional groups in the spaces provided.

| No | Organic compound | Functional group |
|---|---|---|
| a) | $CH_3CH_2CH_2CH_2CH_3$ | |
| b) | $CH_3CH_2C(Cl)_2CH_2(C_2H_5)$ | |
| c) | $(CH_3)_2CHCH_2CH{=}C(Cl)CH_3$ | |
| d) | $CH_3CH_2C(CH_3)_2C{\equiv}CH$ | |
| e) | $CH_3CH_2CH(OH)CH_3$ | |
| f) |  | |
| g) | $CH_3CHO$ | |
| h) | $C_2H_5COOH$ | |
| i) | $CH_3COCH_2CH_3$ | |
| j) | $CH_3NH_2$ | |

4). Hydrocarbons burn in air (oxygen) to give carbon dioxide and water. Could you please balance equations below by putting the correct coefficient numbers in the spaces provided.

a). --- $CH_{4\,(g)}$ + --- $O_{2\,(g)}$ → --- $CO_{2\,(g)}$ + --- $H_2O_{\,(l)}$

b). --- $C_2H_{4\,(g)}$ + --- $O_{2\,(g)}$ → --- $CO_{2\,(g)}$ + --- $H_2O_{\,(l)}$

c). --- $C_2H_{2\,(g)}$ + --- $O_{2\,(g)}$ → --- $CO_{2\,(g)}$ + --- $H_2O_{\,(l)}$

5a). Which of the question(s) do you perceive to be difficult for you?

…………………………………………………………………………………………

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…………………………………………………………………………………………

5b). What are the causes of your difficulties in understanding organic chemistry?

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# APPENDIX C

## UNIVERSITY OF EDUCATION, WINNEBA

## Science Student-Teachers' Organic Chemistry Diagnostic Test (SSTADT)

## PRE-INTERVENTION TEST

**Purpose:** This **test** seeks to find out your conceptual understanding on selected organic chemistry concepts before implementation of POEIA intervention. This exercise is being conducted for research purpose **only**; and that the marks obtained in this test will not form part of your end-of-semester examination score. Thank you for your co-operation

**Section A:-Bio-data of the Respondent**

**SST's Code:-**.......................... **Sex:-** Male: [ ] Female: [ ] **Date:-**.......................

**Section B:-Instruction:** This test consists of 30 multiple choice objective test. Each item is followed by 4 options lettered A to D, read carefully and circle the **correct** option. Answer **all** the questions on this paper for **30 marks**. **Duration:** 90 minutes.

1) Methane reacts with chlorine in the presence of sunlight. This reaction
   I. Is characteristic of the alkanes. II. Is an example of substitution reaction.
   III. Produces chloromethane. IV. Is an example of polymerisation.
   A. I & II. B. I, II & III. C. II & III. D. I & IV.
2) The product formed when propene reacts completely with chlorine is
   A. 1, 1- dichloropropane. B. 1, 3 - dichloropropane.
   C. 1, 2- dichloropropane. D. 1, 1- dichloropropene.
3) The gas used in welding torch belongs to the family of
   A. Alkenes. B. Alkenes. C. Alkynes. D. Benzene.
4) Ethanol is used in each of the following **except**
   A. In the manufacture of alcoholic beverages. B. As a solvent for paints and vanishes.
   C. In the manufacture of ethyl ethanoate. D. In the hardening of vegetable oil.
5) The structure of 2-hydroxypropanoic acid is.
   A. $CH_3$ - CH - CH - COOH (with OH on each CH)
   B. $CH_3$ - O - CH - COOH
   C. $CH_3$ - CH - $CH_2OH$ (with COOH on CH)
   D. $CH_3$ - CH - COOH (with OH on CH)
6) A compound which is isomeric with butanoic acid, $CH_3CH_2CH_2COOH$ is
   A. Methyl butanoate B. Methyl propanoate C. Ethyl propanoate D. Butanol
7) What does $\mathbf{C_xH_y}$ represent in the following equation? $2C_xH_y + 7O_2 \rightarrow 4CO_2 + 6H_2O$
   A. Butane. B. Butene. C. Ethane. D. Ethene.
8) Ethene can be produced from paraffin oil by the process known as
   A. Polymerisation. B . Cracking. C. Vulcanization. D. Hydrogenation.
9) The reaction of $CH_3C\equiv CH$ with dilute $H_2SO_4$ at 60°C will yield
   A. $CH_3CH_2CH_2OH$. B. $CH_3CH_2CHO$ C. $CH_3CH_2COOH$. D. $CH_3COCH_3$
10) The IUPAC name for $(CH_3)_3COH$ is
    A. 1-1-dimethyl ethanol B. 1, 1, 1- trimethylmethanol.
    C. 2-methyl-2-propanol. D. 2, 2-dimethylethanol.
11) Which of the following is **not** true about neutralisation and esterification reactions?
    A. Neutralisation is fast while esterification is slow.
    B. Esterification produces an alkanoate while neutralisation produces a salt.
    C. Esterification is irreversible while neutralisation is reversible.
    D. Neutralisation is ionic while esterification is non-ionic.
12) The IUPAC name for $CH_3CH(CH_3)CH(Cl)CH(CH_3)CH_2CH_3$ is
    A. 2,4-dimethyl-3-chlorohexane. B. 3,5-dimethyl-4-chlorohexane.

C. 4-chloro-3,5-dimethylhexane. D. 3-chloro-2, 4-dimethylhexane.

13) When $CH_3CH=CH_2$ undergoes electrophilic addition with HBr

A. $H^+$ adds first to give a cation. B. $H^-$ adds first to give a free radical.

C. $Br^+$ adds first to give a cation. D. $Br^-$ adds first to give a cation

14) Which of these comments is **true** about compounds $HC\equiv CCH_3$ and $H_2C=CHCH_3$?

A. Both compounds exhibit geometric isomerism.

B. Only $HC\equiv CCH_3$ exhibits geometric isomerism.

C. Only $H_2C=CHCH_3$ exhibits geometric isomerism.

D. None of the compounds exhibits geometric isomerism

15) How many products will be formed when HCl reacts with propene ($CH_3CH=CH_3$)?

A. 1 B. 2 C. 3 D. 4

16) The organic compound present in vinegar is an

A. Alkane. B. Alkanoate C. Alkanol D. Acetic acid.

17) When 2, 4-DNPH reacts with a carbonyl compound in an acidic medium

A. A yellow ppt is obtained. B. A colourless solution is obtained.

C. A purple ppt is obtained. D. A green ppt is obtained.

18) Which of the following compounds has all its carbon atoms $sp^3$ hybridised?

A. $CH_3CHCH_2$. B. $CH_3CH_2CH_3$. C. $CH_3CCH$. D. $(CH_3)_2CCH_2$

19) A substance which decolourises bromine water may contain the functional group

20) The compound $CH_3CH_2CH(OH)CH_3$ is

A. An ester. B. An amide. C. An alkanol. D. An alkanoic acid.

21) When ethanoic acid is allowed to react with aqueous $NH_3$, the product formed is

A. $CH_3CONH_4$ B. $CH_3COOH$ C. $CH_3CH_2NH_2$ D. $CH_3CONH_2$

22) The IUPAC name for $CH_3COCH_3$ is

A. Propanal. B. Propanoic acid. C. Acetone. D. Methyl ethanoate

23) Which of these are necessary for preparation of esters from alkanols and alkanoic acid?

A. Excess water and sodium hydroxide. B. Excess water and a mineral acid.

C. Concentrated tetraoxosulphate(VI) acid and heat. D. A trace of NaOH and heat.

24) Which of the following reactions is a **valid propagation step** in the reaction of methane with chlorine in the presence of sunlight?

A. $CH_4 + C_2 \rightarrow CH_3Cl + HCl$ B. $CH_4 + Cl\cdot \rightarrow CH_3Cl + H\cdot$

C. $CH_3\cdot + Cl\cdot \rightarrow CH_3Cl$ D. $CH_3\cdot + Cl_2 \rightarrow CH_3Cl + Cl\cdot$

25) The product from reaction of $CH_2=CH_2$ with cold aqueous alkaline $KMnO_4$ is

A. $CH_3CHO$ B. $CH_3CH_2OH$. C. $HOCH_2CH_2OH$ D. $CH_3CH_3$

26) The general formula for an alkyne is

A. CnHn, for $n \geq 2$ B. CnH2n, for $n \geq 2$

C. CnH2n-2, for $n \geq 2$ D. CnH2n + 1, for $n \geq 2$

27) When $CH_3CH_2OH$ is boiled with a solution of iodine in aqueous sodium hydroxide

A. There is no observable reaction. B. A yellow ppt is obtained.

C. A white ppt is obtained. D. A brick-red ppt is obtained.

28) The IUPAC name of the compound $C_6H_5CH_2CHClCO_2H$ is

A. 2-chloro-3-benzenepropanoic acid B. 2-chloro-3-phynylpropanoic acid

C. 2-chloro-3- phenylpropanoic acid D. 2-chloro-3-benzylpropanoic acid

29) The reaction $CH_3COOC_2H_5 + NaOH \rightarrow CH_3COONa + C_2H_5OH$ is example of

A. A saponification reaction. B. Esterification reaction.

C. A condensation reaction. D. A neutralisation reaction.

30) The organic compounds containing carbon and hydrogen only are called

A. Carbon compounds. B. Aromatic compounds. C. Hydrocarbons. D. Carbon-hydride

# APPENDIX D

## UNIVERSITY OF EDUCATION, WINNEBA

## Science Student-Teachers' Organic Chemistry Achievement Test (STOCAT)

## POST-INTERVENTION TEST

**Purpose:** This **test** seeks to find out your conceptual understanding on selected organic chemistry concepts after the implementation of POEIA intervention. This exercise is being conducted for research purpose **only**; and that the marks obtained in this test will not form part of your end-of-semester examination score. Thank you.

**Section A:- Bio-data of the Respondent**

**SST's Code:-**.......................... **Sex:-** Male: [ ] Female: [ ] **Date:-**.......................

**Section B:- Instruction:** This test consists of 30 multiple choice objective tests. Each question item is followed by 4 options lettered A to D, read carefully and circle the **correct** option. Answer **all** questions on this paper for **30 marks**. **Duration:** 90 minutes.

1) Which of the following reactions is a valid **termination step** in the reaction of methane with chlorine in the presence of sunlight?
   A. $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ B. $CH_4 + Cl^{\cdot} \rightarrow CH_3Cl + H^{\cdot}$
   C. $CH_3^{\cdot} + Cl^{\cdot} \rightarrow CH_3Cl$ D. $CH_3^{\cdot} + Cl_2 \rightarrow CH_3Cl + Cl^{\cdot}$
2) The general formula of an alkene is
   A. $C_nH_{2n}$, for n = 1. B. $C_nH_{2n-2}$, for n ≥ 2. C. $C_nH_{2n+1}$, for n ≥ 2 D. $C_nH_{2n}$, for n ≥ 2
3) The IUPAC name of the compound $CH_3CH_2C(CH_3)_2C \equiv CH$ is
   A. 3, 3-dimethylpent-1-yne. B. 3, 3- dimethylpentyne.
   C. 3, 3-dimethylpent-1-yne. D. 3, 3- dimethylpent-4-yne.
4) Alkanols can be manufactured from alkenes by the initial reaction of alkenes with
   A. Bromine in tetrachloromethane. B. Conc. tetraoxosulphate(VI) acid.
   C. Aqueous potassium tetraoxomanganate(VII). D. Sodium hydroxide solution.
5) When oranges rot they taste sour. The functional group responsible for the sour taste is A. Ester B. Alkenes. C. Alkanols. D. Alkanoic acids.
6) Alkanoates have lower boiling points than alkanols with similar mass because they
   A. Contain weaker covalent bonds. B. Contain weaker dipole-dipole forces
   C. Contain more hydrogen bonds than alkanols. D. Have lower vapour pressure.
7) When acidified $K_2Cr_2O_7$ is treated with $CH_3CH_2OH$, the solution turns from orange to
   A. Yellow. B. Colourless. C. Purple. D. Green.
8) Which of the following procedures is valid for converting $H_2C{=}CH_2$ to $CH_3CH_2OH$?
   A. Treat with cold, conc. $H_2SO_4$, and then boil the product with water.
   B. Treat with neutral, aqueous $KMnO_4$ at room temperature.
   C. Heat with alcoholic KOH.
   D. Boil with water.
9) Which of the following pairs of reagents can be used to test for terminal alkyne?
   A. $AgNO_3/NH_3$ & $CuCl/NH_3$ B. $AgNO_3/NH_3$ & $KMnO_4$
   C. $KMnO_4$ & $K_2Cr_2O_7$ D. $CuCl/NH_3$ & $K_2Cr_2O_7$
10) The predominant intermolecular force in alkanoic acids is
   A. Electrostatic attraction. B. Van der Waal's forces.
   C. Hydrogen bonding. D. Dipole-dipole interaction.
11) Ammonia gas is evolved when dilute sodium hydroxide solution is warmed with
   A. An amide B. An amine. C. An amino acid. D. Protein.
12) A gas has the following characteristics; it
   I. is unreactive towards most of the oxidising agents.
   II. burns in air with blue flame to give $CO_2$ and water.
   III. reacts with chlorine to produce a gas which gives white fumes with ammonia.

The gas is likely to be an
A. Alkane. B. Alkene. C. Alkyne. D. Alkanoic acid.

13) Electrophilic addition of HBr to $H_2C{=}CH_2$ involves formation of intermediate as
A. A cation with the structure $CH_2BrCH_2^+$ B. A cation with the structure $CH_3CH_2^+$
C. A radical with the structure $CH_2BrCH_2^-$ D. An anion with the structure $CH_2BrCH_2^-$

14) Ethyne burn in air (oxygen) to give
A. Colourless and non-smoky flame. B. Very luminous and smoky flame.
C. Very luminous and non-smoky flame. D. Coloured and smoky flame.

15) The IUPAC name for $CH_3CH_2CH_2CH_2CHO$ is
A. Isopropanol. B. 1-methyl-1-hydroxy ethane. C. Pentanal. D. 1, 1-dimethanol.

16) A pleasant fruity scent is produced when alkanol is warmed with compound A in the presence of conc. HCl. Compound A could be
A. An alkene. B. An Alkanoic acid. C. An Alkanoate. D. A Phenol.

17) The IUPAC name of $CH_3COOCH_2CH_2CH_3$ is
A. Pentanoic acid. B. Pentanol. C. Ethyl propanoate. D. Propyl ethanoate.

18) The reaction $CH_3CH{=}CH_3 + H_2 \rightarrow CH_3CH_2CH_2CH_3$ is an:
I. Addition reaction. II. Elimination reaction.
III. Hydrogenation reaction. IV. Reduction reaction.
A. 1 & III. B. II & III. C. I, II & IV. D. I, III & IV.

19) A compound with molecular formula $(CH_2)n$ where n = 2 is
A. An alkane. B. An alkene. C. An alkyne. D. An alkyl

20) What occurs when terminal alkyne is treated with ammoniacal silver nitrate (V) soln?
A. A red precipitate is formed. B. A cream precipitate is formed.
C. A colourless precipitate is formed. D. A purple precipitate is formed.

21) Which of the following general formulae is **incorrect**?
A. $CnH_2n + 2$, for alkanes. B. $CnH_2n - 2$, for alkynes.
C. $CnH_2nOH$, for alkanols. D. $CnH_2n + 1COOH$, for alkanoic acid.

22) What occurs when an aldehyde is treated with ammoniacal silver nitrate (V) solution?
A. A silver mirror precipitate is formed. B. A cream precipitate is formed.
C. A colourless precipitate is formed. D. A purple precipitate is formed.

23) Which of the following organic acids is present in vinegar?
A. Benzencarboxylic acid. B. Ethanoic acid. C. Butanoic acid D. Hexanoic acid

24) When a mixture of methane and chlorine is left in the dark
A. Hydrogen chloride and chloroethane are formed. B. There is decolourization.
C. Hydro chloride and chloromethane are formed. D. There is no visible reaction.

25) The general formula of an alkyl group is
A. $CnH_2n\text{-}2$ B. $CnH_2n{+}2$ C. $CnH_2n{+}1$ D. $CnH_2n$

26) Which of the following will give a red ppt with ammoniacal copper(I) chloride?
A. $CH_3C \equiv CCH_3$. B. $HC \equiv CCH_2CH_3$. C. $CH_3CH = CH_2$. D. $CH_2 = CH_2$.

27) Which of these alkanols gives immediate cloudiness when treated with Lucas reagent?
A. $CH_3CH_2OH$ B. $(CH_3)_2CHOH$ C. $(CH_3)_3COH$ D. $CH_3CH(OH)CH_3$

28) An atom, a group of atoms or a bond, which give a particular family of organic compounds its characteristic chemical properties is termed as
A. A substituent. B. Homologous series. C. Carbocation. D. Functional group.

29) Acetylene is produced commercially by the
A. Action of water on calcium carbide. B. Action of water on calcium acetylide.
C. Fractional distillation of crude petroleum. D. Passage of steam over white-hot coke.

30) The reaction below represents:

$$CH_3CH_2COOH + CH_3OH \xrightleftharpoons{\text{Conc. } H_2SO_4 \text{ : Heat}} CH_3CH_2COOCH_3 + H_2O$$

A. Neutralisation. B. Esterification. C. Saponification. D. Hydrogenation

# APPENDIX E

## UNIVERSITY OF EDUCATION, WINNEBA

### Science Student-Teachers' Attitude Scale Questionnaire (STASQ)

**Purpose:** This questionnaire contains 14 items that assess your attitudes towards organic chemistry after implementation of POEIA. Your responses will be treated **confidential**.

**Sections A:- Bio-data of the Respondent**

Please, tick your sex and write your code, and the date in the spaces provided below.

**SST's Code:-**.......................... **Sex:-** Male: [ ] Female: [ ] **Date:-**.......................

**Sections B**:- Read each statement carefully and record your reaction by ticking "[√ ]" through the letter that best describes how agree or disagree to it. **Use These Keys: - [SA]-** Strongly Agree; **[A]**-Agree; **[U]**-Uncertain; **[D]**-Disagree; **[SD]** - Strongly Disagree.

| No | Post-attitude scale questionnaire items | [SA] | [A ] | [ U ] | [ D ] | [SD] |
|---|---|---|---|---|---|---|
| 1) | Organic chemistry was difficult for me before the POEIA intervention activities. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 2) | I enjoyed learning organic chemistry concepts taught through activities based on the POEIA. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 3) | I still dislike organic chemistry concepts after the exposure to POEIA intervention | [ ] | [ ] | [ ] | [ ] | [ ] |
| 4) | The POEIA gave me more time to perform more practical activities on the organic chemistry concepts taught. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 5) | The POEIA did not give me enough opportunities to have collaborative interactions with my mates. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 6) | The use of POEIA increases my motivation to learn and also gave me more confident in the concepts taught. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 7) | I did not like the way POEIA was used to teach organic chemistry concepts. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 8) | The POEIA is more engaging during teaching and learning processes of the concepts taught than usual traditional lecture instructions. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 9) | The POEIA did not give me enough opportunities to develop my ability to think critically and independently. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 10 | The POEIA has helped me to improve my performance and had higher morale in organic chemistry concepts taught. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 11 | POEIA did not help me to get deeper understanding of the concepts taught | [ ] | [ ] | [ ] | [ ] | [ ] |
| 12 | The POEIA has helped me to develop systematic approach to the learning of organic chemistry concepts taught. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 13 | POEIA used to teach organic chemistry concepts was demanding and did not want it to be continued in the college. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 14 | The POEIA has helped me to develop positive attitude towards the learning of organic chemistry concepts taught. | [ ] | [ ] | [ ] | [ ] | [ ] |

# APPENDIX F

## UNIVERSITY OF EDUCATION, WINNEBA

## POEIA Post-Interview Schedule (POEPIS)

**Instruction:**-Dear student-teachers, I would like to know what you think about the POE instructional approach intervention activities, which took place in your class recently? There are no right or wrong answers. Your group as well as individual opinion(s) or response(s) is/are what is required; and will be treated confidentially. Thank you for your co-operation

### Items in the Interview Schedule

1) What can you say about POEIA used in teaching you organic chemistry concepts in your class?
2) How have POEIA lessons been different from the normal chemistry class?
3) Did you have hard time in doing different POE instructional approach activities?
4) Were the POEIA materials useful for teaching you the concepts understudy?
5) Has the POEIA intervention activities helped you to improve on your performance and attitudes towards the selected topics in the organic chemistry?
6) Are you in favour of using POE instructional approach in teaching you organic chemistry; and that do you want it to be continued in your college?
7) Do you have any comments, suggestions or other things you would like to say which you think might be useful?

# APPENDIX G

## UNIVERSITY OF EDUCATION, WINNEBA

## DEPARTMENT OF SCIENCE EDUCATION

University of Education,
Science Education Department,
Chemistry Education Department,
P. O. Box 25,
Winneba.

28/02/2022

**INTRODUCTORY LETTER**

The bearer of this letter, **Mr. Anthony Assafuah-Drokow is** a Doctor of Philosophy in science education student in the Department of Science Education of the Faculty of Science Education in the University of Education, Winneba.

He is studying **"Effects of predict-observe-explain instructional approach on science student-teachers' performance and attitudes towards selected organic chemistry topics"**

Your reputable College has been selected as part of his sampling area. I hope you would assist him to do a good thesis write-up.

Thank you.

