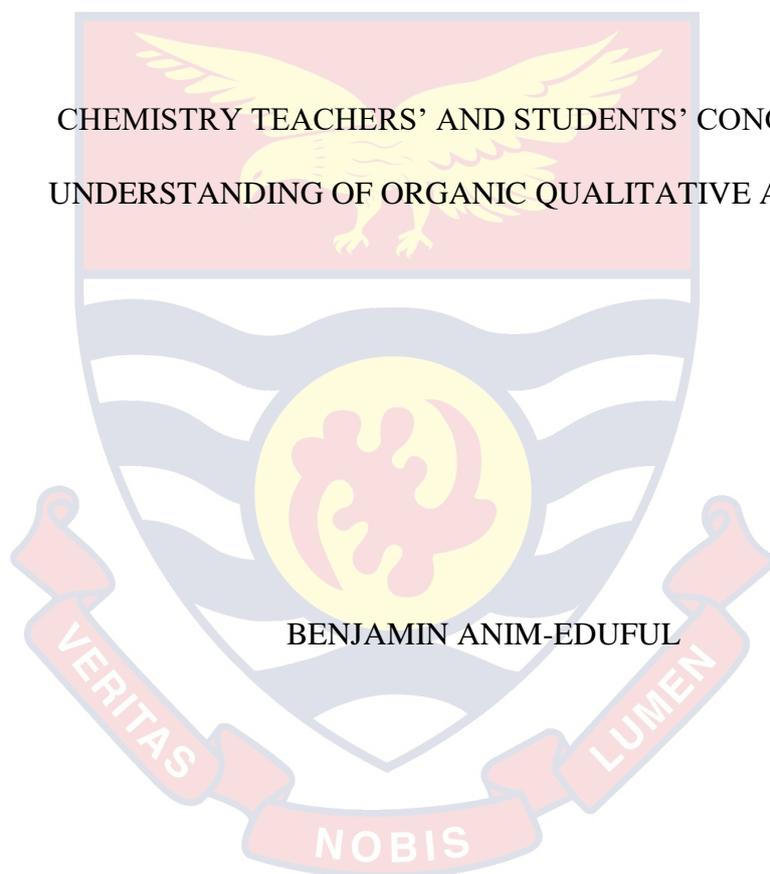


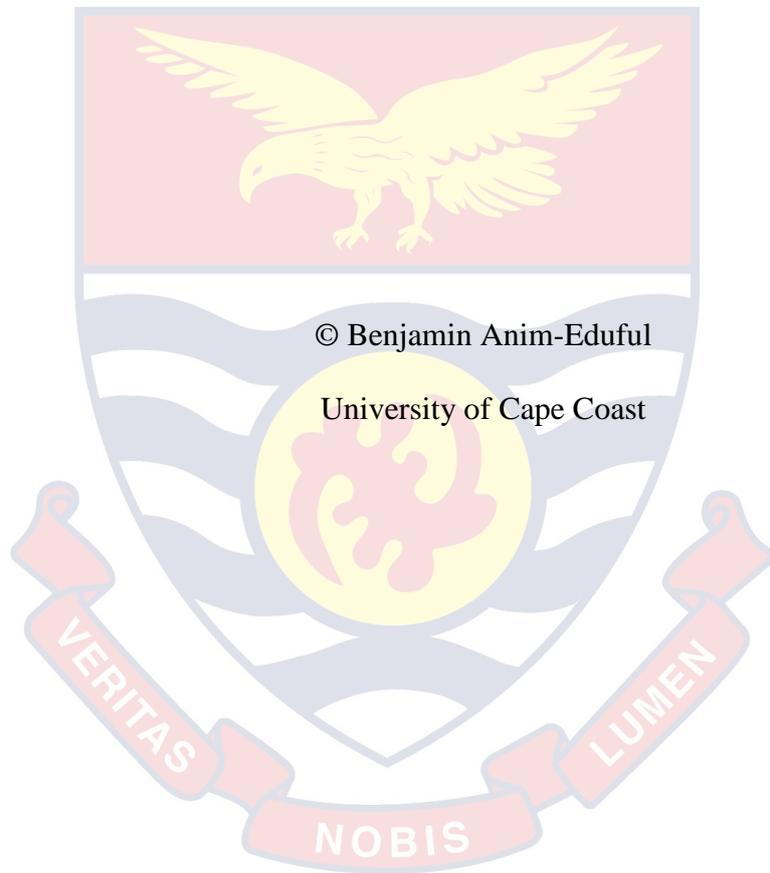
UNIVERSITY OF CAPE COAST

CHEMISTRY TEACHERS' AND STUDENTS' CONCEPTUAL
UNDERSTANDING OF ORGANIC QUALITATIVE ANALYSIS



BENJAMIN ANIM-EDUFUL

2020

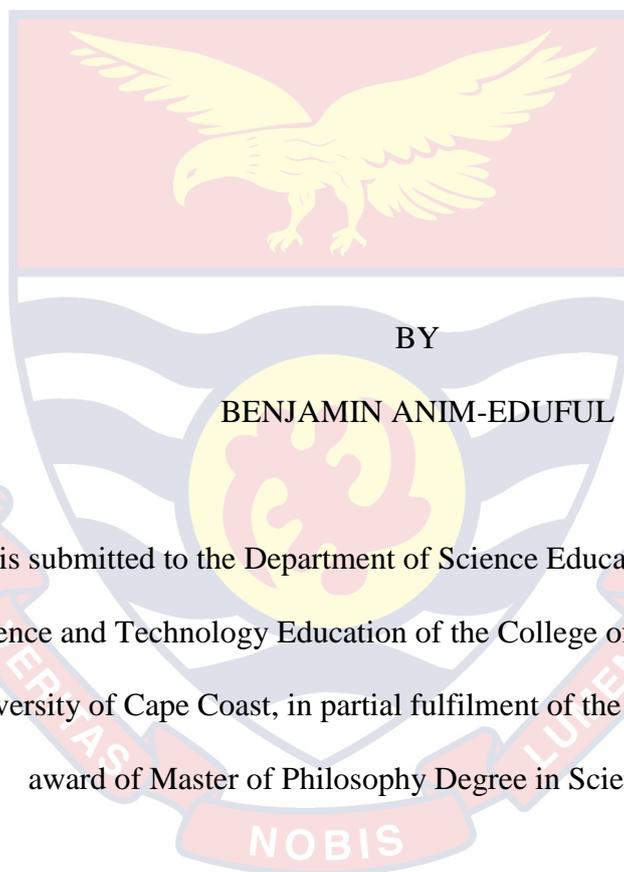


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CHEMISTRY TEACHERS' AND STUDENTS' CONCEPTUAL
UNDERSTANDING OF ORGANIC QUALITATIVE ANALYSIS



BY

BENJAMIN ANIM-EDUFUL

Thesis submitted to the Department of Science Education of the Faculty of
Science and Technology Education of the College of Education Studies,
University of Cape Coast, in partial fulfilment of the requirements for the
award of Master of Philosophy Degree in Science Education

DECEMBER 2020

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature: Date:

Name: Benjamin Anim-Eduful

Supervisor's Declaration

I hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Supervisor's Signature: Date:

Name: Dr. Kenneth Adu-Gyamfi

ABSTRACT

Organic qualitative analysis is one of the challenging chemical concept in the teaching and learning of chemistry. The West African Examinations Council (WAEC) Chemistry Chief Examiners for years, have lamented on students' poor performance in organic qualitative analysis at the senior high school level. This study, therefore, investigated chemistry teachers' and students' conceptual understanding of organic qualitative analysis. A sequential explanatory mixed methods design was used to