Yours faithfully,

……………………………

Professor John K. Eminah
Principal Supervisor

# APPENDIX H

## UNIVERSITY OF EDUCATION, WINNEBA

## Scoring Scheme for Items in Subjects' Pre-Interview Schedule (SSTPIS)

### 1). Solutions for Correct IUPAC Nomenclature

| No | Organic compound | IUPAC Nomenclature |
|---|---|---|
| a) | $CH_3CH_2CH_2CH_2CH_3$ | Pentane (n-pentane) |
| b) | $CH_3CH_2C(Cl)_2CH_2(C_2H_5)$ | 3, 3-dichlorohexane |
| c) | $(CH_3)_2CHCH_2CH{=}C(Cl)CH_3$ | 2-chloro-5-methylhex-2-ene |
| d) | $CH_3CH_2C(CH_3)_2C{\equiv}CH$ | 3,3-dimethylpent-1-yne |
| e) | $CH_3CH_2CH(OH)CH_3$ | 2-butanol (or Butan-2-ol) |
| f) |  | Cyclohexyne |
| g) | $CH_3CHO$ | Ethanal |
| h) | $C_2H_5COOH$ | Propanoic acid |
| i) | $CH_3COCH_2CH_3$ | Butanone |
| j) | $CH_3NH_2$ | Aminomethane |

### 2). Solutions For Reaction Mechanisms

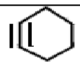
**<u>Solution 2a). Reaction Mechanism for item 2a)</u>**

$$Cl - Cl \xrightarrow[\text{Peroxide}]{\text{U.V light or Heat}} Cl\cdot + Cl\cdot$$

**<u>Solution 2b). Reaction Mechanism for item 2b)</u>**

$$\text{Alkanoic (carboxylic) acid} + \text{Alkanol (alcohol)} \underset{\text{Heat}}{\overset{\text{Conc. } H_2SO_4}{\rightleftharpoons}} \text{Ester/Alkanoate} + \text{water}$$

### 3). Solutions for Functional Group Identification

| No | Organic compound | Functional Group Identification |
|---|---|---|
| a) | $CH_3CH_2CH_2CH_2CH_3$ | Alkane |
| b) | $CH_3CH_2C(Cl)_2CH_2(C_2H_5)$ | Alkane |
| c) | $(CH_3)_2CHCH_2CH{=}C(Cl)CH_3$ | Alkene |
| d) | $CH_3CH_2C(CH_3)_2C{\equiv}CH$ | Alkyne |
| e) | $CH_3CH_2CH(OH)CH_3$ | Alkanol (Alcohol) |
| f) |  | Alkyne |
| g) | $CH_3CHO$ | Carbonyl (Aldehyde) |
| h) | $C_2H_5COOH$ | Alkanoic acid (Carboxylic acid) |
| i) | $CH_3COCH_2CH_3$ | Carbonyl (Ketone) |
| j) | $CH_3NH_2$ | Amine |

### 4). Correct balancing of combustion of hydrocarbon equation

a). $CH_{4\,(g)} + 2\,O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2\,H_2O_{(l)}$

b). $C_2H_{4\,(g)} + 3\,O_{2\,(g)} \rightarrow 2\,CO_{2\,(g)} + 2\,H_2O_{(l)}$

c). $C_2H_{2\,(g)} + 2.5O_{2\,(g)} \rightarrow 2\,CO_{2\,(g)} + H_2O_{(l)}$

**OR**

$$C_2H_{2\,(g)} + \tfrac{5}{2}O_{2\,(g)} \rightarrow 2\,CO_{2\,(g)} + H_2O_{(l)}$$

# APPENDIX I

## UNIVERSITY OF EDUCATION, WINNEBA

## DEPARTMENT OF SCIENCE EDUCATION

### Marking Scheme for Both Pre-& Post-Intervention Tests

| No | **Pre-intervention test correct options** | **No** | **Post-intervention test correct options** |
|---|---|---|---|
| 1). | B | 1). | C |
| 2). | C | 2). | D |
| 3). | C | 3). | C |
| 4). | D | 4). | B |
| 5). | D | 5). | D |
| 6). | D | 6). | B |
| 7). | C | 7). | D |
| 8). | B | 8). | A |
| 9). | D | 9). | A |
| 10). | C | 10). | C |
| 11). | C | 11). | A |
| 12). | D | 12). | A |
| 13). | A | 13). | B |
| 14). | D | 14). | B |
| 15). | B | 15). | C |
| 16). | D | 16). | B |
| 17). | A | 17). | D |
| 18). | B | 18). | D |
| 19). | B | 19). | B |
| 20). | C | 20). | B |
| 21). | D | 21). | C |
| 22). | C | 22). | A |
| 23). | C | 23). | B |
| 24). | D | 24). | D |
| 25). | C | 25). | C |
| 26). | C | 26). | B |
| 27). | C | 27). | C |
| 28). | C | 28). | D |
| 29). | A | 29). | A |
| 30). | C | 30). | B |

# APPENDIX J

## UNIVERSITY OF EDUCATION, WINNEBA

## DEPARTMENT OF SCIENCE EDUCATION

### T-Test Analysis of the Pre-Intervention and Post-Intervention Tests

## T-Test

### Group Statistics

| | Pre_post | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Score | pre score | 40 | 9.6000 | 5.13809 | .81240 |
| | post score | 40 | 18.2750 | 6.47277 | 1.02344 |

### Independent Samples Test

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | |
|---|---|---|---|---|---|
| | | F | Sig. | t | Df |
| Score | Equal variances assumed | 1.048 | .309 | -6.639 | 78 |
| | Equal variances not assumed | | | -6.639 | 74.181 |

### Independent Samples Test

| | | t-test for Equality of Means | | | |
|---|---|---|---|---|---|
| | | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference Lower |
| Score | Equal variances assumed | .000 | -8.67500 | 1.30668 | -11.27641 |
| | Equal variances not assumed | .000 | -8.67500 | 1.30668 | -11.27852 |

### Independent Samples Test

| | | t-test for Equality of Means 95% Confidence Interval of the Difference Upper |
|---|---|---|
| Score | Equal variances assumed | -6.07359 |
| | Equal variances not assumed | -6.07148 |

# APPENDIX K1

## UNIVERSITY OF EDUCATION, WINNEBA

## UNIT 1: LESSON PLAN BASED ON PREDICT-OBSERVE-EXPLAIN INSTRUCTIONAL APPROACH ON ALKANES

**College:** As Applicable
**Subject:** Chemistry (Option:- Organic Chemistry)
**Topic:** Alkane (Paraffins)
**Level:** 200

**Number in Class:** 40
**Average Age:- 23 years**
**Sex:** Mixed
**Duration:** 2 hours (120 minutes)

**Concept Focus:-**Laboratory preparation of a named alkane and perform certain chemical tests.
**Scientific Processes:-** Making predictions, observations, classifications, explanations and drawing conclusions.
**Group(s)**:- Learners work in groups (3- 4 members per team). Facilitator provides all necessary resources.
**Assessment Methods**:-Classroom dialogue; Tutor observations; Worksheets; Post-activity assignment.

**Course Learning Outcome & Indicators:-** By the end of the lesson, learners should be able to;

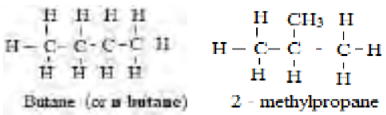
1) Describe alkanes in terms of their nature, formula and functional group.
2) Identify the sources of alkanes.
3) Discuss IUPAC rules and write correct IUPAC names of alkanes using the rules.
4) Describe the isomerism in alkanes (especially with butane, $C_4H_{10}$).
5) Mention the physical properties of alkanes.
6) State the chemical properties of alkanes.
7) Mention the uses of alkanes.
8) Carryout laboratory preparation of a named alkane (methane, $CH_4$ gas).

**Instructional Resources:-** Acetate, sodium hydroxide, calcium oxide, Bunsen burner, beaker, cork, gas jar, delivery tube, beehive shelf, retort stand and clamp, POE activity guide and POE worksheet.

**Lesson Presentation:-**

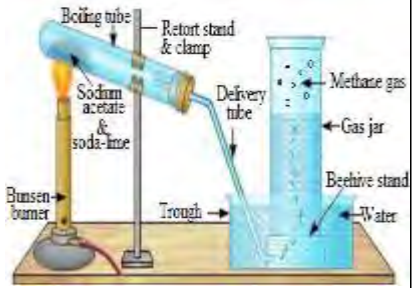
**RPK:-** Learners have learnt aspect of alkanes at the SHS level and in General Chemistry I at COE level.

| Steps | Lesson Development | Time (mins) | Facilitator's (Tutor's) Activities | Learners' Activities | Core-Point(s) |
|---|---|---|---|---|---|
| Step 1 | **Introduction**<br>-Reviewing Previous Knowledge of the learners | **5** | 1. Arouse learners' interests, encourage and motivate them to learn. Make it known to them the teaching technique and its demand on them.<br><br>2. Using question and answer method, review learners' R.P.K on hydrocarbons: E.g. What are hydrocarbons & its three classes?. Let them know that today's lesson is about alkanes. Discuss with them the objectives of the lesson. | Learners listen attentively to the facilitator/tutor. They are encouraged to talk, ask questions and write notes and also write down their ideas where necessary.<br><br>Listen to the tutor and jot down some points as the tutor speaks, and ask various questions based on the topic for clarification. | **Expected Answers:-** They are organic compounds made up of carbon and hydrogen only. The 3 classes are alkanes, alkenes and alkynes. |
| Step 2 | Grouping, Elicitation & Discussion of Learners' thinking/ideas<br><br>Group of learners | **35** | 1). Divide learners into groups (of 3-4) based on ability and inclusivity; ask them to assume the roles of team leader, recorder, time-keeper, etc. Let them be aware that the roles are rotational.<br><br>2). Ask learners to describe alkanes in terms of their nature, formula and functional group. Move round various groups to supervise the activities.<br><br>3). In the form of whole class discussion, assist them to describe systematic steps involved in naming alkanes (both aliphatic and cyclic) using the IUPAC | Learners' move into their respective groups and assume their different roles as agreed by members.<br><br>Learners brainstorm and write their results or findings on the assigned work in their groups.<br><br>Learners pay attention and listen attentively, ask questions to clarify their difficulties on IUPAC rules; | **Expected Answers:-**<br>**a). Nature of Alkanes**<br>Alkanes are saturated hydrocarbons that contain single covalent bonds. Also called **paraffins**. The general formula $\mathbf{C_nH_{2n+2}}$, *where* $n \geq 1$; and the cyclic form is $C_nH_{2n}$. The functional group is C-C<br><br>**Names of some Alkanes**<br>$CH_4$ – Methane<br>$C_2H_6$ – Ethane<br>$C_3H_8$ – Propane |

| | | | | | |
|---|---|---|---|---|---|
| | | | rules. Give some structures of alkanes for them to name using the rules.<br><br>4). In their respective groups, (with the help of their smart phones); ask learners to search and provide their findings on the following areas/aspects:-<br><br>a) Sources of alkanes<br><br>b) Isomerism<br><br>c) Isomerism in alkanes<br><br>d) Physical properties of alkanes<br><br>e) Chemical properties of alkanes | and use the rules to name the given alkane structures.<br><br>Learners in their groups use their phones to search, discuss and write their findings and present them chronologically as assigned to them on:-sources of alkanes; isomerism; isomerism in alkanes; physical properties of alkanes; chemical properties of alkanes; and uses of alkanes. | **a). Sources of Alkanes**<br>They include:- natural gas; coal formation; anaerobic decomposition, destructive distillation, crude oil or petroleum refining.<br>**b). Isomerism**<br>It is the existence of two or more compounds with the same molecular formula but different structural formula.<br>**c). Isomerism in Alkanes**<br>Alkanes undergo structural isomerism. Isomerism occurs in compounds having **four** or **more** carbon atoms.<br>**Example $C_4H_{10}$**<br><br>**d). Physical properties**<br>1). **Nature and states**<br>$C_1$-$C_4$ are gases; $C_5$ - $C_{18}$ are liquids; $C_{19}$ & above are solids.<br>2). **Colour:-** All alkanes are colourless in their pure states.<br>3). **Volatility**:- It decreases along homologous series. |

<table>
<tr>
<td></td>
<td></td>
<td></td>
<td>f) Uses of alkanes<br><br>5). In their respective groups, ask learners to write their findings on cardboards/flip charts and make presentations to the class.<br><br>6). Assist in the plenary discussions on the learners' presentations.<br><br>7). Through an intact or whole class discussion, refine learners' responses and ask them to write the correct responses in a logical manner on the maker board as shown in the core-point column.</td>
<td>Learners write their findings on cardboards/flip charts and make their presentations to the class.<br><br>Learners listen attentively to each group's presentation; ask questions when necessary.<br><br>Learners in their groups take active part in the discussion process; seek clarifications when necessary to refine their thinking/ideas on the various areas of alkanes taught.</td>
<td>4). Boiling & melting points
<table>
<tr><td>Alkane</td><td>M. point</td><td>B. point</td></tr>
<tr><td>$CH_4$</td><td>-183°C</td><td>-162°C</td></tr>
<tr><td>$C_2H_6$</td><td>-182°C</td><td>-89°C</td></tr>
<tr><td>$C_3H_8$</td><td>-188°C</td><td>-42°C</td></tr>
</table>
Order:-<br>$CH_4 < C_2H_6 < C_3H_8$, etc<br>5). Solubility:- Alkanes are non-polar thus; they are insoluble in polar solvent like water, but soluble in non-polar solvents like benzene.<br><br><u>e). Chemical properties</u><br>1. Chemically, alkanes are unreactive but undergo substitution reaction.<br>2. Alkanes react with halogens, e.g. $Cl_2$, in presence of sun or U.V light to give haloakanes and HCl.<br>3 Combustion:-They burn in excess air ($O_2$) to produce carbon dioxide and water.<br><br><u>f). Uses of Alkanes</u><br>1). Methane: Used as fuel for cooking, & manufacture of $H_2$<br>2). Ethane:- Used to produce plastics, ethanol, lye, etc.</td>
</tr>
</table>

| | | | | | |
|---|---|---|---|---|---|
| Step 3 | Introducing the Experiment | **5** | Introduce experiment to the learners and discuss its aim/purpose, steps involved and expected outcome. E.g.:- This experiment involves preparation of a named alkane by using sodium acetate and soda-lime; and perform ignition test.<br><br>Give the POE worksheet 1 on alkanes to learners to read for the next step (step 4). | Learners listen attentively to the facilitator and write down some important points as the tutor speaks. They also ask questions to clarify their thought when necessary.<br><br>Leaners take the POE worksheet 1 on alkanes and read for next stage. | |
| Step 4 | <u>**Predict (P)**</u><br>Learners make predictions on the experiment they are about to do based on their existing ideas; knowledge and/or experience<br><br>Predicting | **15** | In this step, ask learners to predict answers to structured questions based on the experiment they are about to do in their POE worksheets. Let them answer the questions on worksheet in groups:<br>E.g.<br>1) If you mix sodium acetate and soda-lime together in a test tube, what do you think will happen?. etc (see worksheet 1)<br><br>Tutor moves round to supervise them to ensure each member participate in the activities. | Each member in the group is expected to write out his/her prediction in their jotters. The group compare individual answers and brainstorm collectively to come out with group ideas.<br><br>The group's predictions are to be written on POE worksheets supplied to them by the recorder or any member they agreed on to do the writing.<br><br>Facilitator moves round and interacts with the groups as they make their predictions. | |
| | **Reason(s):** | | Ask each group to give reason(s) for their predictions. Move round to supervise the prediction activities among the groups. | Each group write reason(s) for their predictions on the POE worksheet and for discussion. | |

| | | | | | |
|---|---|---|---|---|---|
| Step 5 | **<u>Observe (O)</u>**<br>-Perform experiment.<br><br>Perform expt | **40** | Give the activity guide 1 on alkanes for them to read through.<br>Discuss with them the steps involved in this experiment and ask learners to perform the experiment to prepare an unknown gas X by following the steps in the activity guide 1:-<br>E.g.<br>1). Measure 3grams of anhydrous sodium acetate ($CH_3COONa$) (reagent A) into beaker; etc (see activity guide 1)<br>Facilitator and the laboratory technician move round to assist them when needed.<br>Facilitator ensures that each member in each group participate in the activities. | Carry out the activities as directed by the facilitator. They follow the instructions step by step as stated in the activity guide 1 on the alkanes.<br>Each member in the group record his/her observations and inference in their jotters. They also write the chemical equation representing the preparation of the gas X.<br>The group then compare the individual's observations, dialogue collectively and write the group's ideas as agreed in the POE worksheet. | <br><br>Set-up for the preparation of methane gas (Gas X)<br>**<u>Set-up and expected results</u>**<br><br><br>Set-up for ignition of $CH_4$ gas |
| Step 6 | **<u>Explain (E)</u>**<br><u>E</u>xplaining the observations; & compare the observations with their predictions<br><br>Explaining | **15** | Ask learners in their groups to compare individual explanations and collectively brainstorm to come out with the group's explanations to their observations.<br>Ask learners to correlate their prediction(s) with observation(s) in order to reconstruct their thinking/ideas; and reconcile any conflict between their predictions and observations. | Learners in their groups compare their individual explanations and collectively brainstorm to come out with the group's explanations to their observations.<br>Learners are to compare their predictions and observations so as to reconcile any conflict between their predictions and observations in the whole class discussions. | |

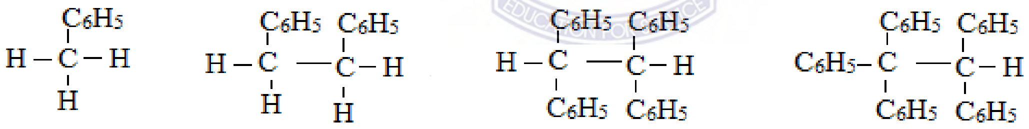
| | | | | | |
|---|---|---|---|---|---|
| | | | Ask learners to disengage from their groupings. Tell them to read on the next topic; alkenes. | Learners move to their seats. They read given assignment. | |
| **Total** | | **115** | | | |

Summary: **(5 minutes)**
Facilitator (Tutor) summarises the lesson: - Alkanes are saturated hydrocarbons that contain single covalent carbon-carbon bonds. They are also called paraffins. The general formula for alkanes is $C_nH_{2n+2}$, where ($n \geq 1$). All the carbon atoms present in an alkane are $sp^3$ hybridised and they exhibit tetrahedral geometry with a bond angle of 109.47° between them. The sources of alkanes include natural gas, anaerobic decomposition, coal formation, refining of crude oil/petroleum and destructive distillation. All alkanes are colourless; odourless in nature and have weak Van der Waals forces between their molecules. They readily undergo combustion reactions when ignited. When sufficient oxygen is present to support total combustion then carbon dioxide and water are formed. They are unreactive and undergo substitution reaction with halogens e.g. $Cl_2$, $Br_2$, $I_2$ in presence of sunlight (U.V light) to give haloakanes (alkyl halides). Alkanes are non-polar and are insoluble in polar solvent like water, but soluble in non-polar solvents like ether, benzene, etc. They have several uses ranging from cooking, lighting and manufacture of several products such as plastics and ethanol. The first member, methane can be prepared in the laboratory by the use of sodium acetate and soda-lime with CaO acting as a catalyst.

**Individual Assignment:**

Tutor/facilitator gives the students take home assignment due for submission the next class. Lets learners read on alkenes.

1). Give the IUPAC names of the following compounds.



(a) (b) (c) (d)

2). With the aid of a diagram, describe how a named alkane, methane gas is prepared in the laboratory.

3). Mention four physical and chemical properties of alkanes each.

**Expected answers to the assignment questions:**

1) a). Phenylmethane b). 1, 2-diphenylethane c). 1,1, 2, 2-tetraphenylethane d) 1,1,1, 2, 2-pentaphenylethane

**For answers to questions 2 and 3 refer to the pore-core point column of the lesson plan**.

**WORKSHEET 1: ON ALKANES**

<table>
<tr><td></td><td colspan="2">SCIENCE STUDENT-TEACHERS' POE WORKSHEET FOR ALKANES</td></tr>
<tr><td>Steps</td><td>Steps in POE</td><td>Group Number:………………… Date: …………………</td></tr>
<tr><td rowspan="2">1</td><td><u>P</u>redict = (P)<br>What do you think will happen……?<br><br>What is in your mind?<br>Please speak out</td><td>1). If you mix sodium acetate and soda-lime together in a test tube, what do you think will happen?:………………………………………………………………………………………………<br>2). If you place the mixture on a Bunsen burner, what do you think will happen?:………………………………………………………………………………………………………<br>3). What do you think the equation for the reaction would be?:…………………………………………………………………………<br>4). If the gas is ignited, it would burn with a particular colour and odour, what do you think the colour and odour are likely to be?: …………………………………………………………………………<br>5). What do think the name of the gas is likely to be?:……………..</td></tr>
<tr><td>Give reason(s) for your prediction(s)<br><br></td><td>…………………………………………………………………………<br>…………………………………………………………………………<br>…………………………………………………………………………</td></tr>
<tr><td>2</td><td><u>O</u>bserve = (O)<br><br>Please observe well</td><td><table><tr><th>Test</th><th>Observation</th><th>Inference</th></tr><tr><td>Soda-lime + $CH_3COONa$ + Heat</td><td>………………………..<br>………………………</td><td>……………<br>……………</td></tr><tr><td>An unknown gas + ignition (combustion)</td><td>……………………....<br>………………………</td><td>……………<br>……………</td></tr></table></td></tr>
<tr><td>3</td><td><u>E</u>xplain = (E)<br><br>Please explain well</td><td>…………………………………………………………………………<br>…………………………………………………………………………<br>…………………………………………………………………………<br>…………………………………………………………………………<br>…………………………………………………………………………<br>…………………………………………………………………………...</td></tr>
</table>

**EXPECTED RESPONSES FROM WORKSHEET 1: ON ALKANES**

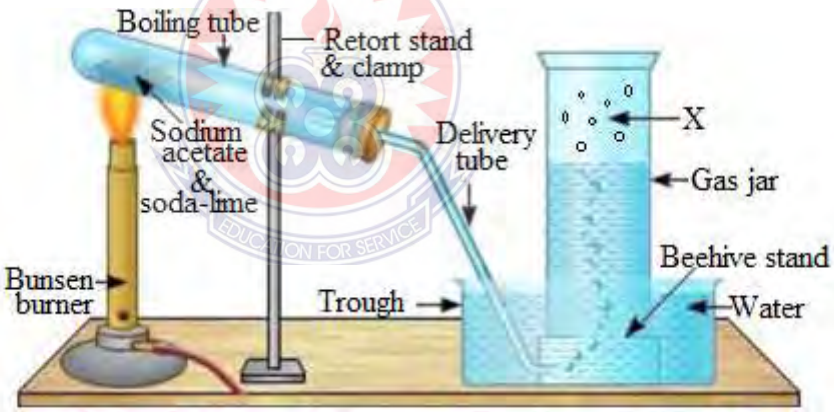
<table>
<tr><th colspan="3">SCIENCE STUDENT-TEACHERS' POE WORKSHEET FOR ALKANES</th></tr>
<tr><th>Steps</th><th>Steps in POE</th><th>Group Number:………………… Date: …………………</th></tr>
<tr><td>1</td><td><u>P</u>redict = (P)<br>What do you think will happen…….?<br><br>What is in your mind?<br><br>Please speak out</td><td>1). If you mix sodium acetate and sodium hydroxide together in a test tube, what do you think will happen? <u>There will be no reaction until it is heated</u>.<br>2). 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>.<br>3). What do you think the equation for the reaction would be?<br>$$NaOH + CH_3COONa \xrightarrow[Heat]{CaO} CH_4 + Na_2CO_3$$<br>4). If the gas is ignited, it would burn with a particular colour and odour, what do you think is the colour and odour?.<br><u>The gas is likely to burn with a blue flame and odourless</u>.<br>5). What do you think the name of the gas would be?<br><u>The unknown gas is likely to be methane ($CH_4$) gas</u>.</td></tr>
<tr><td></td><td>Give reason(s)<br><br></td><td>1). This reaction requires heat and catalyst for the salts of carbonic acids to reacts with NaOH so as to release alkane (methane).<br>2) Methane is an odourless gas and undergoes complete combustion to give a blue flame. A blue flame shows complete combustion whiles red or yellow gas flame signifies incomplete combustion.</td></tr>
<tr><td>2</td><td><u>O</u>bserve = (O)<br><br>Please observe well</td><td><table>
<tr><th>Test</th><th>Observation</th><th>Inference</th></tr>
<tr><td>NaOH + CH<sub></sub>$CH_3COONa$ + Heat</td><td>Within few minutes an unknown gas evolves</td><td>Odourless and colourless gas evolves</td></tr>
<tr><td>An unknown gas + ignition</td><td>The unknown gas burns with a blue flame; and it is odourless & colourless.</td><td>Gas evolved is methane</td></tr>
</table></td></tr>
<tr><td>3</td><td><u>E</u>xplain = (E)<br><br>Please explain well</td><td>The salts of carbonic acids reacts with NaOH in presence of catalyst and heat to release $CH_4$ gas. The unknown gas burns with a blue frame, indicate it undergoes complete combustion and it is an odourless gas. In this regard, an unknown gas X is methane gas or $CH_4$ gas.<br></td></tr>
</table>

## ACTIVITY GUIDE 1: ON ALKANES

| SCIENCE STUDENT-TEACHERS' POE ACTIVITY GUIDE FOR ALKANES | |
|---|---|
| **Group Number:………………………………….** | **Date: ………………………………..** |
| | |

**Instruction**:-Guide student-teachers to carryout these practical activities for the preparation of an unknown gas X using sodium acetate and soda lime as follows:-

1) Measure 3grams of anhydrous sodium acetate ($CH_3COONa$) (reagent A) into a beaker.
2) Add 1.5 grams of soda-lime (mixture of NaOH & CaO), (reagent B) in the ratio of 2:1.
3) Mix reagents A and B thoroughly in a beaker or porcelain dish.
4) Transfer the mixture into a boiling tube.
5) Seal the boiling tube with a cork and connect with a delivery tube (as shown below).
6) Fix the boiling tube and its content on retort stand and clamp it gently.
7) Place beehive shelf in a trough containing water and pass delivery tube through it.
8) Heat the tube gently for a while with the cold part of the flame to avoid overheating and also keep the flame in motion along the tube.
9) Observe the experiment carefully and record your observations.




**Set-up for the preparation of gas X**

10) Collect the gas X carefully in a gas jar and cover it.
11) Use dry test, collect some gas and quickly fix it with a cork containing narrow jet tube and ignite it.
12) Record your observation and inference.

# APPENDIX K2

## UNIVERSITY OF EDUCATION, WINNEBA

## UNIT 2: LESSON PLAN BASED ON PREDICT-OBSERVE-EXPLAIN INSTRUCTIONAL APPROACH ON ALKENES

**College:** As Applicable

**Subject:** Chemistry (Option:- Organic Chemistry)

**Topic:** Alkenes (Olefins)

**Level:** 200

**Number in Class:** 40

**Average Age:- 23 years**

**Sex:** Mixed

**Duration:** 2 hours (120 minutes)

**Concept Focus:-**Laboratory preparation of a named alkene and perform certain chemical tests.

**Scientific Processes:-** Making predictions, observations, classifications, explanations and drawing conclusions.

**Group(s)**:- Learners work in groups (3-4 members per team). Facilitator provides all necessary resources.

**Assessment Methods**:-Classroom dialogue; Tutor observations; Worksheet exercises; Presentations; Post-activity assignment.

**Course Learning Outcome & Indicators:-** By the end of the lesson, learners should be able to;

1) Describe alkenes in terms of their nature, formula and functional group.
2) Identify the source(s) of alkenes.
3) Discuss IUPAC rules and write correct IUPAC names of alkenes using the rules.
4) Describe the isomerism in alkenes.
5) Mention the physical properties of alkenes.
6) State the chemical properties of alkenes.
7) Mention the uses of alkenes.
8) Carryout laboratory preparation of a named alkene (ethane gas).

**Instructional Resources:-** Ethanol, aluminium oxide/porcelain chips, boiling tubes, Bunsen burner, glass wool, cork, delivery tube, trough, retort stand and clamp, POE activity guide and POE worksheet.

**Lesson Presentation:-**

**RPK:-** Learners have learnt aspect of alkenes at the SHS level and in General Chemistry I at COE level.

| Steps | Lesson Development | Time (mins) | Facilitator's (Tutor's) Activities | Learners' Activities | Core-Point(s) |
|---|---|---|---|---|---|
| Step 1 | **Introduction**<br>-Reviewing Previous Knowledge of the learners | **5** | 1. Arouse learners' interests, encourage and motivate them to learn. Make it known to them the teaching technique to be used and its demand on them.<br>2. Using question and answer method, review learners' R.P.K on hydrocarbons: E.g. What are hydrocarbons & its three classes? Let them know that today's lesson is about alkenes. Discuss with them the objectives of the lesson. | Leaners listen attentively to the facilitator/tutor. They are encouraged to talk, ask questions, write notes and also write down their ideas.<br>Listen to the tutor and jot down some points as the tutor speaks, and also ask various questions based on the topic for clarification where and when necessary. | **Expected Answers:-** They are organic compounds made up of carbon and hydrogen only. The 3 classes are alkanes, alkenes and alkynes. |
| Step 2 | Grouping, Elicitation & Discussion of Learners' thinking/ideas<br><br>Group of learners | **35** | 1). Divides learners into groups (of 3-4) based on ability and inclusivity; ask them to assume the roles of team leader, recorder, time-keeper, etc. Let them be aware that the roles are rotational.<br>2). Ask learners to describe alkenes in terms of their nature, formula and functional group. Move round various groups to supervise their activities.<br>3). In the form of whole class discussion, assist them to describe systematic steps involved in naming alkenes (both aliphatic and cyclic) using the IUPAC | Learners' move into their respective groups and assume their new different roles as agreed by members.<br>Learners brainstorm and write their results or findings on the assigned work in their groups.<br>Learners pay much attention and listen attentively; they ask various questions to clarify their difficulties | **Expected Answers:-**<br>**a). Nature of Alkenes**<br>Alkenes are unsaturated hydrocarbons that contain carbon-carbon double bonds. Also called **Olefins**. The general formula is **$C_nH_{2n}$**, whereas *where* n ≥ 2; and the functional group is C=C<br>**Names of Some Alkenes**<br>$C_2H_4$ – Ethene<br>$C_3H_6$ – Propene<br>$C_4H_8$ – Butene |

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| | | | rules. Give some structures of alkenes for them to use the rules to name.<br><br>4). In their respective groups, (with the help of their smart phones); ask learners to search and provide their findings on the following aspects:-<br><br>a). Sources of alkenes<br><br>b). Isomerism in alkenes<br><br>c) Physical properties of alkenes<br><br>d) Chemical properties of alkenes<br><br>e) Test for alkenes<br><br>f) Uses of alkenes | in IUPAC rules; and use the rules to name the given alkene structures.<br><br>Learners in their groups use their phones to search, discuss and write their findings and present them chronologically as assigned to them in relation to sources; isomerism in alkenes; physical and chemical properties of alkenes; chemical tests and the uses of alkenes. | **a). Source(s) of Alkenes**<br>Alkenes are produced from the alkanes in crude oil by a process called cracking.<br><br>**b). Isomerism in Alkenes**<br>Isomerism in alkenes are of two main types namely **structural isomerism** (e.g. chain, position & functional) and stereoisomerism (e.g. optical & geometric). The geometric are cis & trans.<br><br>**c). Physical properties**<br>1). **Nature and states**<br>$C_2$-$C_4$ are gases; $C_5$ - $C_{18}$ are liquids; $C_{19}$ & above are solids.<br>2). **Colour: -** Alkenes are colourless in their pure states.<br>3). **Boiling & melting points**: They have lower boiling and melting point than alkane, etc<br><br>**d). Chemical properties**<br>Chemically, alkenes are very reactive than alkanes and they undergo combustion reaction. They also undergo addition reactions with unsymmetrical and symmetrical reagents; etc |

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| | | | 5). In their respective groups, ask learners to write their findings on cardboards/flip charts and make presentations to the class.<br><br>6). Assist in plenary discussions on the learners' presentations.<br><br>7). Through a whole or an intact class discussion, refine learners' responses and asks them to write the correct responses in a logical manner on the maker board as shown in the core-point column. | Learners write their findings on cardboards/flip charts and make their presentations to the class.<br><br>Learners listen attentively to each group's presentation; ask questions when necessary.<br><br>Learners in their groups take active part in the discussion process; seek clarifications when necessary to refine their thinking/ideas on the various areas of alkenes taught. | **e). Test for Alkenes**<br>Alkenes can be tested in the laboratory using the following reagents: $Br_2/CCl_4$; $Br_2/H_2O$; $KMnO_4$; $K_2Cr_2O_7$; etc.<br>E.g.<br>**Test**:- Add a few drops of bromine water; $Br_2/H_2O$ to an alkene.<br>**Observation**:- The brown colour of bromine water is rapidly decolourises.<br><br>**f). Uses of Alkenes**<br>Manufacture of plastics; alcohol (ethanol); glycerol; detergents; in the process of ripening of fruits, etc. |
| Step 3 | Introducing the Experiment | **5** | Introduce experiment to learners and discuss its aim/purpose, steps involved and expected outcome. E.g.:- This experiment involves preparation of a named alkene by using ethanol and $Al_2O_3$, etc.; and perform certain chemical tests on the prepared alkene.<br><br>Give the POE worksheet 2 on alkenes to learners to read for the next step (step 4). | Learners listen attentively to the facilitator and write down some important points as the tutor speaks. They ask questions to clarify their thoughts when necessary.<br><br>Leaners take the POE worksheet 2 on alkenes and read for the next stage. | |

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| Step 4 | **Predict (P)**<br>Learners make predictions on the activity or experiment they are about to do based on their existing knowledge / experience.<br><br>Predicting | **15** | In this step, ask learners to predict answers to structured questions based on the experiment that they are about to do in their POE worksheets. Let them answer questions on worksheet in groups E.g.<br>1) If you mix glass wool with ethanol and porcelain chips together in a boiling tube and heat to red-hot, the ethanol will produce an unknown gas. What do you think has happened to the ethanol? etc.<br><br>Tutor moves round to supervise them to ensure each member participate in the activities. | Each member in the group is expected to write out his/her prediction in their jotters. The group compare the individual answers and brainstorm collectively to come out with group ideas on all predicted questions raised.<br><br>The group's predictions are to be written on POE worksheets supplied to them by the recorder or any member they agreed on to do the writing.<br><br>Facilitator moves and interacts with the groups as they make their predictions. | |
| | **Reason(s):** | | Ask each group to give reason(s) for their predictions. Tutor moves round to supervise the activities. | Each group write reason(s) for their predictions on the POE worksheet and for discussion. | |

| | | | | | |
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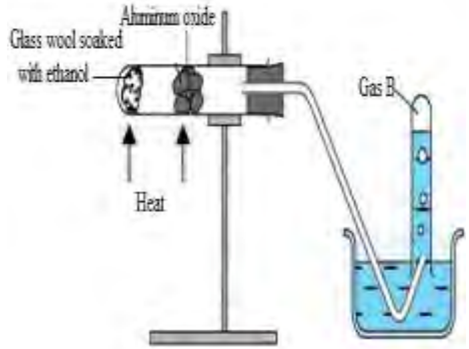
| Step 5 | **<u>Observe (O)</u>**<br>-Perform experiment.<br><br>Perform expt | **40** | Give activity guide 2: on alkenes for them to read through.<br><br>Discuss with them the steps involved in this experiment and ask learners to perform the experiment to prepare an unknown gas B by following the steps in the activity guide 2.<br>E.g.<br>1). Add some glass wool to soak up the ethanol, using a glass rod to push the wool down into a boiling tube; etc.<br><br>Facilitator and the laboratory technician move round to assist them when needed.<br><br>Facilitator ensures that each member in each group participate in the activities. | Leaners in their group carry out the experiment in the activity guide 2; as guided by tutor and lab. technician. They follow the instructions step by step and carry out the expt.<br><br>Each member in the group record his/her observations and inference in their jotters. They also write the chemical equation representing the preparation of the gas B.<br><br>The group then compare the individual's observations, dialogue collectively and write the group's ideas as agreed on the POE worksheet. | <br>Set-up for preparation of gas B (ethene gas) |
| Step 6 | **<u>Explain (E)</u>**<br><u>E</u>xplaining the observations; & compare the observations with their predictions | **15** | Ask learners in their groups to compare individual explanations and collectively brainstorm to come out with the group's explanations to their observations.<br><br>Ask learners to correlate their prediction(s) with observation(s) in order to reconstruct their thinking/ideas; and reconcile any conflict between their predictions and observations. | Learners in their respective groups compare their individual explanations and collectively brainstorm to come out with each of the group's explanations to their observations.<br><br>Learners are to compare their predictions and observations so as to reconcile any conflict between their predictions and observations in the whole class discussions. | |

| | | | | | |
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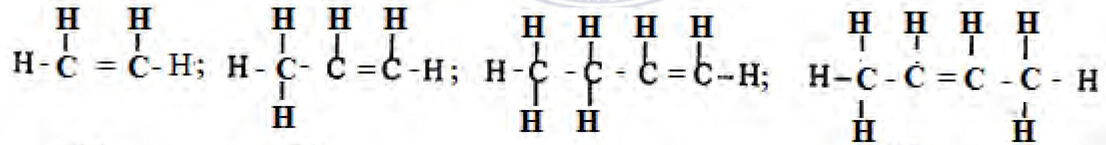
| |  Explaining | | Ask learners to disengage from their groupings. Tell them to read on the next topic; alkynes. | Learners move to their seats. They read given assignment. | |
| **Total** | | **115** | | | |

**Summary: (5 minutes)**
Facilitator (Tutor) summarises the lesson:- Alkenes are unsaturated hydrocarbons that contain carbon-carbon double bonds. They are also known as Olefins. The general molecular formula for alkenes is $CnH_{2n}$, (where n $\geq$ 2). This implies that the first member of the alkenes occur when n is equal to 2 (i.e. $C_2H_4$). The functional group is –C = C-, which is called ethylenic or olefinic double bond. They show two forms of isomerism namely structural isomerism and stereoisomerism. The structural isomerism include chain, position, and functional isomerism whiles stereoisomerism include optical and geometric isomerism. The geometric isomerism include cis and trans isomerism. Alkenes containing 2-4 carbon atoms are gases, 5-18 carbon atoms are volatile liquids; and those with 19 and more are solids. They have lower boiling points than alkanes of the same carbon atoms. They are soluble in organic solvent but insoluble in polar solvent. Chemically, alkenes are more reactive than alkanes; and they undergo several forms of reactions including addition reaction with several reagents. Alkenes burn in air to produce luminous and sooty flame. Alkenes can be tested in the laboratory with several reagents such as $Br_2/CCl_4$; $Br_2/H_2O$; $KMnO_4$; $K_2Cr_2O_7$; etc. They have several uses ranging from manufacture of plastics, glycerol, detergents and ethanol. There are several methods used to prepare alkenes in the laboratory including dehydration of alcohol, dehalogenation of dihalides, cracking of naphtha and many other ways.

**Individual Assignment:**
Tutor/facilitator gives the learners take home assignment due for submission the next class. Lets learners read on alkynes.
1). Give the IUPAC names of the following compounds.



(a) (b) (c) (d)

2). Give the general formula for alkene and the functional group as well.
3). With the aid of a diagram, describe how a named alkene, ethene is prepared in the laboratory.
4). Mention five physical and chemical properties of alkenes.

**Expected answers to the assignment questions:** For answers refer to the pore-core point column and other sources.

**WORKSHEET 2: ON ALKENES**

<table>
<tr><td></td><td colspan="2">SCIENCE STUDENT-TEACHERS' POE WORKSHEET FOR ALKENES</td></tr>
<tr><td>Steps</td><td>Steps in POE</td><td>Group Number:…………………    Date: …………………</td></tr>
<tr><td rowspan="2">1</td><td><u>P</u>redict = (P)<br>What do you think will happen?<br><br>What is in your mind?<br><br>Please speak out</td><td>1). If you mix glass wool with ethanol and aluminium oxide together in boiling tube and heated to red-hot, the ethanol will give an unknown gas B. What do you think has happened to the ethanol?<br>……………………………………………………………………………<br>2). What do you think would be the name of gas B? ………………<br>3). What do you think will happen if:-<br>i) lime water is added to unknown gas B in a test tube:…….............<br>……………………………………………………………………………<br>ii) bromine water is added to unknown gas B in another tube:……..<br>……………………………………………………………………………<br>iii) acidified $KMnO_4$ is added to gas B in a test tube:……..............<br>……………………………………………………………………………<br>iv) cold dilute $KMnO_4$ is added to gas B:……….................................</td></tr>
<tr><td>Give reason(s) for your predictions<br><br></td><td>……………………………………………………………………………<br>……………………………………………………………………………<br>……………………………………………………………………………</td></tr>
<tr><td>2</td><td><u>O</u>bserve = (O)<br><br>Please observe well</td><td>

| Test | Observation | Inference |
|---|---|---|
| Ethanol + porcelain chips + heat | | |
| Unknown gas B + lime water | | |
| Unknown gas B + $Br_2/H_2O$ | | |
| Unknown gas B + acidified $KMnO_4$ | | |
| Unknown gas B + alkaline $KMnO_4$ | | |
| Unknown gas B + ignition | | |
| Unknown gas B + $K_2Cr_2O_7/H^+$ | | |

</td></tr>
<tr><td>3</td><td><u>E</u>xplain = (E)<br><br>Please explain well</td><td>……………………………………………………………………………<br>……………………………………………………………………………<br>……………………………………………………………………………<br>……………………………………………………………………………</td></tr>
</table>

## EXPECTED RESPONSES FROM WORKSHEET 2: ON ALKENES

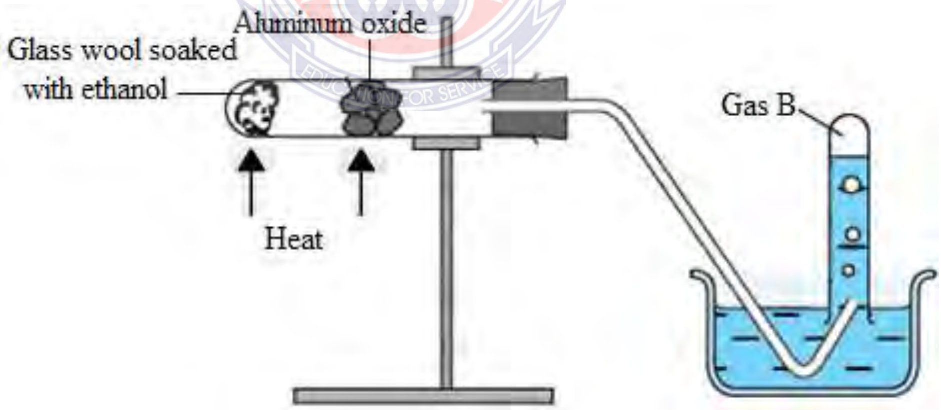
<table>
<tr><th colspan="3">SCIENCE STUDENT-TEACHERS' POE WORKSHEET FOR ALKENES</th></tr>
<tr><th>Steps</th><th>Steps in POE</th><th>Group Number:………………… Date: …………………</th></tr>
<tr><td>1</td><td><u>P</u>redict = (P)<br>What do you think will happen?<br><br>What is in your mind?<br>Please speak out</td><td>1). If you mix glass wool with ethanol and porcelain chips together in a boiling tube and heated to red-hot, the ethanol will produce an unknown gas. What do you think has happened to the ethanol?. <u>The ethanol has been hydrated</u><br>2). What do you think would be the name of gas B?. <u>Ethene gas</u><br>3). What do you think will happen if:-<br>i) lime water is added to the unknown gas in a test tube. <u>The lime water turns milky and carbon dioxide was also produced//evolved.</u><br>ii) bromine water is added to unknown gas in another test tube. <u>The brown bromine water rapidly decolourises</u><br>iii) acidified $KMnO_4$ is added to gas B in a test tube. <u>Purple colour of $KMnO_4$ changes to colourless due to formation of $Mn^{2+}$</u><br>iv) cold dilute $KMnO_4$ is added to gas B. <u>The purple colour of $KMnO_4$ changes to brown due to formation of MnO</u>.</td></tr>
<tr><td></td><td>Give reason(s) for your prediction(s)<br></td><td>1). This is because heat is required to crack the ethanol to ethene and water respectively.<br>2). Due to the interaction between ethanol, heat and porcelain chips<br>3). Porcelain chips ($Al_2O_3$) serves as catalyst to speed up reaction</td></tr>
<tr><td>2</td><td><u>O</u>bserve = (O)<br><br>Please observe well</td><td>
<table>
<tr><th>Test</th><th>Observation</th><th>Inference</th></tr>
<tr><td>Ethanol + porcelain chips + heat</td><td>Evolution of tasteless and colourless gas</td><td>Ethene is present</td></tr>
<tr><td>Unknown gas + lime water</td><td>Lime water turns milky</td><td>Ethene</td></tr>
<tr><td>Unknown gas + $Br_2/H_2O$</td><td>It turns colourless</td><td>Ethene</td></tr>
<tr><td>Gas B + acidified $KMnO_4$</td><td>Purple colour of $KMnO_4$ turns colourless</td><td>Ethene</td></tr>
<tr><td>Gas B + alkaline $KMnO_4$</td><td>Purple colour of $KMnO_4$ turns brown</td><td>Ethene</td></tr>
<tr><td>Gas B + ignition</td><td>Burns with luminous and sooty flame</td><td>Ethene</td></tr>
<tr><td>Gas B + $K_2Cr_2O_7/H^+$</td><td>Orange/yellow colour becomes colourless</td><td>Ethene</td></tr>
</table>
Reaction Equation: $CH_3\text{-}CH_2\text{-}OH \xrightarrow{Al_2O_3} CH_2{=}CH_2 + H_2O$</td></tr>
<tr><td>3</td><td><u>E</u>xplain = (E)<br><br>Please explain well</td><td>Ethanol undergoes a dehydration process of which two atoms of the hydrogen and an atom of oxygen are removed to form ethene; according to equation: $C_2H_5OH_{(g)} \rightarrow C_2H_{4(g)} + H_2O_{(l)}$. Ethene is an alkene; thus, it will show all characteristic of an alkene. Unknown gas B is ethene; it undergoes incomplete combustion to give luminous and sooty flame indicating carbon-carbon double bonds.</td></tr>
</table>

**ACTIVITY GUIDE 2:- ON ALKENES**

| **SCIENCE STUDENT-TEACHERS' POE ACTIVITY GUIDE FOR ALKENES** | |
|---|---|
| **Group Number:……………………………………...** | **Date: ………………………………..** |

**Instruction**:-Guide student-teachers to carryout the following activities for the preparation of **an unknown gas B** by dehydrating ethanol; with catalyst, aluminium oxide 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 deep down into the end portion of the boiling tube.
3. Clamp the boiling tube in a horizontal position using clamp and retort stand. Put a small amount of aluminium oxide (or porcelain chips) about half way along the boiling tube.
4. Light the Bunsen burner, adjust it to a blue flame and heat the aluminium oxide (ensure that test tube in the trough is filled with $H_2O$ when you start to collect the gas evolves).
5. The aluminium oxide is heated to red-hot and then followed by heating of the glass wool.
6. The ethanol turns into vapour and as it passes over the red-hot aluminium oxide and it is dehydrated to produce an unknown gas (B).
7. Let the bubbles produced escape for a short time (these are mainly bubbles of displaced air). Collect 5 test tubes of the gas B and put a stopper on each test tube when it is filled.
8. When all the test tubes have been filled; turn off the Bunsen burner and dismantle all the apparatus completely.




9. Test each gas collected by addition of:- i) lime water; ii) bromine water; iii) acidified $KMnO_4$; iv) cold alkaline $KMnO_4$; v) ignition; & vi) $K_2Cr_2O_7/H^+$ respectively.
10. Then, record your observation and inference in a tabular form.
11. Give the name of an unknown gas B produced.
12. Write the balanced equation for the reaction.

# APPENDIX K3

## UNIVERSITY OF EDUCATION, WINNEBA

## UNIT 3: LESSON PLAN BASED ON PREDICT-OBSERVE-EXPLAIN INSTRUCTIONAL APPROACH ON ALKYNES

**College:** As Applicable

**Subject:** Chemistry (Option:- Organic Chemistry)

**Topic:** Alkynes

**Level:** 200

**Number in Class:** 40

**Average Age:- 23 years**

**Sex:** Mixed

**Duration:** 2 hours (120 minutes)

**Concept Focus:-**Laboratory preparation of a named alkyne and perform certain specific tests.

**Scientific Processes:-** Making predictions, observations, classifications, explanations and drawing conclusions.

**Group(s)**:- Learners work in groups (3-4 members per team). Facilitator provides all necessary resources.

**Assessment Methods**:-Classroom dialogue; Tutor observations; Worksheet exercises; Presentations; Post-activity assignment.

**Course Learning Outcome & Indicators:-** By the end of the lesson, learners should be able to;

1) Describe alkynes in terms of their nature, formula and functional group.
2) Identify the sources of alkynes.
3) Discuss IUPAC rules and write correct IUPAC names of alkynes using the rules.
4) Describe the isomerism in alkynes.
5) Mention the physical properties of alkynes.
6) State the chemical properties of alkynes.
7) Mention the uses of alkynes.
8) Carryout laboratory preparation of a named alkyne (ethyne gas).

**Instructional Resources:-** Calcium carbide, sand, thistle funnel, acidified solution of $CuSO_4$, cork, delivery tube, water trough water, etc, POE activity guide and POE worksheet.