collect both quantitative and qualitative data from 263 SHS 3 students and 47 teachers from six public schools in Central Region. The teachers and students were selected through multistage sampling technique. Diagnostic test, interviews, and observation checklist were used to collect data from the participants. Data was analysed using percentages, means, standard deviations, independent-samples t-test, and themes. The results from the study showed that teachers demonstrated partial level of conceptual understanding and their students demonstrated no scientific understanding on organic qualitative analysis. It is, therefore, recommended that the Ministry of Education through the Ghana Education Service should liaise with teacher education universities to organise short courses for teachers to help them upgrade their content knowledge in chemistry.

KEY WORDS

Alternative conception

Factual difficulties

Organic qualitative analysis

Students

Teachers

Teaching and learning



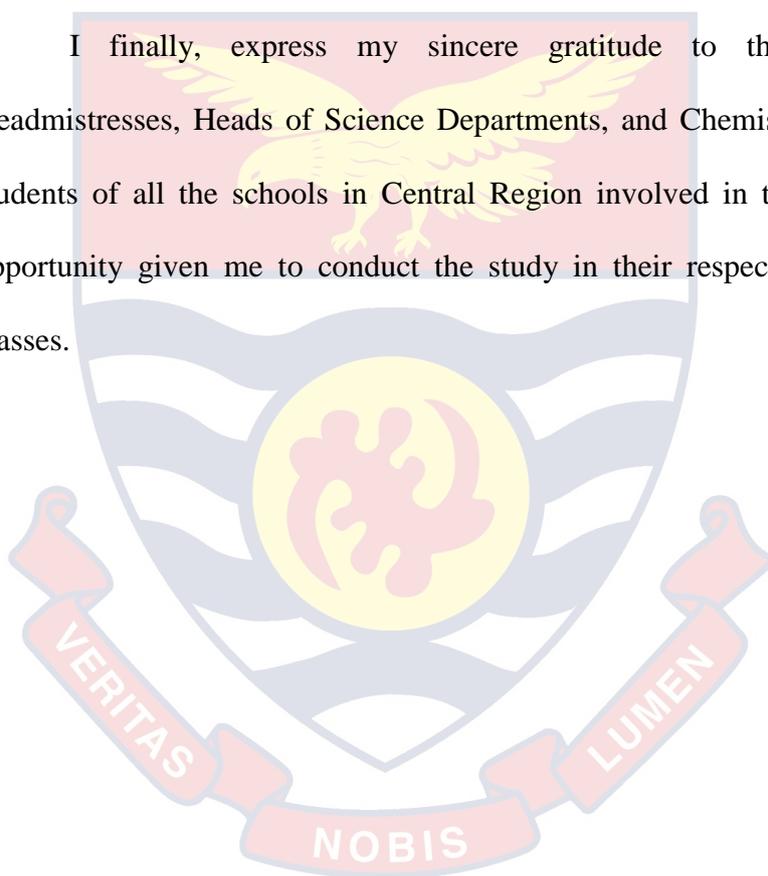
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I finally, express my sincere gratitude to the Headmasters, Headmistresses, Heads of Science Departments, and Chemistry teachers and students of all the schools in Central Region involved in the study for the opportunity given me to conduct the study in their respective schools and classes.



DEDICATION

To my wife, Joyce Anim-Eduful and children, Nhyira, Adeebi, Yeboah and
Anima Anim-Eduful.

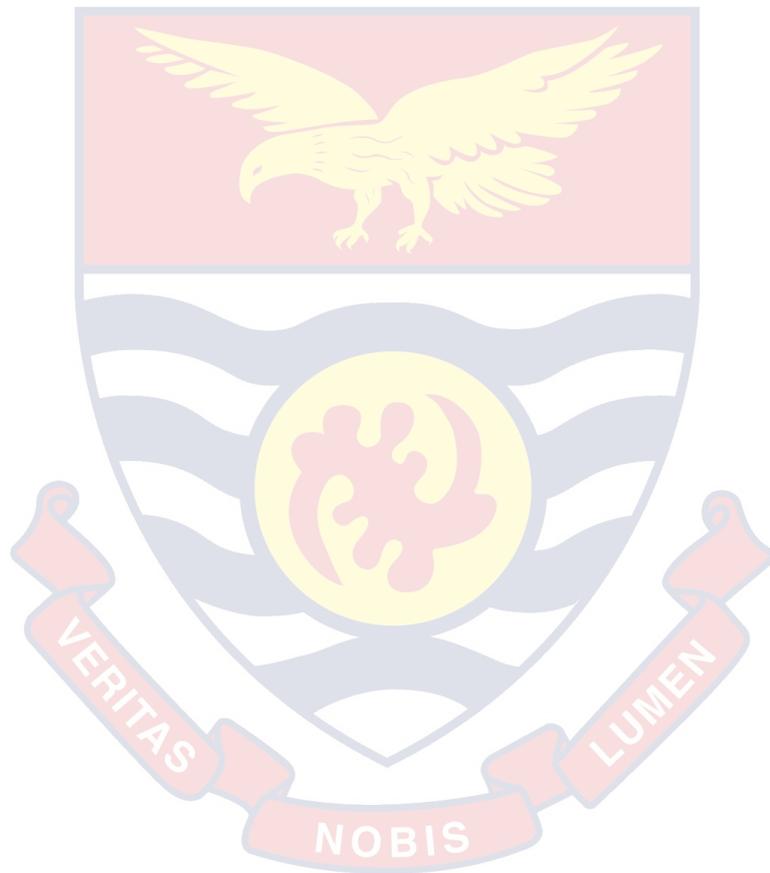


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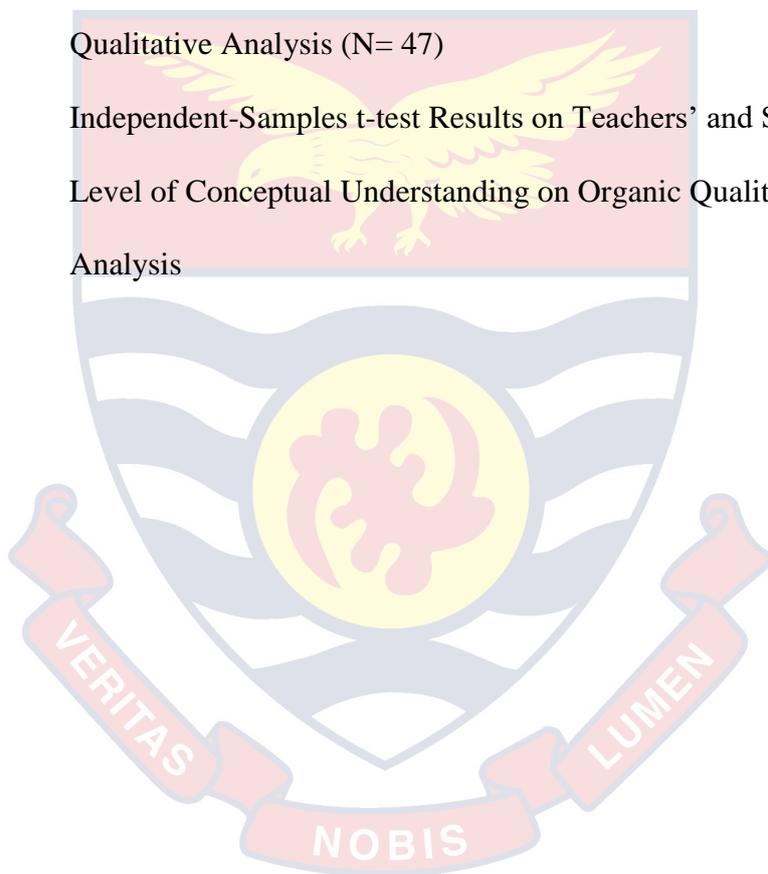
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CHAPTER ONE

INTRODUCTION

In Ghana qualitative analysis is a major component of Senior High School chemistry practical works as stated in the chemistry syllabus. Unfortunately, students encounter difficulties when answering questions on qualitative analysis according to Chemistry Chief Examiner of the West African Examinations Council.

This study tends to determine chemistry teachers' and students' conceptual understanding of organic qualitative analysis.

Background to the Study

Chemistry is a scientific discipline that requires learners with the ability to deal with its concepts at the macroscopic and microscopic level, and be able to link the symbolic representations used at each level. Students usually experience learning difficulties if this symbolic language is not well comprehended, and this results into misunderstanding between the material world and theoretical constructs (Kozma, Chin, Russell, & Marx, 2000; Marais & Jordaan, 2000).

Analysis of chemical compounds is one of the areas under chemistry. Analysis of chemical compounds are classified into two categories; that is quantitative analysis and qualitative analysis. Quantitative analysis finds the volumes or amounts of each element or group present in a given solution while qualitative analysis finds the type of each element or group present in a given sample of solution (Matthews, 2011). Qualitative analysis deals with the detections and identification of elements or group of elements present in a given solution. Qualitative analysis is also classified into two categories:

inorganic qualitative and organic qualitative analysis. Inorganic qualitative analysis is used to detect the presence of inorganic ions (anions, and cations) and gases or compounds in an unknown sample whereas organic qualitative analysis is used to establish the presence or absence of a particular functional groups in a sample as specified in the Ministry of Education [MOE] (2010) syllabus.