**Lesson Presentation:-**

**RPK:-** Learners have learnt aspect of alkenes at the SHS level and in General Chemistry I at COE level.

| Steps | Lesson Development | Time (mins) | Facilitator's (Tutor's) Activities | Learners' Activities | Core-Point(s) |
|---|---|---|---|---|---|
| Step 1 | **<u>Introduction</u>**<br>-Reviewing Previous Knowledge of the learners | **5** | 1. Arouse learners' interests, encourage and motivate them to learn. Make it known to them the teaching technique to be used and its demand on them.<br>2. Using question and answer method, review learners' R.P.K on hydrocarbons: E.g. What are hydrocarbons & its three classes?. Let them know that today's lesson is about alkynes. Discuss with them the objectives of the lesson. | Leaners listen attentively to the facilitator. They are encouraged to talk, ask questions, write notes and also write down their ideas.<br>Listen to the tutor and jot down some points as the tutor speaks, and ask various questions based on the topic for clarification where and when necessary. | **<u>Expected Answers</u>:-** They are organic compounds made up of carbon and hydrogen only. The 3 classes are alkanes, alkenes and alkynes. |
| Step 2 | Grouping, Elicitation & Discussion of Learners' thinking/ideas<br><br>Group of learners | **35** | 1). Divide learners into groups (of 3-4) based on ability and inclusivity; ask them to assume the roles of team leader, recorder, time-keeper, etc. Let them be aware that the roles are rotational.<br>2). Ask learners to describe alkyne in terms of their nature, formula and functional group. Move round various groups to supervise their activities.<br>3). In the form of whole class discussion, assist them to describe systematic steps involved in naming alkynes (both aliphatic and cyclic) using the IUPAC | Learners' move into their respective groups and assume their new different roles as agreed by members.<br>Learners brainstorm and write their results or findings on the assigned work in their groups.<br>Learners pay attention and listen attentively; ask various questions to clarify their difficulties in the IUPAC rules; and use the rules to name the | **<u>Expected Answers</u>:-**<br>**<u>a). Nature of Alkynes</u>**<br>Alkynes are unsaturated hydrocarbons that contain carbon-carbon triple bonds. The general formula is $\mathbf{C_nH_{2n-2}}$, whereas *where* $n \geq 2$; and the functional group is C≡C. the first member of the group is when n=2 and it is called ethyne or acetylene.<br>**<u>Names of Some Alkynes</u>**<br>$C_2H_2$ – Ethyne<br>$C_3H_4$ – Propyne<br>$C_4H_6$ – Butyne |

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| | | | rules. Give some structures of alkynes for them to use the rules to name.<br><br>4). In their respective groups, (with the help of their phones) ask learners to search and provide their findings on the following:-<br><br>a). Sources of alkynes<br><br>b). Isomerism in alkynes<br><br>c) Physical properties of alkynes<br><br>d) Chemical properties of alkynes<br><br>e) Test for alkynes | given alkyne structures (aliphatic and cyclic structures).<br><br>Learners in their groups use their phones to search, discuss and write their findings and present them chronologically as assigned to them in relation to sources; isomerism in alkynes; physical and chemical properties of alkynes; chemical tests and the uses of alkynes. | **a). Sources of Alkynes**<br>Main sources of alkynes are natural gas and petroleum.<br>**b). Isomerism in Alkynes**<br>Alkynes have different structural isomers such as chain isomerism, position isomerism, functional isomerism etc.<br>**c). Physical properties**<br>1). **Nature and states**<br>At room temperature, lower members are gases; but but-2-yne and higher members are liquids<br>2). **Colour:-** Alkynes are colourless in their pure states.<br>3). **Boiling & melting points**:<br>They have lower boiling and melting point than alkene, etc.<br>**d). Chemical properties**<br>Chemically, alkynes are very reactive than alkenes and alkanes and they undergo combustion reaction; addition reactions with symmetrical & unsymmetrical reagents; etc<br>**e). Test for Alkynes**<br>Alkynes can be tested in the laboratory using the following reagents: $Br_2/CCl_4$; $Br_2/H_2O$; $KMnO_4$; $K_2Cr_2O_7$; etc. |

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| | | | f) Uses of alkynes<br><br>5). In their respective groups, ask learners to write their findings on cardboards/flip charts and make presentations to the class.<br><br>6). Assist in plenary discussions on the learners' presentations.<br><br>7). Through a whole or an intact class discussion, refine learners' responses and ask them to write the correct responses in a logical manner on the maker board as shown in the core-point column. | Learners write their findings on cardboards/flip charts and make their presentations to the class.<br><br>Learners listen attentively to each group's presentation; ask questions when necessary.<br><br>Learners in their groups take active part in the discussion process; seek clarifications when necessary to refine their thinking/ideas on the various areas of alkynes taught. | E.g.<br>**Test**:- Add a few drops of bromine water; $Br_2/H_2O$ to an alkyne.<br>**Observation**:- The brown colour of bromine water changes to colourless.<br>**<u>f). Uses of Alkynes</u>**<br>It is used to manufacture of PVC, synthetic fibers, organic chemicals like ethanol, used in oxy-ethyne flame for welding, etc |
| Step 3 | Introducing the Experiment | **5** | Introduce the experiment to the learners and discuss its aim/purpose, steps involved and expected outcome. E.g.:- This experiment involves preparation of a named alkyne by using calcium carbide and water, etc.; and perform certain chemical tests on the prepared alkene.<br><br>Give the POE worksheet 3 on alkynes to learners to read for the next step (step 4). | Learners listen attentively to the facilitator and write down some important points as the tutor speaks. They also ask questions to clarify their thought when necessary.<br><br>Leaners take the POE worksheet 3 on alkynes and read for the next stage. | |

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| Step 4 | **Predict (P)**<br>Learners make predictions on the activity or experiment they are about to do based on their existing knowledge / experience<br><br>Predicting | **15** | In this step, ask learners to predict answers to structured questions based on the experiment that they are about to do in their POE worksheets. Let them answer the questions on worksheet in groups:<br><br>E.g.<br>1) If you put 2-3 pieces of calcium carbide in a flask with sand, and then you add few drop water until it react to produce an unknown gas C; what reaction do you think calcium carbide has undergone. etc.<br><br>Tutor moves round to supervise them to ensure each member participate in the activities. | Each member in the group is expected to write out his/her prediction in their jotters. The group compare the individual answers and brainstorm collectively to come out with group ideas on all predicted questions raised.<br><br>The group's predictions are to be written on POE worksheets supplied to them by the recorder or any member they agreed on to do the writing.<br><br>Facilitator moves and interacts with the groups as they make their predictions. | |
| | **Reason(s):** | | Ask each group to give reason(s) for their predictions. Tutor moves round to supervise the activities. | Each group write reason(s) for their predictions on the POE worksheet and for discussion. | |

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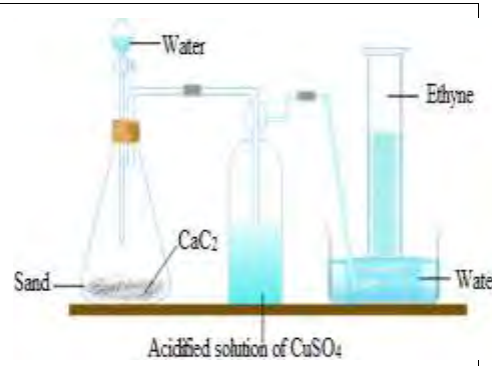
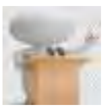
| Step 5 | **<u>Observe (O)</u>**<br>-Perform experiment.<br><br>Perform expt | **40** | Give activity guide 3: on alkynes for them to read through.<br><br>Discuss with them the steps involved in this experiment and ask learners to perform the experiment to prepare an unknown gas C by following the steps in the activity guide 3.<br>E.g.<br>1). Place 2-3 pieces of calcium carbide on layer of sand in a conical flask; etc.<br><br>Facilitator and the laboratory technician move round to assist them when needed.<br><br>Facilitator ensures that each member in each group participate. | Leaners in their group carry out the experiment in the activity guide 3; as guided by tutor and lab. technician. They follow the instructions step by step and carry out the expt.<br><br>Each member in the group record his/her observations and inference in their jotters. They also write the chemical equation representing the preparation of the gas C.<br><br>The group then compare the individual's observations, dialogue collectively and write the group's ideas as agreed on the POE worksheet. | <br><br>Set-up for preparation of gas C (ethyne gas) |
| Step 6 | **<u>Explain (E)</u>**<br><u>E</u>xplaining the observations; & compare the observations with their predictions<br><br>Explaining | **15** | Ask learners in their groups to compare individual explanations and collectively brainstorm to come out with the group's explanations to their observations.<br><br>Ask learners to correlate their prediction(s) with observation(s) in order to reconstruct their thinking/ideas; and reconcile any conflict between their predictions and observations. | In their respective groups, let them compare their individual explanations and collectively brainstorm to come out with the group's explanations to their observations.<br><br>Learners are to compare their predictions and observations so as to reconcile any conflict between their predictions and observations in the whole class discussions. | |

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| | | | Ask learners to disengage from their groupings. Tell them to read on the next topic; alkanols. | Learners move to their seats. They read the given assignment. | |
| | **Total** | **115** | | | |

**Summary: (5 minutes)**

Facilitator (Tutor) summarises the lesson:- Alkynes are unsaturated hydrocarbons that contain carbon-carbon triple bonds. They are called as terminal alkynes if the triple bond is present in the end of the carbon chain. They have the general formula of $C_nH_{2n-2}$.(where $n \geq 2$). Alkynes have different structural isomers like chain isomerism, position isomerism, functional isomerism etc. The first two members of alkyne family- ethyne and propyne have only one isomeric structure but the higher members have more than one isomeric structure. At room temperature, the lower members of alkynes such as ethyne, propyne and 1-butyne are gases; but-2-yne are and higher alkynes are liquids. The boiling points of alkynes are generally lower than that of alkenes with the same carbon atoms. Hence for the aliphatic hydrocarbons, the order of boiling points is:- Alkanes > Alkenes > Alkynes. They are insoluble in polar solvents like water but readily soluble in non-polar solvents like benzene and hexane. Terminal alkynes are however soluble in polar solvents such as water. This is because the C-H bond in terminal alkynes is polar. Alkynes burn in air to give a very luminous and smoky flame. Chemically, alkynes are more reactive than alkenes and alkanes; and they undergo several forms of reactions including combustion and addition reaction with several reagents. Alkynes can be tested in the laboratory with several reagents such as $Br_2/CCl_4$; $Br_2/H_2O$; $KMnO_4$; $K_2Cr_2O_7$; etc. They have several uses ranging from manufacture of PVC, synthetic fibers, organic chemicals like ethanol, used in oxy-ethyne flame for welding, and many others. There are several methods used to prepare alkynes in the laboratory including dehalogenation of Vicinal dihalides, alkylation of terminal alkyne industrial manufacture from calcium carbide and many other ways.

**Individual Assignment:**

Tutor/facilitator gives the learners take home assignment due for submission the next class. Lets learners read on alkanols.

1). Give the IUPAC names of the following compounds.

**(a)**

Br - C ≡ C- Br

**(b)**

H - CH₂ - C ≡ C - H (H above and H below the first C)

**(c)**

H - C ≡ C- H

**(d)**

2). Give the general formula for alkyne and the functional group as well.

3). With the aid of a diagram, describe how a named alkyne, ethyne is prepared in the laboratory.

4). Mention three physical and chemical properties of alkynes.

**Expected answers to the assignment questions:** For answers refer to the pore-core point column and other sources.

**WORKSHEET 3: ON ALKYNES**

<table>
<tr><th></th><th colspan="2">SCIENCE STUDENT-TEACHERS' POE WORKSHEET FOR ALKYNES</th></tr>
<tr><th>Steps</th><th>Steps in POE</th><th>Group Number:………………… Date: …………………</th></tr>
<tr><td rowspan="2">1</td><td><u>P</u>redict = (P)<br>What do you think will happen?<br><br>What is in your mind?<br>Please speak out</td><td>1). If you put 2-3 pieces of calcium carbide on sand in a flask, and then you add few drops of water until it react to produce an unknown gas C; what reaction do you think calcium carbide has undergone?...………………………………………………………..<br>2). C is likely to be.......................................................................<br>3). Write the equation for the reaction?.............................................<br>…………………………………………………………………..<br>4). What do you think will happen if:-<br>i) C is ignited?.......................................................................<br>…………………………………………………………………..<br>ii) bromine water is added to gas C in test tube……………………..<br>…………………………………………………………………<br>iii) $Br_2/CC_4$ is added to gas C in test tube…………………………..<br>…………………………………………………………………..<br>5). Explain why acidified $CuSO_4$ solution used in set-up…………...<br>…………………………………………………………………..</td></tr>
<tr><td>Give reason(s) for your predictions<br></td><td>…………………………………………………………………<br>…………………………………………………………………<br>…………………………………………………………………</td></tr>
<tr><td>2</td><td><u>O</u>bserve = (O)<br><br>Please observe well</td><td><table><tr><th>Test</th><th>Observation</th><th>Inference</th></tr><tr><td>Calcium carbide + water</td><td></td><td></td></tr><tr><td>Unknown gas + ignition</td><td></td><td></td></tr><tr><td>Unknown gas + bromine water</td><td></td><td></td></tr><tr><td>Unknown gas + acidified $KMnO_4$</td><td></td><td></td></tr><tr><td>An unknown gas + ignition</td><td></td><td></td></tr><tr><td>An unknown gas + $K_2Cr_2O_7/H^+$</td><td></td><td></td></tr></table></td></tr>
<tr><td>3</td><td><u>E</u>xplain = (E)<br><br>Please explain well</td><td>…………………………………………………………………<br>…………………………………………………………………<br>…………………………………………………………………<br>…………………………………………………………………</td></tr>
</table>

**EXPECTED RESPONSES FROM WORKSHEET 3: ON ALKYNES**

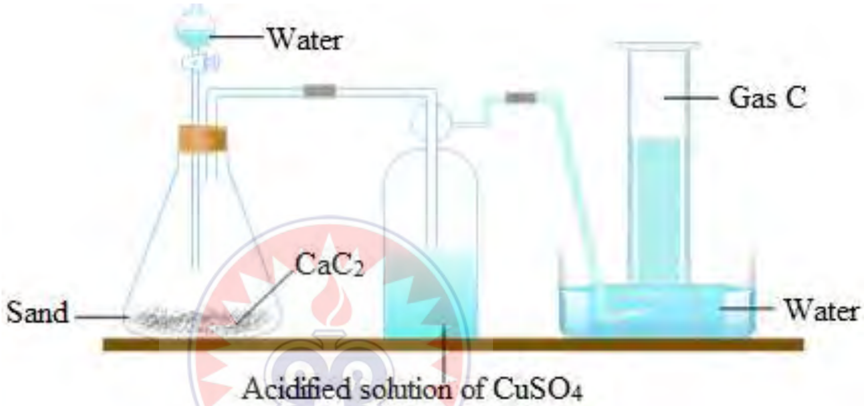
<table>
<tr><th colspan="3">SCIENCE STUDENT-TEACHERS' POE WORKSHEET FOR ALKYNES</th></tr>
<tr><th>Steps</th><th>Steps in POE</th><th>Group Number:………………… Date: …………………</th></tr>
<tr><td>1</td><td><u>P</u>redict = (P)<br>What do you think will happen?<br><br>What is in your mind?<br>Please speak out</td><td>1). If you put 2-3 pieces of calcium carbide in a flask, and then you add few drop water until it react to produce an unknown gas C; what reaction do you think calcium carbide has undergone?. <u>The calcium carbide has undergone hydration reaction.</u><br>2). Unknown gas C is likely to be what?. <u>The unknown gas C is likely to be ethyne (acetylene)</u><br>3). What do you think would be equation for the reaction?<br>$CaC_2 + 2H_2O \longrightarrow H-C\equiv C-H + Ca(OH)_2$<br>Calcium carbide     Ethyne<br>4). What do you think will happen if:-<br>i) The unknown gas C in a test tube is ignited?. <u>Alkyne burn in air to give a very luminous and smoky flame due to unburn carbon due to unsaturation</u><br>ii) bromine water is added to unknown gas C in test tube. <u>The brown bromine water decolourises or turns colourless.</u><br>iii) $Br_2/CCl_4$ is added to gas C in test tube. <u>The brown colour of $Br_2/CCl_4$ changes to colourless.</u><br>5). What do you think that acidified $CuSO_4$ was used in set-up. <u>It is used to catalyse the reaction. It is also used to remove impurities like $H_2S$ and $PH_3$ from the prepared ethyne gas</u></td></tr>
<tr><td></td><td>Give reason(s)<br><br></td><td>1). Heat is not required because the reaction is highly exothermic and thus a layer of sand should be put above the calcium carbide to absorb excess heat to prevent the reaction flask from breaking.<br>2). Because of the triple bonds present, ethyne gas produced is likely to react with and turns $Br_2/H_2O$; $KMnO_4$ and $Br_2/CCl_4$</td></tr>
<tr><td>2</td><td><u>O</u>bserve = (O)<br><br>Please observe well</td><td>
<table>
<tr><th>Test</th><th>Observation</th><th>Inference</th></tr>
<tr><td>Calcium carbide + water</td><td>Colourless and tasteless gas evolves</td><td>Ethyne is produced</td></tr>
<tr><td>Unknown gas + ignition</td><td>Burns with luminous and smoky flame</td><td>Alkyne is present</td></tr>
<tr><td>Unknown gas + bromine water</td><td>Changes to colourless</td><td>Alkyne</td></tr>
<tr><td>Unknown gas + acidified $KMnO_4$</td><td>Purple to colourless</td><td>Alkyne</td></tr>
<tr><td>An unknown gas + $Br_2/CCl_4$</td><td>Brown to colourless</td><td>Alkyne</td></tr>
<tr><td>An unknown gas + $K_2Cr_2O_7/H^+$</td><td>Orange to colourless</td><td>Alkyne</td></tr>
</table>
</td></tr>
<tr><td>3</td><td><u>E</u>xplain = (E)<br><br>Please explain well</td><td>Alkynes burn with a yellow/ luminous very sooty/ smoky flame in excess air to form carbon(IV) oxide and water. Alkyne + air → carbon (IV) oxide + water. Alkynes burn with a yellow/ luminous very sooty/ smoky flame in limited air to form carbon (II) oxide/carbon and water. Alkyne + air → carbon (II) oxide + water. These reactions are due to presence of triple carbon-carbon bonds.</td></tr>
</table>

**ACTIVITY GUIDE 3: ON ALKYNES**

| **SCIENCE STUDENT-TEACHERS' POE ACTIVITY GUIDE FOR ALKYNES** | |
|---|---|
| **Group Number:………………………………...** | **Date: ………………………………..** |

**Instruction:-**Guide student-teachers to carryout these practical activities for the preparation of an unknown gas C using the action of water on calcium carbide as follows:-

1. Place 2-3 pieces of calcium carbide on a layer of sand in a conical flask.
2. Seal the flash with a stopper with a dropping (thistle) funnel and a delivery tube. The delivery tube should look upwards in the trough containing the water; and set the apparatus as shown in diagram below:




**Set-up for the preparation of gas C**

3. Add water from the thistle (dropping) funnel, a few drops at a time until all the calcium carbide have reacted completely.
4. Observe the experiment carefully and then record your observations.

Expected observation: "A colourless unknown gas C is produced"

5. Collect 3 dry test tubes of the gas and put a stopper on each of the tube when it is filled.
6. When all the three (3) test tubes have been filled; then test each of the unknown gas collected by:- i) combustion (ignition); ii) addition of bromine water; and iii) addition of $Br_2/CCl_4$ respectively.
7. Why was acidified $CuSO_4$ solution used in the set-up?.
8. Record your observation and inference.
9. Write the correct balanced equation for the reaction.

# APPENDIX K4

## UNIVERSITY OF EDUCATION, WINNEBA

## UNIT 4: LESSON PLAN BASED ON PREDICT-OBSERVE-EXPLAIN INSTRUCTIONAL APPROACH ON ALKANOLS

**College:** As Applicable

**Subject:** Chemistry (Option:- Organic Chemistry)

**Topic:** Alkanols (Alcohols)

**Level:** 200

**Number in Class:** 40

**Average Age:- 23 years**

**Sex:** Mixed

**Duration:** 2 hours (120 minutes)

**Concept Focus:-**Laboratory preparation of a named alkanols and perform certain specific tests.

**Scientific Processes:-** Making predictions, observations, classifications, explanations and drawing conclusions.

**Group(s)**:- Learners work in groups (3-4 members per team). Facilitator provides all necessary resources.

**Assessment Methods**:-Classroom dialogue; Tutor observations; Worksheet exercises; Presentations; Post-activity assignment.

**Course Learning Outcome & Indicators:-** By the end of the lesson, learners should be able to;

1) Describe alkanols in terms of their nature, formula and functional group.
2) Identify the sources of alkanols.
3) Discuss IUPAC rules and write correct IUPAC names of alkanols using the rules.
4) Describe the isomerism in alkanols.
5) Mention the physical properties of alkanols.
6) State the chemical properties of alkanols.
7) Mention the uses of alkanols.
8) Carryout laboratory preparation of a named alkanol (ethanol).

**Instructional Resources:-** Ethene, water, dilute sulphuric acid, Bunsen burner, wire mesh, potassium dichromate ($K_2Cr_2O_7$) POE activity guide and POE worksheet.

**Lesson Presentation:-**

**RPK:-** Learners have learnt aspect of hydrocarbons & alkanols at the SHS level and in General Chemistry I at COE level.

<table>
<tr><th>Steps</th><th>Lesson Development</th><th>Time (mins)</th><th>Facilitator's (Tutor's) Activities</th><th>Learners' Activities</th><th>Core-Point(s)</th></tr>
<tr><td>Step 1</td><td><u>Introduction</u><br>-Reviewing Previous Knowledge of the learners</td><td>5</td><td>1. Arouse the learners' interests, encourage and motivate them to learn. Make it known to them the teaching technique to be used and its demand on them.<br><br>2. Using question and answer method, review learners' R.P.K on hydrocarbons: E.g. What are hydrocarbons & its three classes?. Let them know that today's lesson is about alkanols. Discuss with them the objectives of the lesson.</td><td>Leaners listen attentively to the facilitator or the tutor. They are encouraged to talk, ask questions, write notes and also write down their ideas.<br><br>Listen to the tutor and jot down some points as the tutor speaks, and ask various questions based on the concept for clarification.</td><td><u>Expected Answers:-</u> They are organic compounds made up of carbon and hydrogen only. The 3 classes are of hydrocarbons are alkanes, alkenes and alkynes.</td></tr>
<tr><td>Step 2</td><td>Grouping, Elicitation & Discussion of Learners' thinking/ideas<br><br>Group of learners</td><td>35</td><td>1). Divide learners into groups (of 3-4) based on ability and inclusivity; ask them to assume the roles of team leader, recorder, time-keeper, etc. Let them be aware that the roles are rotational.<br><br>2). Ask learners to describe alkanols in terms of their nature, formula and functional group. Move round various groups to supervise their activities.<br><br>3). In the form of whole class discussion, assist them to describe systematic steps involved in naming alkanol using the</td><td>Learners' move into their respective groups and assume their new different roles as agreed by members.<br><br>Learners brainstorm and write their results or findings on the assigned work in their groups.<br><br>Learners pay attention and listen attentively, ask various questions to clarify their difficulties in IUPAC</td><td><u>Expected Answers:-</u><br>a). Nature of Alkanols<br>Alkanols are hydroxyl compounds, characterised by the presence of hydroxyl functional group (-OH). The general formula is $C_nH_{2n} + OH$; (whereas where n ≥ 1). they can be monohydric or polyhydric alkanols.<br><br><u>Names of Some Alkanols</u><table><tr><td>$CH_3OH$</td><td>Methanol</td></tr><tr><td>$C_2H_5OH$</td><td>Ethanol</td></tr><tr><td>$C_3H_7OH$</td><td>Propanol</td></tr></table></td></tr>
</table>

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| | | | IUPAC rules. Give some structures of alkanols for them to use the rules to name them.<br><br>4). In their respective groups, (with the help of their phones) ask learners to search and provide their findings on the following:-<br><br>a). Sources of alkanols<br><br>b). Isomerism in alkanols<br><br>c) Physical properties of alkanols<br><br>d) Chemical properties of alkanols<br><br>e) Test for alkanols | rules; and use the rules to name the given alkanols structures.<br><br>Learners in their groups use their phones to search, discuss and write their findings and present them chronologically as assigned to them in relation to sources; isomerism in alkanols; physical and chemical properties of alkanols; chemical tests and the uses of alkanols. | **a). Sources of Alkanols**<br>Natural sources of alkanols include palm wine, sugar cane, starchy food & fruits<br><br>**b). Isomerism in Alkanols**<br>Alcohols exhibits following three types of isomerism. They are chain isomerism; position isomerism & functional isomerism.<br><br>**c). Physical properties**<br>1). **Nature and states**<br>Simpler alkanols, e.g. methanol and ethanol are liquids at room temperature<br>2). **Colour:-** They are colourless and volatile liquids with a characteristic smell<br>3). **Solubility**: They soluble in water due to OH bond; etc<br><br>**d). Chemical properties**<br>Chemically, they exhibit a wide range of chemical reactions due to cleavage of the C-O bond and O-H bond. E.g. are oxidation of alcohol, dehydration of alcohol, catalytic reduction of butanal., etc<br>**e). Test for Alkanols**<br>Alkanols can be tested in the laboratory using the following |

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|---|---|---|---|---|---|
| | | | f) Uses of alkanols<br><br>5). In their respective groups, ask learners to write their findings on cardboards/flip charts and make presentations to the class.<br>6). Assist in plenary discussions on the learners' presentations.<br><br>7). Through a whole or an intact class discussion, refine learners' responses and ask them to write the correct responses in a logical manner on the maker board as shown in the core-point column. | Learners write their findings on cardboards/flip charts and make their presentations to the class.<br><br>Learners listen attentively to each group's presentation; ask questions when necessary.<br><br>Learners in their groups take active part in the discussion process; seek clarifications when necessary to refine their thinking/ideas on the various areas of alkanols taught. | reagents: acidified $KMnO_4$; $K_2Cr_2O_7$; Lucas reagent; etc.<br>E.g.<br>**Test**:- Add a few drops of acidified $K_2Cr_2O_7$ to alkanol<br><br>**Observation**: Orange colour of $K_2Cr_2O_7$ changes to green.<br><br>**f). Uses of Alkanols**<br>It is used in alcoholic beverages; as solvent for food extracts such as vanilla, perfumes, and some types of paints and lacquers; etc |
| Step 3 | Introducing the Experiment | **5** | Introduce the experiment to the learners and discuss its aim/purpose, steps involved and expected outcome. E.g.:- This experiment involves preparation of a named alkanol using ethene, water, dilute $H_2SO_4$ etc.; and perform certain chemical tests on the prepared alkanol.<br><br>Give the POE worksheet 4 on alkanols to learners to read for the next step (step 4). | Learners listen attentively to the facilitator and write down some important points as the tutor speaks. They also ask questions to clarify their thought when necessary.<br><br>Leaners take the POE worksheet 4 on alkanols and read for next stage. | |