According to Cooley and Williams (1999), qualitative analysis is of relevance and importance to learning of chemistry as it improves students' chemistry concepts understanding. Qualitative analysis increases the conceptual understanding of chemical principles as well as the interactions of matter and its application in our daily lives. Qualitative analysis concepts are difficult to students to learn as its' understanding requires process skills as well as understanding of many chemistry concepts (Goh, Toh, & Chia, 1987; Tsoi, 1994). Ferguson and Bodner (2008) pointed out that, there is a weak connection between students' previous knowledge, that is content learned and what really happens during qualitative organic practical activities. Students are unable to transfer contents learned from the theory to practical activities.

Chemistry concepts are difficult for many students, as its very fundamental concepts are insufficiently grasped by students (Coll & Treagust, 2001; Nicoll, 2001). Organic chemistry is an important part of senior high chemistry as its concepts are applied in our everyday lives. From the food we consume, dyes applied in our hair colour, medication used to treat sickness, our everyday lives are rooted in core organic chemical processes (Rice, 2016). Organic chemistry is an indispensable part of daily life (Yong, 1994). These

applications of organic chemistry in our daily lives and the need for scientific progress necessitate constant attention to education in the field.

Tan (2000) conducted a study with grade 10 students between the ages of 15 to 17 years old in Singapore and found out that, students found organic qualitative analysis difficult to learn and understand. The findings of Tan showed that, students' difficulties in organic qualitative analysis were as a result of them not knowing exactly what is required of them during the practical activities. This is attributed to insufficient learning process skills needed by students, and lack of motivation to comprehend the relationship between chemistry theory contents and the practical activities. The usual traditional approach of teaching qualitative organic analysis has not helped students to gain the necessary process skills neither has it helped them to have an in-depth understanding of chemistry contents applied in organic qualitative analysis (Tan, 2000).

Functional group detection categorization has been found to be common feature used by both higher and lower ability students for classifying organic compounds (Domin, Al-Masum, & Mensah, 2008; Hassan, Hill, & Reid, 2004). The categorization of organic compounds using functional group has been known to be difficulty for students. A study by Strickland, Kraft, and Bhattacharyya (2010) pointed out that, many organic chemistry students were unable to explain vividly functional group. To the students, all organic compounds appear to be very similar, as a molecule composed of carbon, hydrogen, and oxygen. Functional groups in organic chemistry at the senior high school level are: hydrocarbons (alkanes, alkenes, alkynes and aromatic

(benzene), alcohols ($-OH$); aldehydes ($-CHO$); ketones ($-C = O$); carboxylic acids ($-COOH$); esters ($-COO -$); and amides ($-CONH_2$) (MOE, 2010).

The presence of oxygen, hydrogen and carbon in most of these functional groups makes it difficult for students to differentiate between them, especially the carbonyl group ($-C = O$) comprising of aldehydes and ketones. Difficulties arise when students classify these organic compounds regarding their understanding of physical properties, reactions and mechanisms of organic (Hassan et al., 2004).

Stieff (2007) pointed out that, organic chemistry is found to be problematic and this eventually results in students developing wide range of alternative conceptions. Students resort to memorizing of formulae that is not a good method in any type of learning. Hence, for good understanding in organic analysis or reactions, the student has to understand the mechanisms from one chemical reaction to another until a stable product is formed. These cognitive steps or mechanisms are among the many difficulties chemistry students are facing. Examples are lacking the skills to analyse the various steps and translating the reactions into the forms that can be used to predict the final product in reasonable and justifiable ways (Tang, Zain, & Abdullah, 2010).

According to O'Dwyer and Childs (2017), research studies comparing teachers' and learners' perspectives of organic chemistry are rare. Literature has identified areas of difficulty in teaching and learning of organic qualitative analysis and the reasons why organic chemistry concepts are difficult to teach and learn. In view of all these studies, it can be understood that organic chemistry can be learned through acquisition of conceptual

understanding. In this study, conceptual understanding is not merely about definition of chemistry concepts but also about understanding the relationship between these concepts and the means through which students construct these concepts. Conceptual understanding occurs when new knowledge is connected with existing knowledge using alternative ways of thinking in a logical way.

Researchers have indicated that students have difficulties in understanding organic chemistry (Childs & Sheehan, 2009; Graulich, 2015; Wasacz, 2010). Students indicated that organic chemistry is an abstract, onerous task and a memorisation-oriented subject with many concepts to be learnt (Bhattacharyya & Bodner, 2005). On the other hand, some studies have indicated that students fail to learn organic chemistry due to their lack of conceptual understanding, as compared to other chemistry areas (Duffy, 2006). Bhattacharyya and Bodner (2005) stated that even with high performance of solving organic chemistry problems, graduate students have very low levels of conceptual understanding, mainly due to their memorisation-oriented approach in learning organic chemistry.

O'Dwyer (2012) revealed that many students cannot see and appreciate the link between what they learn in the classroom or the investigations carried out in the laboratories with their everyday lives and the world that they live in, meanwhile, there are many examples of organic compounds in every aspect of the students' lives, such as foods, clothes, materials, and pharmaceuticals. O'Dwyer stated that, teachers often struggle to or do not make students aware of these due to their complexities. This is, perhaps, a contributing factor for the multitude of studies, which identify students' and

teachers' perception of organic chemistry as one of the most difficult areas of chemistry (Childs & Sheehan, 2009).

Chemistry concepts are related to the structure of matter, which is difficult to many students because chemistry curricula commonly incorporate many abstract concepts, which are central to further learning in both chemistry and other sciences (Taber, 2002). These abstract concepts are relevant because further chemistry concepts or theories cannot be understood without these concepts insufficiently grasped by students (Coll & Treagust, 2001; Nicoll, 2001). This abstract nature of chemistry along with other content learning difficulties means that chemistry contents require a high-level skill set (Taber, 2002).

Schwartz (1993) stated that, an important aspect of acquiring new knowledge is to comprehend the relationships between various related concepts. Likewise, Deci, Vallerand, Pelletier, and Ryan (1991) reported that, learning is a combination of conceptual understanding and flexible use of knowledge. In this sense, modern teaching approaches indicate that permanent learning of chemistry concepts depends on conceptual understanding of the teacher and the learner (Simsek, 2009). This implies that when concepts are used accurately and conveniently to establish relationships between these concepts are properly learned, then effective acquisition of knowledge is achieved. The problems that emerge when a relationship is not established between the concepts cause not only a failure in learning, but also lead to alternative conceptions (Nakhleh, 1992).

Conceptual understanding is generally a learning with understanding (Driver, Asoko, Leach, Scott, & Mortimer, 1994). It is often contrasted with

declarative knowledge learning where learner simply memorises a relationship between things, events, or processes (Greenbowe & Schroeder, 2008). To many, conceptual understanding entails just more than rote memorisation of relationships; but requires ability to apply previous learning across some kind of previously unexpected experiences (Smith & Ragan, 1999). Unless prior knowledge is properly associated with new knowledge, learners may fail to correctly grasp new concepts, and this impedes meaningful learning (Bodner, 1986).

An awareness of the fact that alternative conceptions prevent meaningful learning has paved the way for studies that aims at determining students' levels of conceptual understanding in science concepts including those of chemistry (Adu-Gyamfi & Ampiah, 2019; Adu-Gyamfi, Ampiah, & Agyei, 2015; Cahyadi & Butler, 2004). Conceptual understanding has the potential to promote students' learning thus, have become an area of interest for educational research. Gaining insights into students' existing conceptions might help educators design effective teaching approaches targeting conceptual understanding. Determination of teachers and students' conceptual level in organic qualitative analysis might also help educators in selecting the more effective teaching strategy that promotes conceptual understanding (Özkaya, Üce, Saricayir, & Sahin, 2006).

Conceptual understanding is an important goal in learning in general but is particularly relevant in science education because such understanding is required to make sense of scientific phenomena. To understand means being able to construct meaningful knowledge, interpret and explain (Anderson, Krathwohl, & Bloom, 2001). Concept learning focuses on the aspect of

category formation and the use of concepts to interpret experiences and solve problems (Ormrod, 2003). Students taught to develop a conceptual understanding will be more proficient at problem solving, abstract reasoning, applying their knowledge to new situations and more likely to make connections to related information (Ormrod, 1999).

Sadler, Sonnert, Coyle, Cook-Smith, and Miller (2013) found that teachers' conceptual understanding in science concepts to some extent influences students' conceptual understanding of the concept taught. Hence, teachers' content knowledge greatly improves students' understanding of science concepts and also reduce alternative conceptions among students. Studies that rigorously investigate the relationship between teachers' knowledge and their students' gains in understanding of science concepts are rare (Baumert, Kunter, Blum, Brunner, Voss, Jordan, Klusmann, & Tsai, 2010). Teachers' content knowledge potentially affects their choice of instructional practice and their students' achievement gains (Hill, Rowan, & Ball, 2005). It is found that science teachers with strong content knowledge are better able to communicate scientific concepts and ideas and are skillfully able to engage students in the content (Ball, Thames, & Phelps, 2008). Teachers with inadequate content knowledge mostly misrepresent the content to their students, resulting alternative conceptions by students (Ball et al., 2008).

The findings of Adu-Gyamfi, Ampiah, and Appiah (2017) from a study they conducted in the Kumasi Metropolis of the Ashanti Region of Ghana revealed that SHS chemistry students have difficulties in IUPAC naming of organic compounds. Adu-Gyamfi et al. indicated among others that, students

had difficulties in identifying functional group and correct position and number of multiple bonds in an organic molecule.

According to MOE (2010), one of the aims of the chemistry teaching syllabus is to assist students in SHS 2 to identify organic functional groups, their reactions used to confirm their presence in compounds and also be able to use qualitative analysis to distinguish between various functional groups when provided with suitable reagents. The qualitative organic analysis which is basically functional group detection is studied under areas such as aliphatic hydrocarbons made up of saturated (alkanes) and unsaturated (alkenes and alkynes). Aromatic hydrocarbons (benzene), alkanols, carbonyl compounds made up of alkanals (aldehydes) and alkanones (ketones), amides, carbohydrates (reducing sugars and non-reducing sugars) and proteins (MOE, 2010). The specific objectives outlined in the Chemistry teaching syllabus are:

- a. perform and discuss simple tests with benzene and alkene using the following reagents: cold dilute $KMnO_4$, Br_2/H_2O or $Br_2/CHCl_3$.
- b. distinguish between saturation (alkanes) and unsaturation (alkene and alkyne) using acidified purple $KMnO_4$, and Br_2/H_2O .
- c. perform, identify and discuss the tests for carbonyl compounds (alkanals and alkanones) using 2, 4-dinitrophenylhydrazine, Fehling's or Benedict's solution and Tollen's reagent (ammoniacal silver nitrate).
- d. classify and determine the products formed by the oxidation reactions of primary, secondary and tertiary alkanols using acidified $K_2Cr_2O_7$, acidified $KMnO_4$, I_2 in $NaOH$ and $KMnO_4$ solutions.

- e. perform a simple experiment to test for the presence of amides ($-CONH_2$) using ethanamide or urea with $NaOH$ to give ammonia (NH_3) gas.
- f. discuss the test for alkanoates (esters), a reaction between alkanol and alkanolic acid in the presence of concentrated tetraoxosulphate(VI) (H_2SO_4) (MOE, 2010, pp. 49-60).