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| Step 4 | **Predict (P)**<br>Learners make predictions on the activity or experiment they are about to do based on their existing knowledge / experience<br><br>Predicting | **15** | In this step, ask learners to predict answers to structured questions based on the experiment that they are about to do in their POE worksheets. Let them answer the questions on worksheet in groups:<br><br>E.g.<br>1) What do you think will happen if you mix 5grams of ethene and 10 grams of water together in a beaker,? etc<br><br>Tutor moves round to supervise them to ensure each member participate in the prediction activities. | Each member in the group is expected to write out his/her prediction in their jotters. The group compare the individual answers and brainstorm collectively to come out with group ideas on all predicted questions raised.<br><br>The group's predictions are to be written on POE worksheets supplied to them by the recorder or any member they agreed on to do the writing.<br><br>Facilitator moves and interact with the groups as they make their predictions. | |
| | **Reason(s):** | | Ask each group to give reason(s) for their predictions. Tutor moves round to supervise the activities. | Each group write reason(s) for their predictions on the POE worksheet and for discussion. | |

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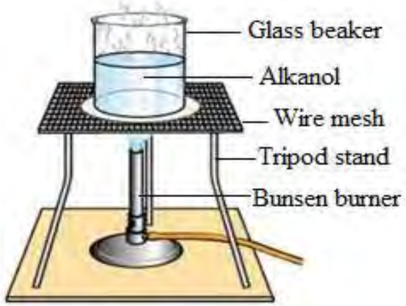
|---|---|---|---|---|---|
| Step 5 | **<u>Observe (O)</u>**<br>-Perform experiment.<br><br>Perform expt | **40** | Give activity guide 4 on alkanols for them to look through.<br>Discuss with them the steps involved in this experiment and ask learners to perform the experiment to prepare an unknown liquid by following the steps in the guide 4.<br>E.g.<br>1). Pour 5gram of ethene (reagent A) into a pyrex glass beaker; etc.<br>Facilitator and the laboratory technician move round to assist them when needed.<br>Facilitator ensures that each member in each group participate. | Leaners in their group carry out the experiment in the activity guide 4; as guided by tutor and lab. technician. They follow the instructions step by step and carry out the experiment.<br>Each member in the group record his/her observations and inference in their jotters. They also write the chemical equation representing the preparation of the liquid D.<br>The group then compare the individual's observations, dialogue collectively and write the group's ideas as agreed on their POE worksheet. | <br><br>Set-up for the preparation of ethanol (Liquid D) |
| Step 6 | **<u>Explain (E)</u>**<br><u>**E**</u>xplaining the observations; & compare the observations with their predictions.<br><br>Explaining | **15** | Ask learners in their groups to compare individual explanations and collectively brainstorm to come out with the group's explanations to their observations.<br>Ask learners to correlate their prediction(s) with observation(s) in order to reconstruct their thinking/ideas; and reconcile any conflict between their predictions and observations. | In their respective groups, let them compare their individual explanations and collectively brainstorm to come out with the group's explanations to their observations.<br>Learners are to compare their predictions and observations so as to reconcile any conflict between their predictions and observations in the whole class discussions. | |

| | | | | | |
|---|---|---|---|---|---|
| | | | Ask learners to disengage from their groupings. Tell them to read on next topic, carbonyl compounds | Learners move to their seats. They read given assignment. | |
| **Total** | | **115** | | | |

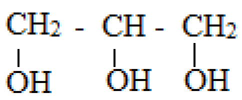
**Summary: (5 minutes)**

Facilitator (Tutor) summarises the lesson:- Alkanols Alcohols are organic compounds in which a hydrogen atom of an aliphatic carbon is replaced with a hydroxyl group. Thus, an alcohol molecule consists of two parts; one containing the alkyl group and the other containing functional group hydroxyl group. They have a sweet odour. They are classified as primary (1°) alcohol; secondary (2°) alcohol; and tertiary (3°) alcohol depending upon whether the hydroxyl group (-OH). They exhibit a unique set of physical and chemical properties. They exhibit a wide range of spontaneous chemical reactions due to the cleavage of the C-O bond and O-H bond. Some prominent chemical reactions of alcohols are oxidation of alcohol, dehydration of alcohol, catalytic reduction of butanal, and many others. Lower alcohols are colourless liquids at normal temperature. The higher alcohols are colourless, odourless waxy solids. Phenols, like alcohols, are either colourless liquids or solids. But they usually turn reddish brown due to atmospheric oxidation. Alcohols are acidic in nature. They react with metals such as sodium, potassium etc. It is due to the polarity of bond between hydrogen atom and oxygen atom of hydroxyl group. In addition to its presence in alcoholic beverages, ethanol also is used as a solvent for food extracts such as vanilla, perfumes, and some types of paints and lacquers. There are several methods used to prepare alkanols in the laboratory including hydration of alkenes, reaction of alkyl halides, hydrolysis of halogenoalkanes, hydration of alkenes with conc. $H_2SO_4$, fermentation of carbohydrates and many others.

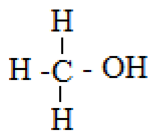
**Individual Assignment:**

Facilitator gives the learners take home assignment due for submission the next class. Lets learners read on carbonyl compounds.

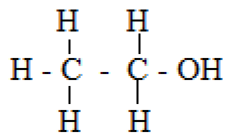
1). Give the IUPAC names of the following compounds.



**(a)**



**(b)**



**(c)**

2). Give the general formula for alkanols and the functional group as well.

3). With the aid of a diagram, describe how ethanol is prepared in the laboratory using hydration of alkenes with conc. $H_2SO_4$.

4). Mention three physical and chemical properties of alkanols.

**Expected answers to the assignment questions:** For answers refer to the pore-core point column and other sources.

**WORKSHEET 4: ON ALKANOLS**

<table>
<tr><th></th><th colspan="2">SCIENCE STUDENT-TEACHERS' POE WORKSHEET FOR ALKANOLS</th></tr>
<tr><th>Steps</th><th>Steps in POE</th><th>Group Number… Date: …………………</th></tr>
<tr><td rowspan="2">1</td><td><u>P</u>redict = (P)<br>What do you think is likely to happen?<br><br>What is in your mind?<br>Please speak out</td><td>1) What do you think will happen if you mix 5grams of ethene and 10 grams of water together in a beaker,? …………………………<br>2). If you add dilute $H_2SO_4$ to the mixture in (1) and heat it on a Bunsen burner, it will react to produce an unknown liquid D, what do you think has happened to the ethene? ………………………...<br>3). Unknown liquid D is likely to be what?........................................<br>4). What do you think would be equation for the reaction?...............<br>……………………………………………………………………<br>5). What do you think will happen if:-<br>i) unknown liquid in a test tube is tested with litmus paper?:……....<br>………………………………………………………………………<br>ii) you smell unknown liquid D; what is likely will be the odour?:<br>………………………………………………………………………<br>iii) $K_2Cr_2O_7$ is added to liquid D in a test tube:……….................<br>………………………………………………………………………</td></tr>
<tr><td>Give reason(s) for your predictions<br></td><td>………………………………………………………………………<br>………………………………………………………………………<br>………………………………………………………………………</td></tr>
<tr><td>2</td><td><u>O</u>bserve = (O)<br><br>Please observe well</td><td><table>
<tr><th>Test</th><th>Observation</th><th>Inference</th></tr>
<tr><td>Ethene + $H_2O$ + dil. $H_2SO_4$ + heat</td><td></td><td></td></tr>
<tr><td>Unknown liquid D + litmus paper</td><td></td><td></td></tr>
<tr><td>Smell an unknown liquid D</td><td></td><td></td></tr>
<tr><td>Unknown liquid D + ignite</td><td></td><td></td></tr>
<tr><td>Unknown liquid D + $KMnO_4/H^+$</td><td></td><td></td></tr>
</table></td></tr>
<tr><td>3</td><td><u>E</u>xplain = (E)<br><br>Please explain well</td><td>………………………………………………………………………<br>………………………………………………………………………<br>………………………………………………………………………<br>………………………………………………………………………</td></tr>
</table>

## EXPECTED RESPONSES FROM WORKSHEET 4: ON ALKANOLS

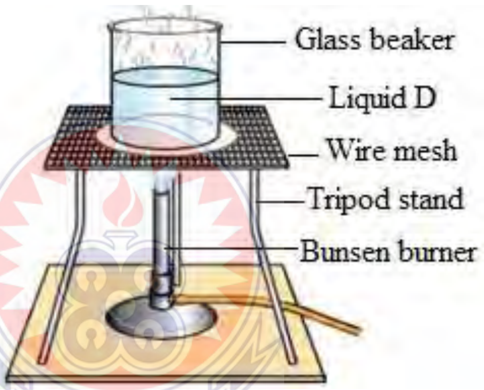
<table>
<tr><th colspan="3">SCIENCE STUDENT-TEACHERS' POE WORKSHEET FOR ALKANOLS</th></tr>
<tr><th>Steps</th><th>Steps in POE</th><th>Group Number:………………… Date: …………………</th></tr>
<tr><td rowspan="2">1</td><td>Predict = (P)<br>What do you think will happen?<br><br>What is in your mind?<br>Please speak out</td><td>1). What do you think will happen if you mix 5grams of ethene and 10 grams of water together in a beaker,? There would be no chemical reaction until it is heated<br>2). If you add dilute $H_2SO_4$ to the mixture in (1) and heat it on a Bunsen burner, it will react to produce an unknown liquid D, what do you think has happened to the ethene?. The ethene undergoes hydration reaction<br>3). Unknown liquid D is likely to be what?. The unknown liquid D is likely to be an alcohol<br>4). What do you think would be equation for the reaction?<br>$C_2H_{2(g)} + H_2O_{(g)} \xrightarrow{\text{dilute } H_2SO_4} C_2H_5OH_{(aq)}$<br>5). What do you think will happen if:-<br>i) unknown liquid in a test tube is tested with litmus paper? Has no effects on both blue and red litmus papers.<br>ii) you smell unknown liquid D; what is likely will be the odour?: It has pleasant odour reminiscent of whiskey<br>iii) $K_2Cr_2O_7$ is added to liquid D in a test tube. The orange/yellow coloured solution of $K_2Cr_2O_7$ turns green.</td></tr>
<tr><td>Give reason(s)<br><br></td><td>1). The reaction requires heat and catalyst to speed up the process.<br>2). The orange solution containing dichromate (VI) ions is reduced to green solution containing chromium (III) ions due to oxidation<br>3). Ethanol burns completely to give bluish, non-sooty flame.</td></tr>
<tr><td>2</td><td>Observe = (O)<br><br>Please observe well</td><td>
<table>
<tr><th>Test</th><th>Observation</th><th>Inference</th></tr>
<tr><td>Ethene + $H_2O$ + dil. $H_2SO_4$ + heat</td><td>colourless volatile liquid is produced</td><td>Ethanol is produced</td></tr>
<tr><td>Unknown liquid D + litmus paper</td><td>Has no effects on both litmus papers</td><td>Alkanol is present</td></tr>
<tr><td>Smell an unknown liquid D</td><td>Pleasant whiskey-like odour</td><td>Alkanol is present</td></tr>
<tr><td>Unknown liquid D + ignite</td><td>Ethanol burns with sootless blue flame.</td><td>Alkanol is present</td></tr>
<tr><td>Unknown liquid D + $KMnO_4/H^+$</td><td>Purple colour turns colourless</td><td>Alkanol is present</td></tr>
</table>
</td></tr>
<tr><td>3</td><td>Explain = (E)<br><br>Please explain well</td><td>The complete combustion of ethanol produces water and carbon dioxide. Equation is: $C_2H_5OH_{(l)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(l)}$.<br>The ethanol undergoes oxidation reaction with $KMnO_4$; $K_2Cr_2O_7$, and other reagents to produce various types of solutions. Ethanol is an alkanol or alcohol; and therefore, it will show all the characteristic of an alkanol with respects to its various reactions.</td></tr>
</table>

**ACTIVITY GUIDE 4: ON ALKANOLS**

| SCIENCE STUDENT-TEACHERS' POE ACTIVITY GUIDE FOR ALKANOLS | |
|---|---|
| **Group Number:…………………………………...** | **Date: ………………………………..** |

**Instruction:-**Guide student-teachers to carryout these practical activities for the preparation of an **unknown liquid D** using ethene, water and dilute sulphuric acid as follows:-

1. Pour 5gram of ethene into a hard pyrex glass beaker.
2. Add 10gram of water (steam) to the beaker containing the ethene and mix thoroughly.
3. Add 2grams of dilute sulphuric acid ($H_2SO_4$) to the beaker containing mixture of ethene and water.
4. Place the beaker containing the mixture on wire mesh over a Bunsen burner flame as shown in the diagram below:




**Set-up for the preparation of an unknown liquid D**

5. Heat the mixture slightly, then record your observation.
   Expected observation: "A colourless unknown liquid D is formed"
6. Divide the "D" unknown liquid into four portions in a clean dry test tube
7. Test the "D" liquid using/with:- i) litmus; ii) odour; & iii) potassium dichromate ($K_2Cr_2O_7$) respectively.
8. Then record your observation and inference in a tabular form.
9. Write the chemical equation for the reaction in the beaker.

# APPENDIX K5

## UNIVERSITY OF EDUCATION, WINNEBA

## UNIT 5: LESSON PLAN BASED ON PREDICT-OBSERVE-EXPLAIN INSTRUCTIONAL APPROACH ON CARBONYLS

**College:** As Applicable

**Subject:** Chemistry (Option:- Organic Chemistry)

**Topic:** Carbonyl Compounds (Aldehydes & Ketones)

**Level:** 200

**Number in Class:** 40

**Average Age:- 23 years**

**Sex:** Mixed

**Duration:** 2 hours (120 minutes)

**Concept Focus:-**Laboratory preparation of a named carbonyl compound and perform certain specific tests.

**Scientific Processes:-** Making predictions, observations, classifications, explanations and drawing conclusions.

**Group(s)**:- Students work in groups (3-4 members per team). Facilitator provides all necessary resources.

**Assessment Methods**:-Classroom dialogue; Tutor observations; Worksheet exercises; Presentations; Post-activity assignment.

**Course Learning Outcome & Indicators:-** By the end of the lesson, learners should be able to;

1) Describe carbonyl compounds in terms of their nature, formula and functional group.
2) Describe aldehyde and ketones in terms of their nature and functional group.
3) Discuss IUPAC rules and write correct IUPAC names of aldehyde and ketones using the rules.
4) Describe the isomerism in carbonyls (aldehyde and ketones).
5) Mention the physical properties of carbonyl compounds.
6) State the chemical properties of carbonyl compounds.
7) Mention the uses of aldehydes and ketones.
8) Carryout laboratory preparation of a named carbonyl compound (ethanal:- an aldehyde).

**Instructional Resources:-** Ethanol, potassium dichromate ($K_2Cr_2O_7$), sulphuric acid ($H_2SO_4$); thistle funnel; electric heater; iced cubes/water; water; round bottomed flask; trough, condenser; POE activity guide and POE worksheet.

**Lesson Presentation:-**

**RPK:-** Learners have learnt aspect of carbonyls at the SHS level and in General Chemistry I at COE level.

| Steps | Lesson Development | Time (mins) | Facilitator's (Tutor's) Activities | Learners' Activities | Core-Point(s) |
|---|---|---|---|---|---|
| Step 1 | **Introduction**<br>-Reviewing Previous Knowledge of the learners | **5** | 1. Arouses learners' interests, encourage and motivates them to learn. Make it known to them the teaching technique to be used and its demand on them.<br>2. Using question and answer method, review learners' R.P.K on carbonyls: E.g. aldehyde and ketones belong to what class of organic compounds?. Let them know that today's lesson is about carbonyl compounds. Discuss with them objectives of the lesson. | Leaners listen attentively to the facilitator. They are encouraged to talk, ask questions, write notes and also write down their ideas.<br>Listen to the tutor and jot down some points as the tutor speaks, and they also ask various questions based on the topic for clarification when and where necessary. | **Expected Answers:-**<br>Aldehydes and ketones are commonly known as carbonyl compounds. The functional group of carbonyls is (>C=O). They have the same general formula $CnH_2nO$ |
| Step 2 | Grouping, Elicitation & Discussion of Learners' thinking/ideas<br><br>Group of learners | **35** | 1). Divide learners into groups (of 3-4) based on ability and inclusivity; asks them to assume the roles of team leader, recorder, time-keeper, etc. Let them be aware that the roles are rotational.<br>2). Ask learners to describe carbonyls in terms of their nature, formula and functional group. Move round various groups to supervise their activities.<br>3). In the form of whole class discussion, assist them to describe systematic steps involved in naming carbonyls (both aldehydes and ketones) using the IUPAC | Learners' move into their respective groups and assume their new different roles as agreed by members.<br>Learners brainstorm and write their results or findings on the assigned work in their groups.<br>Learners pay much attention and listen attentively; ask questions to clarify their difficulties in IUPAC | **Expected Answers:-**<br>**a). Nature of Carbonyls**<br>In aldehydes, the carbonyl group with the hydrogen atom is always present at the end of the chain. It is written as −CHO never as COH. In ketones, the carbonyl group -CO- is attached to two hydrocarbon groups, alkyl or benzene rings<br>**Names of Some Alkanals**<br>HCHO - Methanal<br>$CH_3CHO$ - Ethanal |

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| | | | rules. Give some structures of aldehydes and ketones for them to use the rules to name them.<br><br>4). In their respective groups, (with the help of their phones) ask learners to search and provide their findings on the following:-<br><br>a). Isomerism in the carbonyl compounds<br><br>b) Physical properties of the carbonyl compounds<br><br>c) Chemical properties of the carbonyl compounds<br><br>d) Test for carbonyl compounds<br><br>e) Uses of carbonyl compounds | rules; and use the rules to name the given aldehydes and ketones structures.<br><br>Learners in their groups use their phones to search, discuss and write their findings and present them chronologically as assigned to them in relation to isomerism in carbonyls; physical and chemical properties of carbonyls; chemical tests and the uses of carbonyl compounds. | $CH_3CH_2CHO$ - Propanal<br>**<u>Names of Some Alkanones</u>**<br>$CH_3COCH_3$ - Propanone<br>$CH_3COCH_2CH_3$-Butanone<br><br>**<u>a). Isomerism in carbonyls</u>**<br>Carbonyls (aldehydes & ketones) exhibit structural isomerism i.e. chain, position and functional isomerism<br><br>**<u>b). Physical properties</u>**<br>❖ They are polar in nature.<br>❖ They are insoluble in water but sometimes they dissolve other forms of polar<br>❖ Have higher boiling point than alkanes with similar molecular weight, etc<br><br>**<u>c). Chemical properties</u>**<br>Chemically, carbonyls are very reactive compounds; and they undergo nucleophilic addition and substitution reactions; etc<br><br>**<u>d). Test for carbonyls</u>**<br>They can be tested in the laboratory with these reagents 2,4-DNPH; Fehling's soln; Benedict's solution, Tollen's reagent; etc |

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| | | | 5). In their respective groups, ask learners to write their findings on cardboards/flip charts and make presentations to the whole class.<br><br>6). Assist in the plenary discussions on the learners' presentations.<br><br>7). Through a whole or an intact class discussion, refine learners' responses and ask them to write the correct responses in a logical manner on the maker board as shown in the core-point column. | Learners write their findings on cardboards/flip charts and make their presentations to the class.<br><br>Learners listen attentively to each group's presentation; ask questions when necessary.<br><br>Learners in their groups take active part in the discussion process; seek clarifications when necessary to refine their thinking/ideas on the various areas of carbonyls taught. | E.g.<br>**Test**:- Add a few drops of 2, 4-DNPH to carbonyl reagent<br>**Observation**:- A yellow or orange precipitate forms.<br><br>**e). Uses of carbonyls**<br>It is used as solvents; in making perfumes, flavouring agents or as intermediates; in the manufacture of plastics, dyes, and pharmaceuticals; etc |
| Step 3 | Introducing the Experiment | **5** | Introduce the experiment to the learners and discuss its aim/purpose, steps involved and expected outcome.<br>E.g.:-<br>This experiment involves preparation of a named carbonyl using ethanol, $K_2Cr_2O_7$, $H_2SO_4$, etc.; and perform certain chemical tests on the prepared carbonyl compound.<br><br>Give the POE worksheet 5 on carbonyl compounds to learners to read for the next step (step 4). | Learners listen attentively to the facilitator and write down some important points as the tutor speaks. They also ask questions to clarify their thought when necessary.<br><br>Leaners take the POE worksheet 5 on the carbonyl compounds and read for the next stage. | |

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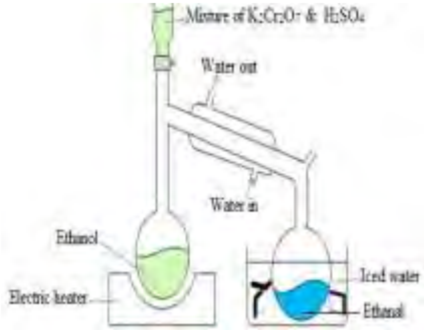
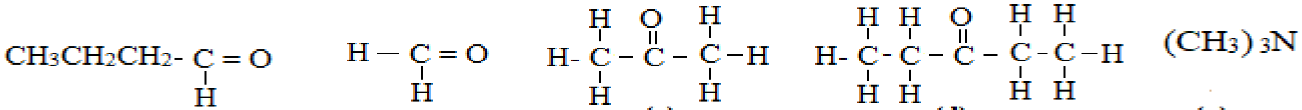
| Step 4 | **Predict (P)**<br>Learners make predictions on the activity or experiment they are about to do based on their existing knowledge / experience.<br><br>Predicting | **15** | In this step, ask learners to predict answers to some questions based on the experiment that they are about to do in their POE worksheets. Let them answer the questions on worksheet in groups:<br>E.g.<br>1) If you put 2-3 pieces of calcium carbide in a flask with sand, and then you add few drop water until it react to produce an unknown gas C; what reaction do you think calcium carbide has undergone? etc.<br><br>Tutor moves round to supervise them to ensure each member participate in the activities. | Each member in the group is expected to write out his/her prediction in their jotters. The group compare the individual answers and brainstorm collectively to come out with group ideas on all predicted questions raised.<br>The group's predictions are to be written on POE worksheets supplied to them by the recorder or any member they agreed on to do the writing.<br>Facilitator moves and interacts with the groups as they make their predictions. | |
| | **Reason(s):** | | Ask each group to give reason(s) for their predictions. Tutor moves round to supervise the activities. | Each group write reason(s) for their predictions on the POE worksheet and for discussion. | |

| | | | | | |
|---|---|---|---|---|---|
| Step 5 | **<u>Observe (O)</u>**<br>-Perform experiment.<br><br>Perform expt | **40** | Give activity guide 5: on carbonyl compounds for them to read.<br>Discuss with them the steps involved in this experiment and ask learners to perform the experiment to prepare an unknown liquid X by following the steps in the activity guide 5.<br>E.g.<br>1). Assemble the set-up as shown in the diagram 1 below.<br>2). Place about 20 ml ethanol into a flask and heat to about 60°C using Bunsen burner or an electric heater. etc.<br>Facilitator and the laboratory technician move round to assist them when needed. | Leaners in their group carry out the experiment in the activity guide 5; as guided by tutor and lab. technician. They follow the instructions step by step and carry out the expt.<br>Each member in the group record his/her observations and inference in their jotters. They also write the chemical equation representing the preparation of the liquid X.<br>The group then compare the individual's observations, dialogue collectively and write the group's ideas as agreed on POE worksheet | <br>Set-up for the preparation of ethanal (an aldehyde) |
| Step 6 | **<u>Explain (E)</u>**<br><u>E</u>xplaining the observations; & compare the observations with their predictions.<br><br>Explaining | **15** | Ask learners in their groups to compare individual explanations and collectively brainstorm to come out with the group's explanations to their observations.<br>Ask learners to correlate their prediction(s) with observation(s) in order to reconstruct their thinking/ideas; and reconcile any conflict between their predictions and observations. | In their respective groups, let them compare their individual explanations and collectively brainstorm to come out with the group's explanations to their observations.<br>Learners are to compare their predictions and observations so as to reconcile any conflict between their predictions and observations in the whole class discussions. | |

| | | | | | |
|---|---|---|---|---|---|
| | | | Ask learners to disengage from their groupings. Tell them to read on the next topic; alkanoic acids. | Learners move to their seats. They read given assignment. | |
| **Total** | | **115** | | | |

**Summary: (5 minutes)**
Facilitator (Tutor) summarises the lesson:- Aldehydes and ketones are commonly known as carbonyl compounds. This is because the functional group in these compounds is the carbonyl group [>C=O]. Hence, aldehydes and ketones are also known as carbonyl compounds. Aldehydes and ketones have a lot of similarities due to functional group similarity. The carbonyl group (>C=O) in these compounds is polarised due to the electronegativity difference between the carbon atom and oxygen atom. Aldehydes and ketones exhibit similar properties as they have the same general formula $CnH_2nO$; hence, in ketones, no hydrogen atom is directly attached to the carbonyl group, whereas in aldehydes, a hydrogen atom is directly attached to the carbonyl group. They are polar in nature. They exhibit both positive and negative charges in slight form. Hence, these are said to be polar molecules. These compounds are reported to be insoluble in water but sometimes they dissolve other forms of polar molecules. These are known to be chemically reactive compounds. These undergo nucleophilic addition and substitution reactions. The carbon atom of the carbonyl group is said to be electrophilic in nature as they tend to attract electron-rich compounds. Aldehydes and ketones undergo a variety of reactions which leads to the formation of different products. The most common reactions are nucleophilic addition reactions, which lead to the formation of alcohols, alkenes, diols and cyanohydrins. These also undergo nucleophilic addition reactions. They are used as solvents; in making perfumes and flavouring agents or as intermediates in the manufacture of plastics, and pharmaceuticals. Specifically, formaldehyde is used in the manufacture of plastics and also it is used in the biological laboratories for preservation purposes; butanol is used to provide fragrance for keeping the bread fresh whiles acetaldehyde is used as a synthesizer in many organic reactions.