In Ghana, the West African Examinations Council (WAEC) sets test items on qualitative analysis both in practical and theory papers. In the theory papers, students are given organic compounds containing many functional groups and are asked to identify the functional groups present and explain how these functional groups identified can be tested experimentally. In the practical papers, students are given unknown samples and asked to perform tests on them, record observations based on the experiment carried out and draw inferences from the observations.

Reports of Chemistry Chief Examiner for SHS available at WAEC for the years (WAEC, 2012; 2014; 2015; 2016; 2017; 2018) attest to the fact that SHS students have conceptual difficulties in qualitative organic analysis during their practical and theory examination sections.

From the MOE (2010), students' understanding in qualitative analysis will help improve their understanding in chemistry as a whole since they confirm what they have learnt theoretically. It was, therefore, right to investigate chemistry teachers' and students' conceptual understanding on organic qualitative analysis.

Statement of the Problem

In Ghana, the WAEC Chemistry Chief Examiner's reports have repeatedly lamented on the weakness of most students in organic qualitative analysis both in practical or theory examination (WAEC, 2001; 2003; 2004; 2005; 2007; 2012; 2014; 2016; 2017; 2018). In 2001, the Chief Examiner's report indicated that many candidates attempted a question on suitable reagents and condition necessary for ethanol (C_2H_5OH) to be converted to ethene (CH_2CH_2) and ethanoic acid (CH_3COOH) but most students were unable to answer the question correctly.

In 2003, the report revealed that students showed weakness in stating and explaining the observation to be made when 1-butyne ($CH_3CH_2C \equiv CH$) reacts with Tollen's reagent [ammoniacal silver nitrate ($AgNO_3/NH_3$)] and ethanamide (CH_3CONH_2) reacting with diluted sodium hydroxide ($NaOH$). In 2004, students were provided with organic compounds 2-butyne ($CH_3C \equiv CCH_3$), methyl ethanoate (CH_3COOCH_3), propanoic acid (CH_3CH_2COOH), 2-amino propanoic acid ($CH_3(NH_2)COOH$), and ethanamide (CH_3CONH_2) and asked to explain which of them;

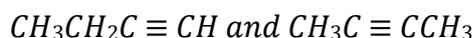
- i. could readily decolorize Br_2/CCl_4
- ii. has two functional groups
- iii. can be prepared from an alkanol and alkanolic acid
- iv. give effervescence with $NaHCO_3$.

From WAEC (2004), the report indicated that students could not perform well. Most of the students had difficulties in identifying the functional groups. In 2005, the report revealed that students showed weakness in distinguishing qualitatively between two organic compounds when provided

with reagents. Most students stated that chemical reaction will occur but, could not explain vividly what would be observed at the end of the reaction. For example, students could not distinguish and state the observation that would be envisaged in CH_3CH_2COOH and $CH_3CH_2CH_2OH$ with Na_2CO_3 and CH_3CH_2OH and $CH_3CH_2CH_2OH$ with $I_2/(aq)$.

In 2012, the report pointed out that students could not state a chemical test for the functional group of butanoic acid [C_3H_7COOH] and 1,1-dimethylethanol [$(CH_3)_3COH$]. Further in 2014, students were asked to give their observation when benzene is added to neutral $KMnO_4$ and bromine water. The report indicated that most students said both reagents will turn colourless instead purple colour of $KMnO_4$ will remain unchanged since benzene do not exhibit unsaturation and same to bromine solution.

In 2016, students were asked to consider $CH_3CONHCH_2CH_2OH$, and draw the structure of the compound, name the functional group(s) present in the compound. Students were further asked to name the functional group(s) present in the compound $(HOOC)_6H_3(CH=CH_2)(CH_2OH)$. Also students were asked to complete the following reactions; $CH_3CH_2CONH_2 + H_2O$ in the presence of dilute H^+ and heat, $CH_3CH_2CH_2CH_2OH + H^+/KMnO_4$ and heat, and name the major products obtained in the reactions. Furthermore, Students were asked to give reagent(s) that could be used to distinguish between each of the following pairs of compounds:



The report pointed out that most of the students who tackled had difficulties giving correct suitable reagents and products. From WAEC (2017), students were asked to state the: functional group and name the compound $H_3CCOOCH_2CH_3$. (b) (i) Name the class of organic compounds that could be identified using each of the following reagents:

- (α) acidified tetraoxomanganate(VII) solution
- (β) ethanoic acid and concentrated tetraoxosulphate(VI) acid;
- (γ) sodium trioxocarbonate(IV) solution

(ii) State what is observed in each of the tests in b (i) above

Chief Examiner's report pointed out that students could not state the functional group of those reagents used to test for, and were unable to give the correct functional group(s) in those organic compounds. Further, in 2018, students were asked to state:

- i. two reasons why soda lime is used instead of caustic soda in the preparation of methane,
- ii. three deductions that could be made from the qualitative and quantitative analysis of a given organic compound.

Chief Examiner's report pointed out that most students had difficulties in answering those questions. These reports suggest that SHS chemistry students have challenges with conceptual understanding of organic qualitative analysis. However, the reports were not clear about the nature of the challenge and whether there was problem with the teaching and learning of qualitative organic analysis. It is important therefore to investigate chemistry teachers' and students' conceptual understanding of organic qualitative analysis.

Purpose of the Study

The intent of this study was to investigate the conceptual understanding of chemistry teachers and their students with regard to organic qualitative analysis. To achieve this, the study:

1. explored teachers' and students' conceptual levels on understanding organic qualitative analysis.
2. examined teachers' and students' alternative conceptions and factual difficulties on organic qualitative analysis.
3. explored what accounts for teachers' and students' problems on teaching and learning of organic qualitative analysis.