**Individual Assignment:**
Tutor/facilitator gives the learners take home assignment due for submission the next class. Lets learners read on alkanoic acids.
1). Give the IUPAC names of the following compounds.




(a) (b) (c) (d) (e)

2). Give the general formula for carbonyl and the functional group as well.
3). With the aid of a diagram, describe how a named carbonyl, liquid ethanal is prepared in the laboratory.
4). Mention three physical and chemical properties of carbonyl compounds.
**Expected answers to the assignment questions:** For answers refer to the pore-core point column and other sources.

## WORKSHEET 5: CARBONYL COMPOUNDS

**SCIENCE STUDENT-TEACHERS' POE WORKSHEET FOR CARBONYL COMPOUNDS**

| Steps | Steps in POE | Group Number:………………… Date: ………………… |
|---|---|---|
| 1 | **Predict = (P)**<br>What do you think will happen?<br><br>What is in your mind?<br>Please speak out | 1) What do you think will happen if you mix 20 ml of ethanol and $H_2SO_{4\,(aq)}$ and $K_2Cr_2O_7$ together in a flask? ……………………...<br>2). If the mixture in (1) is then heated on an electric heater slowly, it will react to produce an unknown liquid X, what do you think has happened to the ethanol? ……………………..........................<br>3). Unknown liquid X is likely to be what?.......................................<br>4). What do you think would be equation for the reaction?...............<br>……………………………………………………………………<br>5). What do you think will happen if:-<br>i) unknown liquid X in a test tube is tested with litmus paper?:……<br>……………………………………………………………………<br>ii) you smell unknown liquid X; what is likely will be the odour?:<br>……………………………………………………………………<br>iii) $K_2Cr_2O_7$ is added to liquid X in a test tube:……….....................<br>…………………………………………………………………… |
| | Give reason(s) for your predictions<br> | ……………………………………………………………………<br>……………………………………………………………………<br>…………………………………………………………………… |
| 2 | **Observe = (O)**<br><br>Please observe well | (see table below) |
| 3 | **Explain = (E)**<br><br>Please explain well | ……………………………………………………………………<br>……………………………………………………………………<br>…………………………………………………………………… |

| Test | Observation | Inference |
|---|---|---|
| Ethanol + $H_2SO_4$ + $K_2Cr_2O_7$ | | |
| Ethanol + $H_2SO_4$ + $K_2Cr_2O_7$ + heat | | |
| Uknown liquid X + litmus | | |
| Smell an uknown liquid X | | |
| Uknown liquid X + 2,4-DNPH | | |
| Uknown liquid X + $K_2Cr_2O_{7\,(aq)}$ | | |

## EXPECTED RESPONSES FROM WORKSHEET 5: ON CARBONYLS

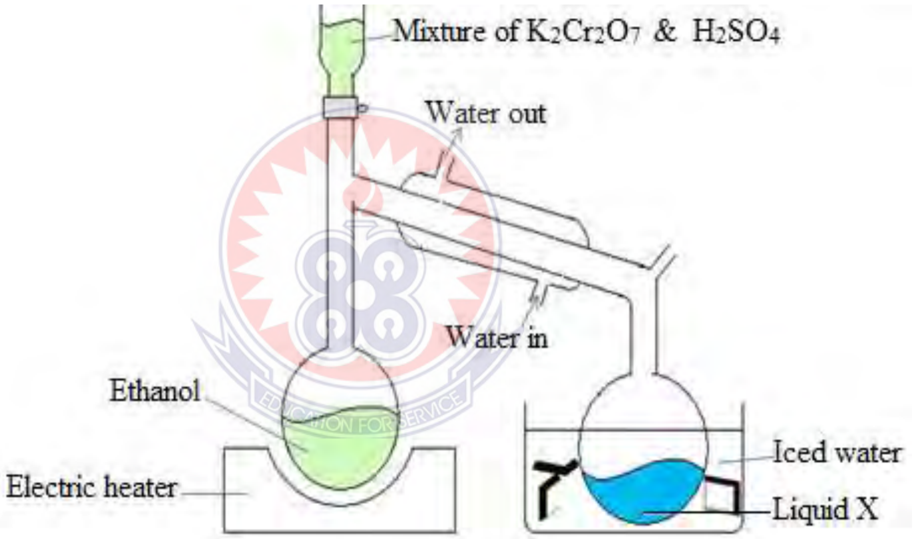
<table>
<tr><th colspan="3">SCIENCE STUDENT-TEACHERS' POE WORKSHEET FOR CARBONYL COMPOUNDS</th></tr>
<tr><th>Steps</th><th>Steps in POE</th><th>Group Number:………………… Date: …………………</th></tr>
<tr><td rowspan="2">1</td><td><u>P</u>redict = (P)<br>What do you think will happen?<br><br>What is in your mind?<br>Please speak out</td><td>1). What do you think will happen if you mix 20 ml of ethanol and $H_2SO_{4\,(aq)}$ and $K_2Cr_2O_7$ together in a flask?. <u>There will be no reaction until it is heated</u><br>2). If the mixture in (1) is then heated on an electric heater slowly, it will react to produce an unknown liquid X, what do you think has happened to the ethanol?. <u>The ethanol is oxidised to aldehyde</u><br>3). Unknown liquid X is likely to be what?. <u>The unknown liquid X is likely to be an ethanal (aldehyde)</u><br>4). What do you think would be equation for the reaction?.<br>$$CH_3CH_2OH \xrightarrow[Heat]{H_2SO_4 \ + \ K_2Cr_2O_7} CH_3CHO \ + \ H_2O$$<br>5). What do you think will happen if:-<br>i) unknown liquid X in a test tube is tested with litmus paper?: <u>Liquid X has no effects on either blue or red litmus paper</u>.<br>ii) you smell unknown liquid X; what is likely will be the odour?: <u>It is a volatile liquid with pungent odour</u><br>iii) $K_2Cr_2O_7$ is added to liquid X in a test tube. <u>The orange/yellow colour of $K_2Cr_2O_7$ solution turns to green.</u></td></tr>
<tr><td>Give reason(s)<br></td><td>1). This reaction requires heat and catalyst to speed up the process.<br>2). Carbonyl compounds react with 2,4-dinitrophenylhydrazine to give an orange-yellow precipitate; and other reagents like $K_2Cr_2O_7$, $KmnO_4$, etc to give varied solutions.</td></tr>
<tr><td>2</td><td><u>O</u>bserve = (O)<br><br>Please observe well</td><td><table>
<tr><th>Test</th><th>Observation</th><th>Inference</th></tr>
<tr><td>Ethanol + $H_2SO_4$ + $K_2Cr_2O_7$</td><td>No observable change</td><td>Ethanal is absent</td></tr>
<tr><td>Ethanol + $H_2SO_4$ + $K_2Cr_2O_7$ + heat</td><td>A colourless liquid with pungent odour smell</td><td>Ethanal is produced</td></tr>
<tr><td>Uknown liquid X + litmus</td><td>Has no effect on litmus</td><td>Ethanal</td></tr>
<tr><td>Smell an uknown liquid X</td><td>Has pungent odour smell</td><td>Ethanal</td></tr>
<tr><td>Uknown liquid X + 2,4-DNPH</td><td>Yellow/orange ppt</td><td>Ethanal</td></tr>
<tr><td>Uknown liquid X + $K_2Cr_2O_{7(aq}$</td><td>Orange/yellow solution turns green</td><td>Ethanal</td></tr>
</table></td></tr>
<tr><td>3</td><td><u>E</u>xplain = (E)<br><br>Please explain well</td><td>A mixture of ethyl alcohol and sodium dichromate solution is run into boiling dilute sulphuric acid. Instantly an energetic reaction happens and the acetaldehyde formed in the liquid state is instantly distilled off. This avoids the oxidation of acetaldehyde to acetic acid. Ethyl alcohol stays in the solution until it is oxidized. Pure acetaldehyde is obtained by redistillation.</td></tr>
</table>

## ACTIVITY GUIDE 5: ON CARBONYL COMPOUNDS

| STUDENT-TEACHERS' POE ACTIVITYGUIDE FOR CARBONYL COMPOUNDS | |
|---|---|
| **Group Number:…………………………………...** | **Date: ………………………………..** |

**Instruction:-**Guide student-teachers to carryout these practical activities for the preparation of an **unknown liquid X** using ethanol; and a mixture of $K_2Cr_2O_7$ & $H_2SO_4$ as follows:-

1) Assemble the set-up as shown in the diagram below.
2) Place about 20 ml ethanol into a flask and heat to about 60°C using a Bunsen burner or an electric heater.
3) Add a mixture potassium dichromate ($K_2Cr_2O_7$) and dilute sulphuric acid ($H_2SO_4$) in small amount from the tap or thistle funnel.
4) Observe the experiment careful and record your observations.




**Set-up for the preparation of an unknown liquid X**

5) An unknown liquid is boiled off as it forms and then condenses as it passes down the condenser (which is cooled by water) and it is collected in the receiving flask.

**NB:-** Expected observation: "An colourless **unknown liquid X** is formed"

6) In a tabular form write your observation and inference by testing the liquid "X" with:- i) litmus; ii) odour; iii) potassium dichromate ($K_2Cr_2O_7$) respectively.
7) Write the chemical equation for the reaction.

# APPENDIX K6

## UNIVERSITY OF EDUCATION, WINNEBA

## UNIT 6: LESSON PLAN BASED ON PREDICT-OBSERVE-EXPLAIN INSTRUCTIONAL APPROACH ON ALKANOIC ACIDS

**College:** As Applicable

**Subject:** Chemistry (Option:- Organic Chemistry)

**Topic:** Alkanoic (Carboxylic) acids

**Level:** 200

**Number in Class:** 40

**Average Age:- 23 years**

**Sex:** Mixed

**Duration:** 2 hours (120 minutes)

**Concept Focus:-**Laboratory preparation of a named alkanoic acid and perform certain specific tests.

**Scientific Processes:-** Making predictions, observations, classifications, explanations and drawing conclusions.

**Group(s)**:- Learners work in groups (3-4 members per team). Facilitator provides all necessary resources.

**Assessment Methods**:-Classroom dialogue; Tutor observations; Worksheet exercises; Presentations; Post-activity assignment.

**Course Learning Outcome & Indicators:-** By the end of the lesson, learners should be able to;

1) Describe alkanoic acids in terms of their nature, formula and functional group.
2) Identify the sources of alkanoic acids.
3) Discuss IUPAC rules and write correct IUPAC names of alkanoic acids using the rules.
4) Describe the isomerism in alkanoic acids.
5) Mention the physical properties of alkanoic acids.
6) State the chemical properties of alkanoic acids.
7) Mention the uses of alkanoic acids.
8) Carryout laboratory preparation of a named alkanoic acid (ethanoic acid).

**Instructional Resources:-** Ethanol, potassium dichromate(VI); conc. sulphuric acid, water bath, Bunsen burner, cork, wire water, mesh, delivery tube, retort stand and clamp, POE activity guide and POE worksheet.

**Lesson Presentation:-**

**RPK:-** Learners have learnt aspect of alkanoic acid at the SHS level and in General Chemistry I at COE level.

| Steps | Lesson Development | Time (mins) | Facilitator's (Tutor's) Activities | Learners' Activities | Core-Point(s) |
|---|---|---|---|---|---|
| Step 1 | **<u>Introduction</u>**<br>-Reviewing Previous Knowledge of the learners | **5** | 1. Arouse the learners' interests, encourage and motivate them to learn. Make it known to them the teaching technique to be used and its demand on them.<br>2. Using question and answer method, review learners' R.P.K on alkanols: E.g. What are alkanols & its three classes?. Let them know that today's lesson is about alkanoic acids. Discuss with them the objectives of the lesson. | Leaners listen attentively to the facilitator/tutor. They are encouraged to talk, ask questions, write notes and also write down their ideas.<br>Listen to the tutor and jot down some points as the tutor speaks, and they also ask questions for clarification. | **<u>Expected Answers:-</u>** They are organic compounds having OH as functional group. The 3 classes are primary, secondary & tertiary. let them know that alkanoic acids have 2 functional groups: that is carbonyl group (-C = O) & hydroxyl group (-OH). |
| Step 2 | Grouping, Elicitation & Discussion of Learners' thinking/ideas<br><br>Group of learners | **35** | 1). Divide learners into groups (of 3-4) based on ability and inclusivity; ask them to assume the roles of team leader, recorder, time-keeper, etc. Let them be aware that the roles are rotational.<br>2). Ask learners to describe alkanoic acids in terms of their nature, formula and functional group. Move round various groups to supervise their activities.<br>3). In the form of whole class discussion, assist them to describe systematic steps involved in naming alkanoic acid using the IUPAC rules. Give some structures of | Learners' move into their respective groups and assume their new different roles as agreed by members.<br>Learners brainstorm and write their results or findings on the assigned work in their groups.<br>Learners listen attentively, ask various questions to clarify their difficulties in IUPAC rules; and use | **<u>Expected Answers:-</u>**<br>**a). <u>Nature of Alkanoic Acids</u>**<br>Alkanoic acids are also called **Carboxylic acid**. They are polar compounds identify by the presence of the carboxyl functional group, (-COOH), made up of a carbonyl functional group (-C = O) & hydroxyl group (-OH).<br>**<u>Names of Alkanoic Acids</u>**<br>$HCOOH$ — Methanoic<br>$CH_3COOH$ — Ethanoic<br>$C_2H_5COOH$ — Propanoic |

| | | | | | |
|---|---|---|---|---|---|
| | | | alkanoic acid for them to use the rules to name them<br><br>4). In their respective groups, (with the help of their phones) ask learners to search and provide their findings on the following:-<br><br>a). Isomerism in alkanoic acids<br><br>b) Physical properties of alkanoic acids<br><br>c) Chemical properties of alkanoic acids<br><br>d) Test for alkanoic acids | the rules to name the various given alkanoic acid structures.<br><br>Learners in their groups use their phones to search, discuss and write their findings and present them chronologically as assigned to them in relation to isomerism; physical and chemical properties; chemical tests and the uses of alkanoic acid respectively. | **<u>a). Isomerism in Alkanoic Acids</u>**<br>Alkanoic acid have different structural isomers like chain isomerism and functional isomerism etc.<br>**<u>b). Physical properties</u>**<br>❖ It is a colourless liquid<br>❖ Has a sharp odour of vinegar<br>❖ It has a sour taste.<br>❖ It is soluble in water.<br>**<u>c). Chemical properties</u>**<br>Chemically, alkanoic acids are very reactive and they undergo several reactions. e.g.<br>❖ They reacts with metal carbonates to liberate $CO_2$.<br>❖ React with bases to form salt and water in neutralization reactions<br>❖ They react with active metals to produce $H_2$ gas<br>❖ React with alkanols with conc. $H_2SO_4$ as a catalyst to produce ester & $H_2O$; etc.<br>❖ Turns blue litmus papers to red; & has no effect on blue.<br>**<u>d). Test for Alkanoic Acids</u>**<br>Alkanoic acid can be tested in the laboratory using the following |

| | | | | | |
|---|---|---|---|---|---|
| | | | e) Uses of alkanoic acids<br><br>5). In their respective groups, ask learners to write their findings on cardboards/flip charts and make presentations to the class.<br><br>6). Assist in the plenary discussions on the learners' presentations.<br><br>7). Through a whole or an intact class discussion, refine learners' responses and ask them to write the correct responses in a logical manner on the maker board as shown in the core-point column. | Learners write their findings on cardboards/flip charts and make their presentations to the class.<br><br>Learners listen attentively to each group's presentation; ask questions when necessary.<br><br>Learners in their groups take active part in the discussion process; seek clarifications when necessary to refine their thinking/ideas on the various areas of alkanoic acids taught. | reagents: litmus papers; $Na_2CO_3$ solution; $NaHCO_3$ solution; etc. E.g.<br>**Test**:- Add a few drops of $Na_2CO_3$ solution to alkanoic acid<br>**Observation**: Brisk evolution of colourless & odourless $CO_2$ gas which turns lime water milky.<br>**e). Uses of Alkanoic Acids**<br>It is used in making cellulose ethanoate, dyes etc. It is used as an organic solvent. It is used in the food industries for preserving and flavouring food. Used for coagulating rubber latex; etc. |
| Step 3 | Introducing the Experiment | **5** | Introduce the experiment to the learners and discuss its aim/purpose, steps involved and expected outcome. E.g.:- This experiment involves preparation of a named alkanoic acid using ethanol, $K_2Cr_2O_7$; conc. $H_2SO_4$, etc.; and perform certain chemical tests on the prepared alkanoic acid.<br><br>Give the POE worksheet 6 on alkanoic acids to learners to read for the next step (step 4). | Learners listen attentively to the facilitator and write down some important points as the tutor speaks. They also ask questions to clarify their thought when necessary.<br><br>Leaners take the POE worksheet 6 on alkanoic acids and read thoroughly for the next stage. | |

| | | | | | |
|---|---|---|---|---|---|
| Step 4 | **<u>Predict (P)</u>**<br>Learners make predictions on the activity or experiment they are about to do based on their existing knowledge / experience.<br><br>Predicting | **15** | In this step, ask learners to predict answers to structured questions based on the experiment that they are about to do in their POE worksheets. Let them answer the questions on worksheet in groups:<br><br>E.g.<br>1) What do you think will happen if you mix 5 grams of potassium dichromate with 10ml of conc.$H_2SO_4$ acid; ethanol and deionised water together in a flask? etc.<br><br>Tutor moves round to supervise them to ensure each member participate in the activities of the day. | Each member in the group is expected to write out his/her prediction in their jotters. The group compare the individual answers and brainstorm collectively to come out with group ideas on all the predicted questions raised.<br><br>The group's predictions are to be written on POE worksheets supplied to them by the recorder or any member they agreed on to do the writing.<br><br>Facilitator moves and interacts with the groups as they make their predictions. | |
| | **Reason(s):** | | Ask each group to give reason(s) for their predictions. Tutor moves round to supervise the activities. | Each group write reason(s) for their predictions on the POE worksheet and for discussion. | |

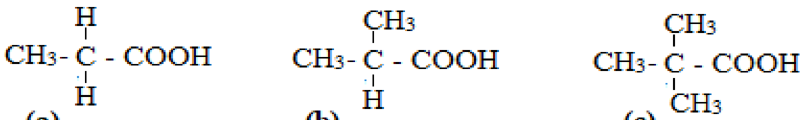
| | | | | | |
|---|---|---|---|---|---|
| Step 5 | **<u>Observe (O)</u>**<br>-Perform experiment.<br><br>Perform expt | **40** | Give activity guide 6: on alkanoic acid for them to read through.<br>Discuss with them the steps involved in this experiment and ask learners to perform the experiment to prepare an unknown organic acid following the steps in activity guide 6. E.g.<br>1). Put a few anti-bumping granules and $10cm^3$ of dilute sulphuric acid in the round bottomed flask; etc.<br>Facilitator and the laboratory technician move round to assist them when needed.<br>Move round to supervise them to ensure each member participate in the activities. | Leaners in their group carry out the experiment on the activity guide; as guided by tutor and lab. technician. They follow the instructions step by step and carry out the expt.<br>Each member in the group record his/her observations and inference in their jotters. They also write the chemical equation representing the preparation of the liquid W.<br>The group then compare the individual's observations, dialogue collectively and write the group's ideas as agreed on the POE worksheet | <br>Set-up for preparation of an unknown acid (ethanoic acid) or liquid W |
| Step 6 | **<u>Explain (E)</u>**<br><u>E</u>xplaining the observations; & compare the observations with their predictions.<br><br>Explaining | **15** | Ask learners in their groups to compare individual explanations and collectively brainstorm to come out with the group's explanations to their observations.<br>Ask learners to correlate their prediction(s) with observation(s) in order to reconstruct their thinking/ideas; and reconcile any conflict between their predictions and observations. | Learners in their respective groups compare their individual explanations and collectively brainstorm to come out with the group's explanations on observations.<br>Learners are to compare their predictions and observations so as to reconcile any conflict between their predictions and observations in the whole class discussions. | |

| | | | | | |
|---|---|---|---|---|---|
| | | | Ask learners to disengage from their groupings. Tell them to read on the next topic; alkanoates/esters | Learners move to their seats. They read given assignment. | |
| **Total** | | **115** | | | |

**Summary: (5 minutes)**
Facilitator (Tutor) summarises the lesson:- Alkanoic acid are also called carboxylic acid. They are polar compounds, characterised by the presence of the carboxyl functional group, (-COOH), which is made up of a carbonyl functional group (-C = O) and hydroxyl group, (-OH). The -COOH group may be attached to an alkyl group or to a benzene (or phenyl) ring. When the functional group is attached to an alkyl group, it is called aliphatic carboxylic acid. When the functional group is attached to a phenyl ring, it is called aromatic acid. Most organic acids occur in nature and are usually called saturated aliphatic acids or fatty acids. Saturated aliphatic acids have the general molecular formula: $C_nH_{2n+1}COOH$; where $n \geq 0$. They exhibit structural isomerism namely chain and functional isomerism. They have general physical properties. The first eight (8) of aliphatic alkanoic acids are liquids; the rest are soft solids. All aromatic acids are solids. Alkanoic acids have high boiling point, melting point and density than alkanol of comparable molecular mass. Chemically, alkanoic acids are very reactive and they undergo several reactions E.g. react with alkanols with conc. $H_2SO_4$ as a catalyst to produce ester and $H_2O$. They can be synthesized in many ways including oxidation of alcohols; oxidation of alkyl benzene Hydrolysis of alkyl alkanoate; complete hydrolysis of alkanonitriles; alkaline hydrolysis and many others.

**Individual Assignment:**
Tutor/facilitator gives the learners take home assignment due for submission the next class. Lets learners read on **alkanoates/esters**

1). Give the IUPAC names of the following compounds.



(a) (b) (c)

2). Give the general formula for alkanoic acid and the functional group as well.

3). With the aid of a diagram, describe how ethanoic acid is prepared in the laboratory (using potassium dichromate, conc.$H_2SO_4$ acid; ethanol and water).

4). Mention two physical and chemical properties of alkanoic acid.

**Expected answers to the assignment questions:** For answers refer to the pore-core point column and other sources.

**WORKSHEET 6: ALKANOIC ACIDS**

<table>
<tr><td></td><td colspan="2">SCIENCE STUDENT-TEACHERS' POE WORKSHEET FOR ALKANOIC ACIDS</td></tr>
<tr><td>Steps</td><td>Steps in POE</td><td>Group Number…    Date: ……………………………………</td></tr>
<tr><td rowspan="2">1</td><td><u>P</u>redict = (P)<br><br>What do you think will happen?<br><br>What is in your mind?<br><br>Please speak out</td><td>1) What do you think will happen if you mix 5 grams of potassium dichromate with 10ml of conc.$H_2SO_4$ acid; ethanol and deionised water together in a flask? ……………………..................................<br>2). If the mixture in (1) is then heated on water-bath over a burner, it will react to produce an unknown acid, what do you think has happened to the ethanol? …………………….....................................<br>3). Unknown acid is likely to be what?......................................<br>4). What do you think would be equation for the reaction?...............<br>……………………………………………………………………<br>5). What do you think will happen if:-<br>i) the liquid W is tested with red litmus paper?:……………………..<br>……………………………………………………………………..<br>ii) the liquid W is tested with blue litmus paper?:……………………<br>……………………………………………………………………...<br>iii) sodium carbonate is added to liquid W:……..................................<br>……………………………………………………………………</td></tr>
<tr><td>Give reason(s) for your predictions<br><br></td><td>……………………………………………………………………<br>……………………………………………………………………<br>……………………………………………………………………</td></tr>
<tr><td>2</td><td><u>O</u>bserve = (O)<br><br>Please observe well</td><td><table>
<tr><th>Test</th><th>Observation</th><th>Inference</th></tr>
<tr><td>$K_2Cr_2O_7 + H_2SO_4$ + ethanol + water</td><td></td><td></td></tr>
<tr><td>$K_2Cr_2O_7 + H_2SO_4$ + ethanol + $H_2O$ + heat</td><td></td><td></td></tr>
<tr><td>Smell an unknown acid</td><td></td><td></td></tr>
<tr><td>Unknown acid + red litmus</td><td></td><td></td></tr>
<tr><td>Unknown acid + blue litmus</td><td></td><td></td></tr>
<tr><td>Unknown acid + $Na_2CO_3$</td><td></td><td></td></tr>
<tr><td>Unknown acid + acidified $KMnO_4$</td><td></td><td></td></tr>
</table></td></tr>
<tr><td>3</td><td><u>E</u>xplain = (E)<br><br>Please explain well</td><td>……………………………………………………………………<br>……………………………………………………………………<br>……………………………………………………………………</td></tr>
</table>

## EXPECTED RESPONSES FROM WORKSHEET 6: ON ALKANOIC ACIDS

<table>
<tr><th colspan="3">SCIENCE STUDENT-TEACHERS' POE WORKSHEET FOR ALKANOIC ACIDS</th></tr>
<tr><th>Steps</th><th>Steps in POE</th><th>Group Number:………………… Date: …………………</th></tr>
<tr><td rowspan="2">1</td><td>Predict = (P)<br>What do you think will happen?<br><br>What is in your mind?<br><br>Please speak out</td><td>1). What do you think will happen if you mix 5 grams of potassium dichromate with 10ml of conc.$H_2SO_4$ acid; ethanol and deionised water together in a flask?. There will be no reaction.<br>2). If the mixture in (1) is then heated on water-bath over a burner, it will react to produce an unknown acid, what do you think has happened to the ethanol? Ethanol has been oxidised<br>3). Unknown acid is likely to be what?. It likely to be Ethanoic acid<br>4). What do you think would be equation for the reaction?.<br>$CH_3CH_2OH \xrightarrow[Heat]{H_2SO_4 + K_2Cr_2O_7} CH_3COOH + H_2O$<br>5). What do you think will happen if:-<br>i) liquid W is tested with red litmus paper?: Has no effects on red<br>ii) liquid W is tested with blue litmus paper? Turns blue litmus to red<br>iiii) sodium carbonate is added to liquid W. There will be brisk evolution of $CO_2$ effervescence.</td></tr>
<tr><td>Give reason(s)<br></td><td>1). This reaction needs heat and catalyst to speed up the process.<br>2). Alkanoic acid is acidic in nature and therefore, can reacts with several substances including litmus, oxidising agents and others.</td></tr>
<tr><td>2</td><td>Observe = (O)<br><br>Please observe well</td><td>
<table>
<tr><th>Test</th><th>Observation</th><th>Inference</th></tr>
<tr><td>$K_2Cr_2O_7 + H_2SO_4$+ ethanol + $H_2O$</td><td>No reaction</td><td>Ethanoic is absent</td></tr>
<tr><td>$K_2Cr_2O_7 + H_2SO_4$ + ethanol + $H_2O$ + heat</td><td>Vinegar odour-like liquid is produced</td><td>Ethanoic produced</td></tr>
<tr><td>Smell an unknown acid</td><td>Vinegar odour smell</td><td>Same</td></tr>
<tr><td>Unknown acid + red litmus</td><td>No effect (same red)</td><td>Same</td></tr>
<tr><td>Unknown acid + blue litmus</td><td>Blue litmus turns red</td><td>Same</td></tr>
<tr><td>Unknown acid + $NaHCO_3$</td><td>Brisk evolution of $CO_2$ effervescence</td><td>Ethanoic produced</td></tr>
<tr><td>Unknown acid + acidified $KMnO_4$</td><td>Pink colour of $KMnO_4$ is discharged</td><td>Same</td></tr>
</table>
</td></tr>
<tr><td>3</td><td>Explain = (E)<br><br>Please explain well</td><td>Alcohols can be oxidised to carboxylic acids using potassium dichromate(VI) solution in the presence of dilute sulphuric acid as catalyst. The carboxylic acid produced has a vinegar-like smell; has effects on moist blue litmus paper; reacts with oxidising agents and evolves $CO_2$ when reacts with metal carbonate. Ethanoic acid is alkanoic acid; thus, it will show all characteristic of an alkanoic acid.</td></tr>
</table>

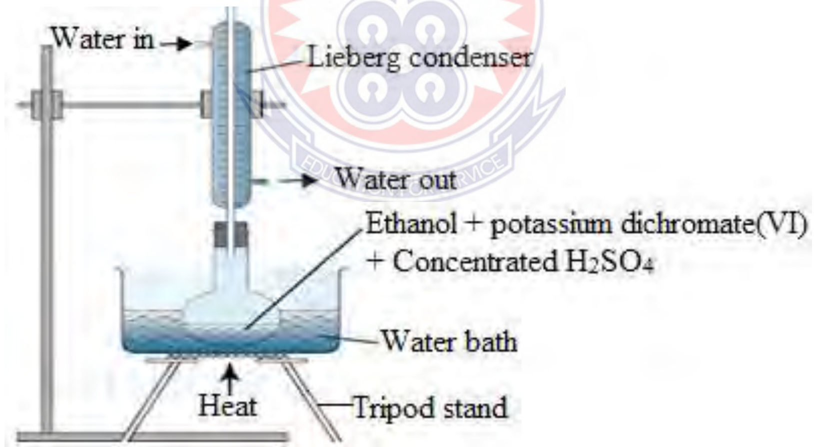
## ACTIVITY GUIDE 6: ON ALKANOIC ACIDS

| STUDENT-TEACHERS' POE ACTIVITY GUIDE FOR ALKANOIC ACIDS | |
|---|---|
| **Group Number:…………………………………...** | **Date: ………………………………..** |

**Instruction:-**Guide student-teachers to carryout these activities for preparation of **an unknown acid** by oxidation of ethanol with sodium dichromate, sulphuric acid, etc as follows:

1. Put a few anti-bumping granules and $10cm^3$ of dilute sulphuric acid in the round bottomed flask.
2. In a fume cupboard, add in 9g of potassium dichromate and dissolve by careful swirling.
3. Use a small dry funnel to avoid crystals of dichromate being caught on the neck of flask.
4. Slowly with swirling and cooling in an ice bath, add $6cm^3$ of conc. sulphuric 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.

<u>**Note:**</u> Direct heating without water bath must not be used, as the boiling point of the mixture will eventually exceed 100ºC. The mixture is heated by using a water bath so as to keep the temperature constant; and also to ensure a uniform heating (heat is evenly supplied). The mixture is heated under reflux to prevent the ethanol to evaporate and escape to the surrounding before it has time to be oxidised to the carboxylic acid.




**Set-up for preparation of an unknown acid**

6. Distil off about $15cm^3$ to obtain aqueous solution of an unknown acid (liquid W).
7. Divide the distillate of an unknown acid into three portions in test tubes.
8. Test the unknown aqueous acid using or with:- i) red litmus; ii) blue litmus; iii) sodium carbonate-($Na_2CO_3$) solution respectively.
9. Record your observations and inference.

# APPENDIX K7

## UNIVERSITY OF EDUCATION, WINNEBA

## UNIT 7: LESSON PLAN BASED ON PREDICT-OBSERVE-EXPLAIN INSTRUCTIONAL APPROACH ON ESTERS

**College:** As Applicable

**Subject:** Chemistry (Option:- Organic Chemistry)

**Topic:** Alkanoates (Esters)

**Level:** 200

**Number in Class:** 40

**Average Age:- 23 years**

**Sex:** Mixed

**Duration:** 2 hours (120 minutes)

**Concept Focus:-**Laboratory preparation of alkanoate (ethyl ethanoate) and perform four tests.

**Scientific Processes:-** Making predictions, observations, classifications, explanations and drawing inferences/conclusions.

**Group(s)**:- Learners work in groups (3- 4 members per team). Facilitator provides all necessary resources.

**Assessment Methods**:-Classroom dialogue; Tutor observations; Worksheets; Post-activity assignment.

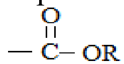
**Course Learning Outcome & Indicators:-** By the end of the lesson, learners should be able to;

1) Describe alkanoates in terms of their nature, formulae and functional group.
2) Identify the sources of alkanoates.
3) Discuss IUPAC rules and write correct names of alkanoates using the rules.
4) Mention the physical properties of alkanoates.
5) State the chemical properties of alkanoates.
6) Mention the uses of alkanoates.
7) Carryout laboratory preparation of a named alkanoate (ethyl ethanoate).

**Instructional Resources:-** Ethanoic acid, ethanol, conc. $H_2SO_4$, boiling-tube, test-tubes, test-tube holder, test-tubes rack, Bunsen burner, POE activity guide and POE worksheet

**Lesson Presentation:-**

**RPK:-** Learners have learnt alkanoates at the SHS level and alkanoic acid in previous lesson in General Chemistry I at COE level

| Steps | Lesson Development | Time (mins) | Facilitator's (Tutor's) Activities | Learners' Activities | Core-Point(s) |
|---|---|---|---|---|---|
| Step 1 | **<u>Introduction</u>**<br>-Reviewing Previous Knowledge of the learners | **5** | 1. Arouse the learners' interests and encourage them to learn. Make it known to them the teaching technique. Allow learners to ask questions based on previous lesson.<br><br>2. Using question and answer method, review learners' R.P.K on esters: E.g. What are the derivatives of alkanoic acid and which of them is sweet scented?. Let them know that today's lesson is on alkanoates. Discuss with them objectives of the lesson. | Learners listen attentively to the facilitator or the tutor. They are encouraged to talk, ask questions and take notes and also write down their ideas.<br><br>Learners listen to the tutor and jot down some important points as the facilitator or tutor speaks, and ask various questions for clarification. | **<u>Expected Answers</u>**:-<br>The derivatives of alkanoic acids are esters/alkanoates, acid halides, acid anhydrides and amides. The sweet scented derivative is the esters (alkanoates). |
| Step 2 | Grouping, Elicitation & Discussion of Learners' thinking/ideas<br><br>Group of learners | **35** | 1). Divide learners into groups (of 3-4) based on ability and inclusivity; asks them to assume the roles of team leader, recorder, time-keeper and so on. Let them know that the roles are rotational.<br><br>2). Ask learners to describe alkanoates in terms of their nature, and functional group. Move round various groups to supervise the activities.<br><br>3). In the form of whole class discussion, assist them to describe systematic steps involved in naming of alkanoates using the | Learners move into their respective groups and assume their different roles as agreed by members; and perform the responsibilities of that role.<br><br>Learners brainstorm and write their results or findings on the assigned work in their groups.<br><br>Learners pay attention and listen attentively, ask questions to clarify their difficulties on IUPAC rules; | **<u>Expected Answers</u>**:-<br>**Nature of Alkanoates**<br>Esters are organic compounds and are also known as **alkanoates**. They are fats & oils. They have the functional group –COOR or<br><br>can be written as R[!]COOR where **R[!]** can be **H**; alkyl or aromatic groups<br>**<u>Names of Some Alkanoates</u>**<br>$CH_3COOCH_2CH_3$<br>**Ethylethanoate** |

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| | | | IUPAC rules. Give them some structures of alkanoates to name them.<br><br>4). In their respective groups, with the help of their phones ask learners to search and provide their findings on the following:-<br>a) Sources of alkanoates<br>b) Physical properties of alkanoates<br>c) Chemical properties of alkanoates<br>d) Uses of alkanoates<br><br>5). In their respective groups, ask learners to write their findings on cardboards and make presentations to the class.<br><br>6). Assist in the plenary discussions on the learners' presentations.<br><br>7). Through brief whole class discussion, refine learners' responses and ask them to write the correct responses in a logical manner on the maker board as shown in the core-point column. | and use the rules to name the given alkanoates structures.<br><br>Learners in their groups use their phones to search, discuss and write their findings and present them logically manner as assigned to them on:-sources of alkanoates; physical and chemical properties of alkanoates; and uses of alkanoates.<br><br>Learners write their findings on cardboards and make presentations to the class<br><br>Learners listen attentively to each group's presentation; and ask questions when necessary.<br><br>Learners in their groups take active part in the discussion process; seek clarifications when necessary to refine their thinking/ideas on the various alkanoates taught in class. | $CH_3CH_2CH_2COOCH_3$<br>**Methyl butanoate**<br>**a). Sources of Alkanoates**<br>Alkanoates are obtained from animals and plants. Animals store them as fats, in plants exist as oils.<br><br>**b). Physical properties**<br>They are usually colourless liquids. They have sweet smelling odour. Short chain esters are soluble in water. etc<br><br>**c). Chemical properties**<br>1). They can be hydrolysed by $H_2O$ to produce ethanoic acid & ethanol<br>2). They reacts with ammonia, $NH_3$ to produce ethanol and amide<br>3). They can be reduced by hydrogen from lithium tetrahydridoalluminute (III) as reducing agent, etc<br><br>**d). Uses of Alkanoates**<br>1). Used as food flavours.<br>2). Used in perfumes and other sweet cosmetics<br>3). Used as cellulose nitrate solvent.<br>3). Used for quick-drying of substances like paints, nail varnishes, etc. |

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| Step 3 | Introducing the Experiment | **5** | Introduce the experiment to the learners and discuss its aim/purpose, steps involved and expected outcome.<br>E.g.:- This experiment involves preparation of a named alkanoate from ethanol, ethanoic acid, conc. $H_2SO_4$; and perform tests on it.<br><br>Give the POE worksheet 7 on alkanoates to learners to read for the next step (step 4). | Learners listen attentively to the facilitator and write down some important points as the tutor speaks. They also ask questions to clarify their thought or thinking pattern when and where necessary.<br><br>Leaners take the POE worksheet 7 on esters and read for the next step | |
| Step 4 | **<u>Predict (P)</u>**<br>Students make predictions on the activity based on their existing knowledge / experience.<br><br><br>Predicting | **15** | In this step, ask learners to predict answers to structured questions based on the experiment that they are about to do in their POE worksheets. Let them answer the questions on worksheet in groups:<br>E.g.<br><br>1) What do you think is likely to happen if you mix $3cm^3$ of ethanol with 3ml of ethanoic acid, few drops of conc. $H_2SO_4$ together in a boiling tube? etc.<br><br>Tutor moves round to supervise them to ensure each member participate in the activities. | Each member in the group is expected to write out his/her prediction in their jotters. The group compare the individual answers and brainstorm collectively to come out with group ideas on all questions raised.<br><br>The group's predictions are to be written on POE worksheets supplied to them by the recorder or any member they agreed on to do the writing for them. | |
| | **Reason(s):** | | Ask each group to give reason(s) for their predictions. Move round to supervise the activities. | Each group write reason(s) for their predictions in the POE worksheet and for discussion. | |

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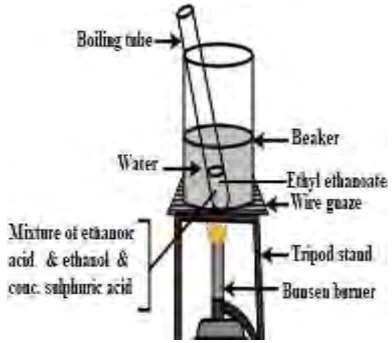
| Step 5 | **Observe (O)**<br>-Perform experiment.<br><br>Perform expt | **40** | Give activity guide 7 on alkanoate for them to read through well.<br><br>Discuss with them the steps involved in this experiment and ask learners to perform the experiment to prepare an unknown liquid Y following the steps in the guide 7:<br>E.g.<br>1). Measure 3cm$^3$ of ethanol into a separate test-tube, (Reagent A) etc.<br><br>Facilitator and the laboratory technician move round to assist them when needed.<br><br>Tutor moves round to supervise them to ensure each member participate in the activities. | Carry out the activities as directed by the facilitator.<br><br>Learners follow the instructions step by step as stated in the activity guide 7.<br><br>Each member in the group record his/her observations and inference in their jotters. They also write the chemical equation representing the preparation of the liquid Y.<br><br>The group then compare the individual's observations, dialogue collectively and write the group's ideas as agreed in the POE worksheet by the recorder. | <br><br>Set-up for preparation of ester (ethyl ethanoate)or liquid Y |
| Step 6 | **Explain (E)**<br>Explaining the observations & compare their observations with their predictions. | **15** | Ask learners in their groups to compare individual explanations and collectively brainstorm to come out with the group's explanations to their observations.<br><br>Ask learners to correlate their prediction(s) with observation(s) in order to reconstruct their thinking/ideas; and reconcile any conflict between their predictions and observations. | Learners in their respective groups compare their individual explanations and collectively brainstorm to come out with the group's explanations to their observations.<br><br>Learners are to compare their predictions and observations so as to reconcile any conflict between their predictions and observations in short class discussions. | |

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| |  Explaining | | Ask learners to disengage from their groupings. Tell them to read on the next topic; amines. | Learners move to their seats. They read given assignment. | |
| | **Total** | **115** | | | |

Summary: **(5 minutes)**
Facilitator (Tutor) summarises the lesson:- Esters are organic compounds and they are also called alkanoates. They have the functional group –COOR ; where R is an alkyl group. In general esters have the general formula: - R[!] COOR; where R[!] can be H; an alkyl or aromatic groups. In the presence of an acid catalyst, such as HCl, esters undergo hydrolysis to yield a carboxylic acid and an alcohol. Esters/alkanoates are fats and oils in nature. They are used to manufacture products such as margarine, soap, and many others. A typical ester, example ethyl ethanoate can be prepared in the laboratory using ethanol and ethanoic acid the presence of conc. $H_2SO_4$ and heat. They are colourless. Also they sweet in nature and that they have sweet scents.

**Individual Assignment:**

Tutor/facilitator gives the students take home assignment due for submission the next class. Lets learners read on amines.

1). Give the IUPAC names of the following compounds.

**(a).** $CH_3-\overset{\overset{\large O}{||}}{C}-OH$ **(b).** $H-\overset{\overset{\large O}{||}}{C}-OCH_3$

2). With the aid of a diagram, describe how a named alkanoate (ethyl ethanoate) is prepared in the laboratory.

3). Mention three physical and chemical properties of alkanoates.

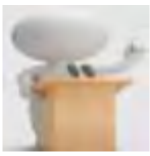
**Expected answers to the assignment questions:**

**(a).** $CH_3-\overset{\overset{\large O}{||}}{C}-OH$
**Ethanoic acid**

**(b).** $H-\overset{\overset{\large O}{||}}{C}-OCH_3$
**Methyl methanoate**

**Expected answers to the assignment questions:** For answers refer to 2 & 3 look at pore-core point column and other sources.

## WORKSHEET 7: ON ALKANOATES/ESTERS

<table>
<tr><td></td><td colspan="2">STUDENT-TEACHERS' POE WORKSHEET FOR ALKANOATES/ESTERS</td></tr>
<tr><td>Steps</td><td>Steps in POE</td><td>Group Number:…………………  Date: ………………………</td></tr>
<tr><td rowspan="2">1</td><td><u>P</u>redict = (P)<br>-What do you think will happen?<br><br>What is in your mind?<br>Please speak out</td><td>1). What do you think is likely to happen if you mix 3cm$^3$ of ethanol with 3ml of ethanoic acid, few drops of conc. $H_2SO_4$ together in a boiling tube? ……………………………………………………...<br>2). If the mixture in (1) is then heated on water-bath over a burner, it will react to produce an unknown liquid Y, what do you think has happened to the ethanol?.........................................................<br>3). Unknown liquid Y is likely to be what?.......................................<br>4). What do you think would be equation for the reaction?...............<br>………………………………………………………………………<br>5). What do you think will happen if:-<br>i) you smell liquid Y; what is likely will be the odour?:……………..<br>ii) dilute $Na_2CO_3$ is added to liquid Y and heat:………….....................<br>6). What do you think is function of Conc. $H_2SO_4$ in this reaction?:<br>………………………………………………………………………<br>7). What do you think the reaction was done on water bath?..............<br>……………………………………………………………………...<br>8). What do you think would be name for this reaction?:……………</td></tr>
<tr><td>Give reason(s) for your predictions<br><br></td><td>………………………………………………………………………<br>………………………………………………………………………<br>………………………………………………………………………</td></tr>
<tr><td>2</td><td><u>O</u>bserve = (O)<br><br>Please observe well</td><td><table><tr><th>Test</th><th>Observation</th><th>Inference</th></tr><tr><td>Ethanol + ethanoic acid + conc. $H_2SO_4$</td><td></td><td></td></tr><tr><td>Ethanol + ethanoic acid + conc. $H_2SO_4$ + heat</td><td></td><td></td></tr><tr><td>Smell an unknown liquid Y</td><td></td><td></td></tr><tr><td>Unknown liquid Y + red litmus paper</td><td></td><td></td></tr><tr><td>Unknown liquid Y + blue litmus paper</td><td></td><td></td></tr><tr><td>Unknown liquid Y + Water</td><td></td><td></td></tr><tr><td>Unknown liquid Y + $K_2Cr_2O_7$</td><td></td><td></td></tr></table></td></tr>
<tr><td>3</td><td><u>E</u>xplain = (E)<br><br>Please explain well</td><td>………………………………………………………………………<br>………………………………………………………………………<br>………………………………………………………………………<br>…………………………………………………………………………</td></tr>
</table>

## EXPECTED RESPONSES FROM WORKSHEET 7: ON ALKANOATES

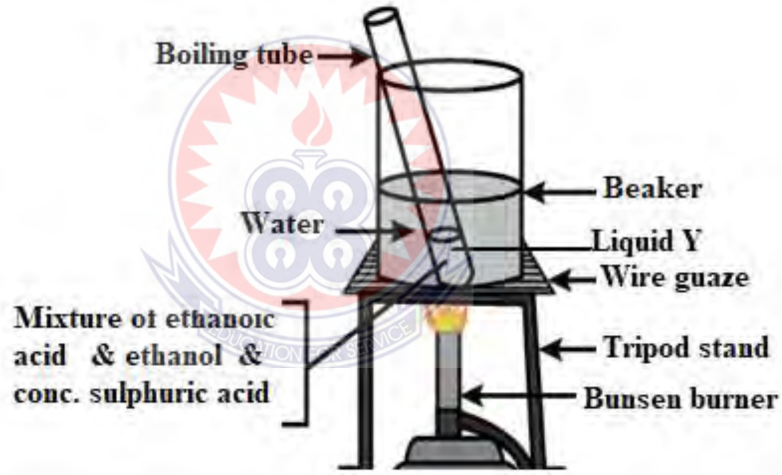
<table>
<tr><th></th><th colspan="2">STUDENT-TEACHERS' POE WORKSHEET FOR ALKANOATES/ESTERS</th></tr>
<tr><th>Steps</th><th>Steps in POE</th><th>Group Number:………………… Date: ………………………</th></tr>
<tr><td rowspan="2">1</td><td>Predict = (P)<br><br>What do you think will happen?<br><br><br>What is in your mind?<br><br><br>Please speak out</td><td>1). What do you think is likely to happen if you mix 3cm$^3$ of ethanol with 3ml of ethanoic acid, few drops of conc. $H_2SO_4$ together in a boiling tube?. There will be no reaction<br>2). If the mixture in (1) is then heated on a water-bath over a burner, it will react to produce an unknown liquid Y, what do you think has happened to the ethanol?. The ethanol has been oxidised<br>3). Unknown liquid Y is likely to be what? Ethyl ethanoate (E.E)<br>4). What do you think would be equation for the reaction?<br>$$\underset{\text{(Ethanol)}}{C_2H_5OH} + \underset{\text{(Ethanoic acid)}}{CH_3COOH} \xrightleftharpoons[\text{Heat}]{\text{Conc. } H_2SO_4} \underset{\text{(Ethylethanoate)}}{CH_3COOC_2H_5} + H_2O$$<br>5). What do you think will happen if:-<br>i) you smell liquid Y; what is likely will be the odour?. A pleasant or sweet fruity smell is detected.<br>ii) dilute $Na_2CO_3$ is added to liquid Y and heated. There will be brisk evolution of $CO_2$.<br>6). What do you think is the function of conc. $H_2SO_4$ in this reaction?. Concentrated $H_2SO_4$ serves a catalyst.<br>7). Why do you think the reaction was done on a water bath?. Both ethanol and ethanoic acids are flammable and may catch fire easily<br>8). What is the name for this reaction? The name for this reaction is esterification reaction.</td></tr>
<tr><td>Give reason(s) for your predictions<br><br></td><td>This reaction needs heat and catalyst to speed up the process. Esters have sweet fruity smell and also has acidic characteristics and thus, can have some effect on litmus papers, metal carbonate, oxidising agents such as $KMnO_4$, $K_2Cr_2O_7$ and many others.</td></tr>
<tr><td>2</td><td>Observe = (O)<br><br>Please observe well</td><td><table>
<tr><th>Test</th><th>Observation</th><th>Inference</th></tr>
<tr><td>Ethanol + ethanoic acid + conc. $H_2SO_4$</td><td>No reaction</td><td>E.E absent</td></tr>
<tr><td>Ethanol + ethanoic acid + conc. $H_2SO_4$ + heat</td><td>Colourless liquid with sweet smell</td><td>E. E is present</td></tr>
<tr><td>Smell an unknown liquid Y</td><td>Sweet fruity smell</td><td>Same</td></tr>
<tr><td>Unknown liquid Y + red litmus paper</td><td>Has no effect</td><td>Same</td></tr>
<tr><td>Unknown liquid Y + blue litmus paper</td><td>Turns blue to red</td><td>Same</td></tr>
<tr><td>Unknown liquid Y + water</td><td>Soluble in water</td><td>Same</td></tr>
<tr><td>Unknown liquid Y + $K_2Cr_2O_7$</td><td>Orange $K_2Cr_2O_7$ changes to green</td><td>E. E is present</td></tr>
</table></td></tr>
<tr><td>3</td><td>Explain = (E)<br><br>Please explain well</td><td>The liquid is acidic in nature because it was able turn moist blue litmus paper red and has no effect on moist red litmus paper. The oxidation occurs and the orange solution containing dichromate (VI) ionises reduced to a green solution with chromium (III) ions. The liquid is slightly soluble in water because, it is less dense than water.</td></tr>
</table>

## ACTIVITY GUIDE 7: ON ALKANOATES/ESTERS

| STUDENT-TEACHERS' POE ACTIVITY GUIDE FOR ALKANOATES/ESTERS | |
|---|---|
| **Group Number:......................................** | **Date: .......................................** |
| | |

**Instruction:-**Guide student-teachers to carryout these activities for preparation of **an unknown liquid Y** using ethanol, ethanoic acid, conc $H_2SO_4$, etc. as follows:-

1) Measure $3cm^3$ of ethanol into a separate test-tube, (Reagent A).
2) $3cm^3$ of ethanoic acid into another test-tube, (Reagent B).
3) Mix the two solutions in the ratio of 1:1 in a clean and dry boiling-tube.
4) Add a few drops of concentrated $H_2SO_4$ (Reagent C) and reflux for few minutes.
5) Place the boiling tube and its contents in a water bath over a Bunsen burner flame shown in the diagram below.
6) Warm the mixture carefully in the water-bath for at least for 15 minutes.