Research Questions

The following research questions guided the study:

1. What different is chemistry teachers' level of conceptual understanding on organic qualitative analysis from their students?
2. How are teachers' alternative conceptions and factual difficulties on organic qualitative analysis different from their students?
3. What accounts for teachers' and students' problems on teaching and learning of organic qualitative analysis?

Significance of the Study

The findings from the study in relation to differences in teachers' conceptual understanding in organic qualitative analysis from their students would help to establish where the challenge of students in responding to examination questions lie. If the conceptual challenge lies with students, it would help chemistry educators and researchers to design and develop the

most appropriate instructional strategies for enhancing students' conceptual understanding on organic qualitative analysis.

The findings from this study such as chemistry teachers' and students' alternative conceptions and factual difficulties on teaching and learning organic qualitative analysis would enable Heads of SHS and Heads of Science Departments to create the conducive teaching and learning environment necessary for chemistry teachers and students to overcome such difficulties they have in the concept.

The findings in the area of conceptual difficulties were categorised into alternative conceptions and factual difficulties. Chemistry educators and researchers would be able to select the most appropriate cognitive conflicting learning strategies for teaching the concept to help students overcome their conceptual difficulties.

Delimitation of the Study

Qualitative analysis is of two parts; inorganic qualitative analysis and organic qualitative analysis. However, in this study the organic qualitative analysis was the focus. Under organic qualitative analysis, the study centered on detection of functional groups in organic samples using some reagents recommended by MOE (2010).

There are various forms of mixed methods research designs. Examples are convergent parallel mixed methods, concurrent triangulation mixed methods, sequential mixed methods, and embedded mixed methods. The study used the sequential mixed methods design. Under the sequential mixed methods design, the study used explanatory sequential mixed methods design

instead of the exploratory sequential mixed methods design. This helped to explain the phenomenon under study.

In this study, there are a number of research instruments that can be used to collect data for the research. However, in this study, diagnostic test, interviews, and observations were used to collect data to help answer the research questions.

Limitations of the Study

The study confined only to public secondary schools within Central Region and therefore its finding would not be applied to all the secondary schools in Ghana, but only be generalised to public secondary schools within similar regions in terms of culture and socio-economic factors. Duration for data collection for the study was affected due to scattered nature of the selected schools in the region and disruptive classroom experienced as a result of COVID-19 pandemic.

Organisation of the Study

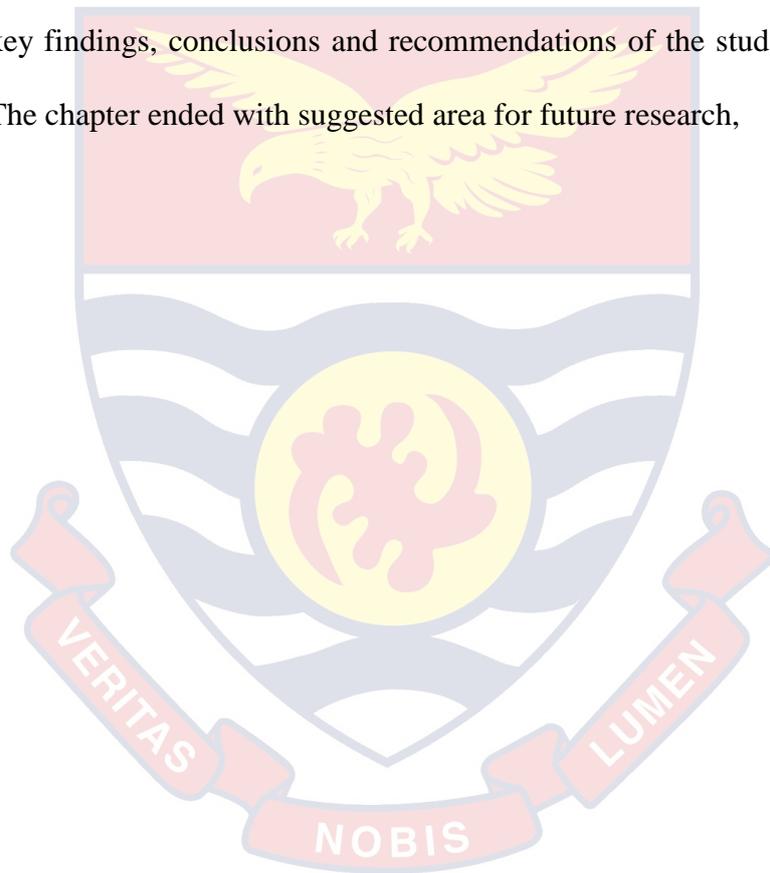
This study has four additional chapters which are arranged in a manner to provide an in-depth understanding into the issues under investigation and to answer research questions stated in this chapter. The rest of the chapters were organised as follows:

Chapter Two, which was a general review of relevant related literature on chemistry teachers' and students' level of conceptual understanding and their difficulties in organic qualitative analysis. The following areas were also looked under Chapter Two; introduction to qualitative analysis of compounds, effects of teachers' content knowledge on their students' learning and academic performances.

Chapter Three dealt with the research methodology for the study which included the type of study and research design employed in the study. Population, sampling procedure, instruments, and data collection procedures and data analysis were also discussed in this chapter in details.

Under Chapter Four, presentation of results and discussion of findings of the study were done with respect to the research questions raised.