**Set-up for preparation of an unknown liquid Y**

7) Record what you observe in the boiling tube.

   **NB:-** Expected observation: "an unknown **liquid Y** was formed"
8) Divide the unknown liquid "**Y**" into three portions into separate test-tube.
9) In each test-tube containing portions of unknown liquid **Y**, i) determine the odour; ii) add few drops of $Na_2CO_3$; and iii) test with litmus paper .
10) In a tabular form in each case, record your observation and inference.

**APPENDIX K8**
**UNIVERSITY OF EDUCATION, WINNEBA**
**UNIT 8: LESSON PLAN BASED ON PREDICT-OBSERVE-EXPLAIN INSTRUCTIONAL APPROACH ON AMINES**

**College:** As Applicable
**Subject:** Chemistry (Option:- Organic Chemistry)
**Topic:** Amines
**Level:** 200

**Number in Class:** 40
**Average Age:- 23 years**
**Sex:** Mixed
**Duration:** 2 hours (120 minutes)

**Concept Focus:-**Laboratory preparation of a named amine and perform certain specific tests.

**Scientific Processes:-** Making predictions, observations, classifications, explanations and drawing conclusions.

**Group(s)**:- Learners work in groups (3-4 members per team). Facilitator provides all necessary resources.

**Assessment Methods**:-Classroom dialogue; Tutor observations; Worksheet exercises; Presentations; Post-activity assignment.

**Course Learning Outcome & Indicators:-** By the end of the lesson, learners should be able to;

1) Describe amines in terms of their nature, formula and functional group.
2) Identify the sources of amines.
3) Discuss IUPAC rules and write correct IUPAC names of amines using the rules.
4) Describe the isomerism in amines.
5) Mention the physical properties of amines.
6) State the chemical properties of amines.
7) Mention the uses of amines.
8) Carryout laboratory preparation of a named amines (ethylamine).

**Instructional Resources:-** Propanamide; bromine; dilute (10%) solution of KOH solution; conc. (50%) solution of KOH; Bunsen burner; wire mesh; delivery tube, water-bath; retort stand and clamp, POE activity guide and POE worksheet.

**Lesson Presentation:-**

**RPK:-** Learners have learnt aspect of amines at the SHS level and in General Chemistry I at COE level.

| Steps | Lesson Development | Time (mins) | Facilitator's (Tutor's) Activities | Learners' Activities | Core-Point(s) |
|---|---|---|---|---|---|
| Step 1 | **Introduction**<br>-Reviewing Previous Knowledge of the learners | **5** | 1. Arouse the learners' interests, encourage and motivate them to learn. Make it known to them the teaching technique to be used and its demand on them.<br>2. Using question and answer method, review learners' R.P.K on amines: E.g. What is the functional group of amine?. Let them know that today's lesson is about amines. Discuss with them the objectives of the lesson. | Leaners listen attentively to the facilitator or the tutor. They are encouraged to talk, ask questions, write notes and also write down their ideas.<br>Learners listen to the tutor and jot down some points as the facilitator or tutor speaks; and ask various questions for clarification when necessary. | **Expected Answers:-** Amines are formed by replacing one, two, or all three hydrogen atoms in an ammonia molecule with alkyl and/or aryl groups. |
| Step 2 | Grouping, Elicitation & Discussion of Learners' thinking/ideas<br><br>Group of learners | **35** | 1). Divide learners into groups (of 3-4) based on ability and inclusivity; ask them to assume the roles of team leader, recorder, time-keeper, etc. Let them be aware that the roles are rotational.<br>2). Ask learners to describe amines in terms of their nature, formula and functional group. Move round various groups to supervise their activities.<br>3). In the form of whole class discussion, assist them to describe systematic steps involved in naming amines using the | Learners' move into their respective groups and assume their new and different roles as agreed on by the members in the group.<br>Learners brainstorm and write their results or findings on the assigned work in their groups.<br>Learners pay attention and listen attentively; ask questions to clarify their difficulties in IUPAC rules; | **Expected Answers:-**<br>**a). Nature of Amines**<br>Amines are nitrogen-based organic compounds that are derived from ammonia ($NH_3$). They have $-NH_2$ as their functional group. Naturally, amines occur in proteins, vitamins, hormones, etc.<br>**Names of Some Amines**<br>1) $CH_3NH_2$ – Methylamine<br>2) $CH_3CH_2NH_2$ – Ethylamine<br>3) $CH_3CH_2CH_2NH_2$ - Propylamine |

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| | | | IUPAC rules. Give some structures of amines for them to use the rules to name.<br><br>4). In their respective groups, (with the help of their phones); ask learners to search and provide their findings on the following aspects:-<br><br>a). Sources of amines<br><br>b). Isomerism in amines<br><br>c) Physical properties of amines<br><br>d) Chemical properties of amines<br><br>e) Test for amines<br><br>f) Uses of amines | and use the rules to name the given amine structures.<br><br>Learners in their groups use their phones to search, discuss and write their findings and present them chronologically as assigned to them in relation to sources of amines; isomerism in amines; physical and chemical properties of amines; chemical tests and the uses of amines. | **a). Sources of Amines**<br>Amines are obtain from plants and some animals. They are major parts of proteins; alkaloids, etc.<br>**b). Isomerism in Amines**<br>They have chain, positional, functional & metamerism isomerism.<br>**c). Physical properties**<br>❖ The lower aliphatic amines are gaseous in nature.<br>❖ Lower molecular-weight amines smell like ammonia whiles higher amines have a rotting fishy smell.<br>❖ Primary amines with 3 or 4 carbon atoms are liquids & higher ones are solids at 25°C<br>**d). Chemical properties**<br>Chemically, amines are basic in nature so they reacts with:-<br>❖ Acids to form salts and water.<br>❖ Amine salts react with NaOH to regenerate the parent amine. etc.<br>**e). Test for Amines**<br>Amines can be tested in the laboratory using the following |

| | | | | | |
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| | | | 5). In their respective groups, ask learners to write their findings on cardboards/flip charts and make presentations to class.<br><br>6). Assist in the plenary discussions on the learners' presentations.<br><br>7). Through a whole or an intact class discussion, refine learners' responses and ask them to write the correct responses in a logical manner on the maker board as shown in the core-point column. | Learners write their findings on cardboards/flip charts and make their presentations to the class.<br><br>Learners listen attentively to each group's presentation; ask questions when and where necessary.<br><br>Learners in their groups take active part in the discussion process; seek clarifications when necessary to refine their ideas on various areas of amines taught. | reagents: litmus paper; acids like dilute $HNO_3$, HCl, etc. E.g.<br>**Test**:- Add a drop or 2 of amine to red litmus paper.<br><br>**Observation**:- It turns moist red paper to blue.<br><br>**f). Uses of Amines**<br>It is used to manufacture of drugs like morphine and demerol; azo dyes; in gas treatment; in the synthesis of many products; also as corrosion inhibitors; etc |
| Step 3 | Introducing the Experiment | **5** | Introduce the experiment to the learners and discuss its aim/purpose, steps involved and expected outcome. E.g.:-<br>This experiment involves preparation of a named amine using propanamide; bromine; KOH; etc. and perform certain tests on the prepared amine.<br><br>Give the POE worksheet 8 on amines to learners to read for the next step (step 4). | Learners listen attentively to the facilitator and write down some important points as the tutor speaks. They also ask questions to clarify their thought when necessary.<br><br>Leaners take the POE worksheet 8 on amines and read for the next step | |

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| Step 4 | **Predict (P)**<br>Learners make predictions on the activity or experiment they are about to do based on their existing knowledge / experience.<br><br>Predicting | **15** | In this step, ask learners to predict answers to structured questions based on the experiment that they are about to do in their POE worksheets. Let them answer the questions on the worksheet in groups:<br><br>E.g.<br>1) What do you think is likely to happen if you mix 40 grams of propanamide; 36ml bromine; 10% KOH solution and 50ml 50% KOH solution into a round bottom? etc.<br><br>Tutor moves round to supervise them to ensure each member participate in the activities for the day. | Each member in the group is expected to write out his/her prediction in their jotters. The group compare the individual answers and brainstorm collectively to come out with group ideas on all predicted questions raised.<br><br>The group's predictions are to be written on POE worksheets supplied to them by the recorder or any member they agreed on to do the writing.<br><br>Facilitator moves and interacts with the groups as they make their predictions. | |
| | **Reason(s):** | | Ask each group to give reason(s) for their predictions. Tutor moves round to supervise the activities. | Each group write reason(s) for their predictions on the POE worksheet and for discussion. | |

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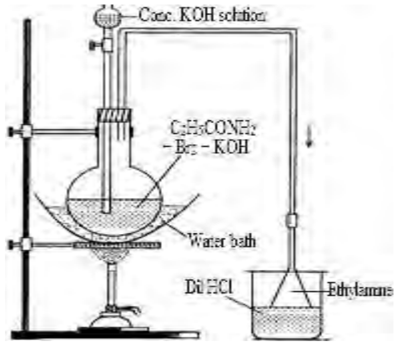
| Step 5 | **<u>Observe (O)</u>**<br>-Perform experiment.<br><br>Perform expt | **40** | Give activity guide 8 on amines for them to read through well.<br>Discuss with them the steps involved in this experiment and ask learners to perform the experiment to prepare an unknown liquid Z by following the steps in the activity guide 8.<br>E.g.<br>1). Measure 40 grams of propanamide into round bottom distillation flask. etc.<br>Facilitator and the laboratory technician move round to assist them when needed.<br>Move round to supervise them to ensure each member takes part in the activities. | Leaners in their group carry out the experiment in the activity guide 8; as guided by tutor and lab. technician. They follow the instructions step by step and carry out the expt.<br>Each member in the group record his/her observations and inference in their jotters. They also write the chemical equation representing the preparation of the liquid Z.<br>The group compare individual's observation, dialogue collectively and write the group's ideas as agreed on the POE worksheet | <br><br>Set-up for preparation of liquid Z (ethylamine) |
| Step 6 | **<u>Explain (E)</u>**<br><u>E</u>xplaining the observations; & compare the observations with their predictions.<br><br>Explaining | **15** | Ask learners in their groups to compare individual explanations and collectively brainstorm to come out with the group's explanations to their observations.<br>Ask learners to correlate their prediction(s) with observation(s) in order to reconstruct their thinking/ideas; and reconcile any conflict between their predictions and observations. | In their respective groups, let them compare their individual explanations and collectively brainstorm to come out with the group's explanations to their observations.<br>Learners are to compare their predictions and observations so as to reconcile any conflict between their predictions and observations in the whole class discussions. | |

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| | | | Ask learners to disengage from their groupings. Tell them to read on all topics as revision for the next test. | Learners move to their seats. They do the given assignment; and also do revision for all the topics learnt. | |
| **Total** | | **115** | | | |

**Summary: (5 minutes)**
Facilitator (Tutor) summarises the lesson:- Amines are nitrogen-based organic compounds that are considered as derivatives of ammonia. These compounds are formed by replacing one, two, or all three hydrogen atoms in an ammonia molecule with alkyl and/or aryl groups. Amines are derivatives of ammonia that contain a basic nitrogen atom with a lone pair of electrons. In amines, the nitrogen orbitals are sp3 hybridised with a pyramidal geometry. Each of the three $sp^3$ hybridised orbitals of nitrogen overlap with carbon or hydrogen orbitals as per the amines' composition. In all amines, an unshared pair of electrons are found in the fourth orbital of nitrogen. The C–N–E (where E is C or H) bond angle is reduced from 109.5° to 108° due to this unshared electron pair. Amines are classed as primary (1°); secondary (2°), tertiary (3°) or quaternary amines (4° amines) based on the number of hydrogen atoms replaced by alkyl or aryl groups in ammonia molecules. If one hydrogen atom of ammonia is replaced by R or Ar, we get a primary amine (1°)-$RNH_2$ or $ArNH_2$. The different spatial arrangement of atoms in amines results in the chain, positional, functional, and metamerism isomerism. There are several methods used in preparation of amines and they include reduction of nitroethane; reduction of methyl cyanide; reduction of acetamide; reduction of aldoxime; hydrolysis of ethyl isocyanate; acid hydrolysis of ethyl isocyanide and many others. Amines are basic in nature, so they turn red litmus paper blue. They are used to manufacture of drugs like morphine and demerol; azo dyes; in drugs mainly to interfere with the action of natural amine neurotransmitters; in gas treatment mainly in the removal of carbon dioxide from natural gas; as corrosion inhibitors; in the synthesis of many products, etc.

**Individual Assignment:**

Tutor/facilitator gives learners take home assignment due for submission the next day. Lets learners do revision on **<u>all topics</u>**.

1). Give the IUPAC names of the following compounds.

| | | | |
|---|---|---|---|
| $CH_3CH_2CH_2NH_2$ | $CH_3CH\ (Cl)CH(NH_2)CH_3$ | $CH_3NHCH_3$ | $(CH_3)_3N$ |
| **(a)** | **(b)** | **(c)** | **(d)** |

2). Give the general formula for amine and the functional group as well.

3). With the aid of a diagram, describe how ethylamine is prepared in the laboratory.

4). Mention five physical and chemical properties of amines.

**Expected answers to the assignment questions:** For answers refer to the pore-core point column and other sources.

**WORKSHEET 8: ON AMINES**

<table>
<tr><td></td><td colspan="2">SCIENCE STUDENT-TEACHERS' POE WORKSHEET FOR AMINES</td></tr>
<tr><td>Steps</td><td>Steps in POE</td><td>Group Number:…………………  Date: …………………</td></tr>
<tr><td rowspan="2">1</td><td><u>P</u>redict = (P)<br>What do you think will happen?<br><br>What is in your mind?<br><br>Please speak out</td><td>1). What do you think is likely to happen if you mix 40 grams of propanamide; 36ml bromine; 10% KOH solution and 50ml 50% KOH solution into a round bottom……………………………………<br>2). If the mixture in (1) is then heated on water-bath over a burner, it will react to produce an unknown liquid Z, what do you think has happened to the propanamide?...................................................<br>3). Unknown liquid Z is likely to be what?.........................................<br>4). What do you think would be equation for the reaction?...............<br>……………………………………………………………………<br>5). What do you think will happen if:-<br>i) you smell unknown acid; what is likely will be the odour?:……..<br>………………………………………………………………………<br>ii) the liquid Z is tested with blue litmus paper?:……………………<br>iii) the liquid Z is tested with red litmus paper?:…………………...<br>iv) dilute HCl is added to unknown liquid Z:……..............................</td></tr>
<tr><td>Give reason(s) for your predictions<br></td><td>………………………………………………………………………<br>………………………………………………………………………</td></tr>
<tr><td>2</td><td><u>O</u>bserve = (O)<br><br>Please observe well</td><td>
<table>
<tr><th>Test</th><th>Observation</th><th>Inference</th></tr>
<tr><td>Propanamide + $Br_2$ + dil. KOH + Conc. KOH</td><td></td><td></td></tr>
<tr><td>Propanamide + $Br_2$ + dil. KOH + Conc. KOH + Heat</td><td></td><td></td></tr>
<tr><td>Smell of an unknown liquid Z</td><td></td><td></td></tr>
<tr><td>Liquid Z + blue litmus paper</td><td></td><td></td></tr>
<tr><td>Liquid Z + red litmus paper</td><td></td><td></td></tr>
<tr><td>liquid Z + dilute HCl</td><td></td><td></td></tr>
</table></td></tr>
<tr><td>3</td><td><u>E</u>xplain = (E)<br><br>Please explain well</td><td>………………………………………………………………………<br>………………………………………………………………………<br>………………………………………………………………………</td></tr>
</table>

## EXPECTED RESPONSES FROM WORKSHEET 8: ON AMINES

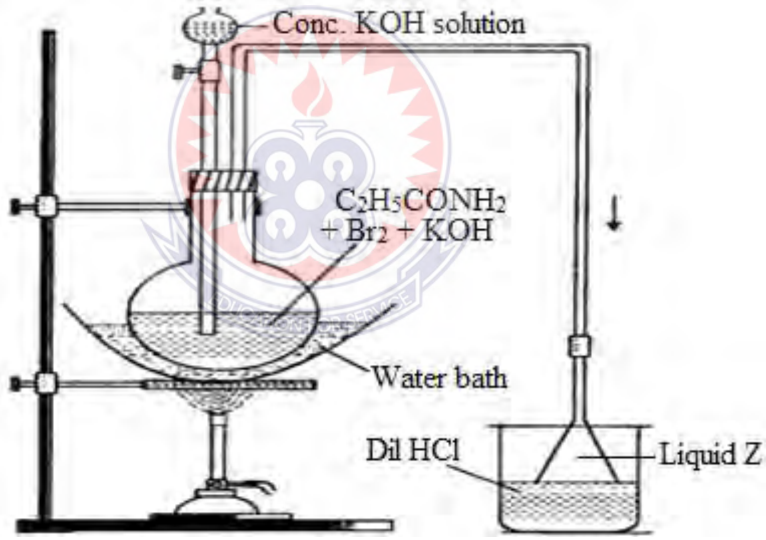
<table>
<tr><th colspan="3">SCIENCE STUDENT-TEACHERS' POE WORKSHEET FOR AMINES</th></tr>
<tr><th>Steps</th><th>Steps in POE</th><th>Group Number:………………… Date: …………………</th></tr>
<tr><td rowspan="2">1</td><td>Predict = (P)<br>What do you think will happen?<br><br>What is in your mind?<br>Please speak out</td><td>1). What do you think is likely to happen if you mix 40 grams of propanamide; 36ml bromine; 10% KOH solution and 50ml 50% KOH solution into a flask? There will be no reaction until heated<br>2) If the mixture in (1) is then heated on water-bath over a burner, it will react to produce an unknown liquid Z, what do you think has happened to the propanamide?:- The propanamide has been oxidised completely<br>3). Unknown liquid Z is likely to be what? The unknown liquid Z is Ethyl amine (Ethanamine)<br>4). What do you think would be equation for the reaction?<br>$C_2H_5CONH_2 + Br_2 + 4KOH \rightarrow C_2H_5NH_2 + 2KBr + K_2CO_3 + 2H_2O$<br>5). What do you think will happen if:-<br>i) you smell unknown acid. Uknown liquid smells like ammonia<br>ii) the liquid Z is tested with blue litmus paper? Has no effect<br>iii) the liquid Z is tested with red litmus paper?: It turns moist red litmus to paper blue.<br>iv) dilute HCl is added to uknown liquid Z:- The liquid Z is basic in nature, so it dissolve in HCl. Thus, liquid Z is soluble in dil. HCl</td></tr>
<tr><td>Give reason(s)<br><br></td><td>1). This reaction needs heat for the propanamide, bromine and KOH to react to release the ethyl amine (ethanamine) liquid.<br>2). The KOH was to remove brown colour of bromine in the process<br>3). Due to the interaction between propanamide and bromine.</td></tr>
<tr><td>2</td><td>Observe = (O)<br><br>Please observe well</td><td>
<table>
<tr><th>Test</th><th>Observation</th><th>Inference</th></tr>
<tr><td>Propanamide + $Br_2$ + dil. KOH + Conc. KOH</td><td>No observation reaction</td><td>Amine absent</td></tr>
<tr><td>Propanamide + $Br_2$ + dil. KOH + Conc. KOH + Heat</td><td>Formation of colourless liquid</td><td>Amine present</td></tr>
<tr><td>Smell of an unknown liquid Z</td><td>Pungent smell ($NH_3$)</td><td>Amine P</td></tr>
<tr><td>Liquid Z + blue litmus paper</td><td>No effects on blue litmus</td><td>Amine P</td></tr>
<tr><td>Liquid Z + red litmus paper</td><td>Turns red litmus to blue</td><td>Amine</td></tr>
<tr><td>liquid Z + dilute HCl</td><td>Dissolves in dil. HCl</td><td>Amine</td></tr>
</table>
</td></tr>
<tr><td>3</td><td>Explain = (E)<br><br>Please explain well</td><td>Ethyl amine is made from Hoffmann bromide reaction in the laboratory. Ethyl amine is obtained by heating propanamide with a mixture of bromine and caustic potash. Ethyl amine is a colourless liquid; smells like ammonia; soluble in water; and its aqueous solution is alkaline. Thus, as alkaline (base), it has effects on litmus moist red paper and also reacts with mineral acids.</td></tr>
</table>

**ACTIVITY GUIDE 8: ON AMINES**

| SCIENCE STUDENT-TEACHERS' POE ACTIVITY GUIDE FOR AMINES | |
|---|---|
| **Group Number:………………………………….** | **Date: ………………………………….** |

**Instruction:-**Guide student-teachers to carryout these activities for preparation of **an unknown liquid Z** using propanamide, bromine, etc. as follows:-

1. Measure 40 grams of propanamide into a round bottom distillation flask.
2. Add 36ml of bromine into the flask and keep the flask in ice cold water.
3. Add a drop of 10% KOH solution into the mixture in the flask.
4. Now keep the flask on water-bath and slowly pour about 50ml 50% KOH solution from the point funnel.
5. Remove the flask from water-bath and heat the mixture on wire mesh over a flame.
6. When the solution becomes colourless, unknown liquid Z starts to be distilled which is absorbed in dilute HCl in the receiver.
7. Add two drops of 50ml 50% KOH solution caustic potash to the solution in the receiver to obtain pure liquid Z (an amine).




**Set-up for preparation of unknown liquid Z**

8. Record your observation that occur in boiling tube.

   **NB:-** Expected observation: "an unknown liquid Z was formed"
9. Divide the unknown liquid "Z" into four portions into separate test-tube.
10. In each test-tube containing portions of liquid Z, test with:- i) odour; ii) blue litmus paper; iii) red litmus paper; & iv) dilute HCl respectively.
11. In a tabular form in each case, record your observation and inference.