The final chapter is Chapter Five. Under this chapter the summary, key findings, conclusions and recommendations of the study were provided. The chapter ended with suggested area for future research,



CHAPTER TWO

LITERATURE REVIEW

This study intended to investigate chemistry teachers' and students' conceptual understanding of organic qualitative analysis. Based on this, some research works relating to chemistry teachers' and students' difficulties in organic qualitative analysis, introduction to qualitative analysis of compounds, conceptual understanding and its implications on teaching and learning of chemistry, and effects of teachers' content knowledge on their students learning and academic performances were reviewed in this chapter. The following review and discussion of related literature were organised in areas such as:

1. Introduction to qualitative analysis of compounds,
2. Conceptual understanding and its implications on teaching and learning,
3. Effects of teachers' content knowledge on their students' learning,
4. Factors influencing students' conceptual understanding difficulties.
5. Constructivist theory of learning
6. Conceptual framework of the study

Introduction to Qualitative Analysis of Compounds

Chemistry is a branch of science that deals with the composition, properties (physical and chemical) and reactions of matter (Ebbing& Gammon, 2005). Sirhan (2007) stated that chemistry is very vital in studying science since most of the concepts are about the structure of matter which provides detail explanation and enables students' understanding of an occurring chemical phenomena.

According to Ebbing & Gammon (2005), chemistry is a branch of science concerned with the properties, composition, and structure of substances and the changes they undergo. Furthermore, chemistry can be characterised into various branches namely; organic, inorganic, physical, and analytical. Organic chemistry is the branch of chemistry that deals with the structure, properties and reactions of compounds that contain the element carbon except compounds like metallic carbonates such as sodium carbonate (Na_2CO_3), potassium cyanide (KCN) and carbon oxides such as carbon dioxide (CO_2). Compounds obtained from living things like sugars, proteins, amino acids, urea, vitamins and antibiotics are classified as organic (Bettelheim, Brown & March, 2004).

Hanson (2017) opined that adequate understanding of organic chemistry is a pre-requisite for many graduate and professional programmes. It is a key to the development of new products in the society and it is the basis for the production of food flavours, plastics, clothing, car tyres, fuels, cement, pharmaceuticals and house cleaning agents. It is also important in the investigation and security agencies.

Analysis of chemical compounds is one of the areas under chemistry. Analysis of chemical compounds are classified into two categories; that is quantitative (volumetric) and qualitative analysis. Quantitative analysis finds the amount of each element or group present while qualitative analysis finds the type of each element or group present in a given sample of solution (Matthews, 2011).

The qualitative organic analysis which is basically functional group detection is studied under areas such as aliphatic hydrocarbons made up of

saturated (alkanes) and unsaturated (alkenes and alkynes). Aromatic hydrocarbons (benzene), alkanols, carbonyl compounds made up of alkanals (aldehydes) and alkanones (ketones), amides, carbohydrates (reducing sugars and non-reducing sugars) and proteins (MOE, 2010). Functional group detections deals with writing appropriate reaction for different functional groups, indicating correct method for preparation/synthesis of different organic compounds, and proposing mechanism of reaction for different functional groups (Domin, Al-Masum, & Mensah, 2008; Hassan, Hill, & Reid, 2004). The functional groups studied in organic chemistry at the senior high school level are: hydrocarbons consisting of aliphatic hydrocarbons (alkenes and alkynes) and aromatic (benzene), alcohols ($-OH$); aldehydes ($-CHO$); ketones ($-C = O$); carboxylic acids ($-COOH$); esters ($-COO -$); Amides ($-CONH_2$) (MOE, 2010).

Based on the specific objectives outlined in the Chemistry teaching syllabus (MOE, 2010), all functional groups were discussed in detailed with regards to the kind of reagents used to detect them.

Organic Qualitative Analysis

Identification and characterisation of the structures of unknown substances are important part of organic chemistry. It is often of necessity, a micro process.

For example, in drug analyses, chemists frequently use qualitative patterns of reactivity to identify the functional groups of unknown compounds. This technique, called qualitative analysis, was especially important tool for structure determination in the early days of organic chemistry (Fieser & Williamson, 1992). An alkene or alkyne, for example, can be identified by its

reaction with Br_2 in water, decolourisation or disappearance of the reddish-brown colour of the bromine provides clear visual evidence that a reaction has occurred, hence the carbon double bond carbon or carbon triple bond carbon is present in that unknown solution (Atkins & Beran, 1992).

Similarly, upon treatment with chromic acid (H_2CrO_4) certain functional groups are oxidized, and this is accompanied by reduction of the orange chromium Cr^{+6} to the blue-green Cr^{+3} an obvious change (Atkins & Beran, 1992). In addition, the permanganate test, at room temperature KMnO_4 will hydroxylate an alkene or alkyne in an acidic solution, by reacting to break it into two pieces by cleaving pi (π) bonds and this will lead to change in colour of the permanganate from purple to colourless. Both of these reactions are oxidations of the organic compound; the manganese is reduced from Mn^{+7} to Mn^{+4} in the process. This reduction changes the purple permanganate solution in basic solution to a brown precipitate of MnO_2 (Morrison & Boyd, 1992; Vishnoi, 2009).

Functional group are atoms or groups of bonded atoms that give an organic compound its characteristic chemical properties or groups of atoms in organic molecules that are particularly reactive and have characteristic properties (Atkins & Carey, 1990; Ebbing & Gammon, 2005; Fieser & Williamson, 1992).

Hydrocarbons that contain carbon single bond carbon are called saturated hydrocarbons. Alkanes have no functional groups and undergo mainly free radical substitution reactions. Carbons in alkanes are sp^3 hybridised with σ (sigma) bonds between carbon-carbon and carbon-hydrogen bonds. They may have straight chain, branched or ring structure with the

general molecular formula C_nH_{2n+2} . Alkanes are saturated compounds because C-C and C-H bonds are relatively strong, and are fairly unreactive. For example, at normal room temperature 25°C , they do not react with acids, bases, or oxidizing agents.

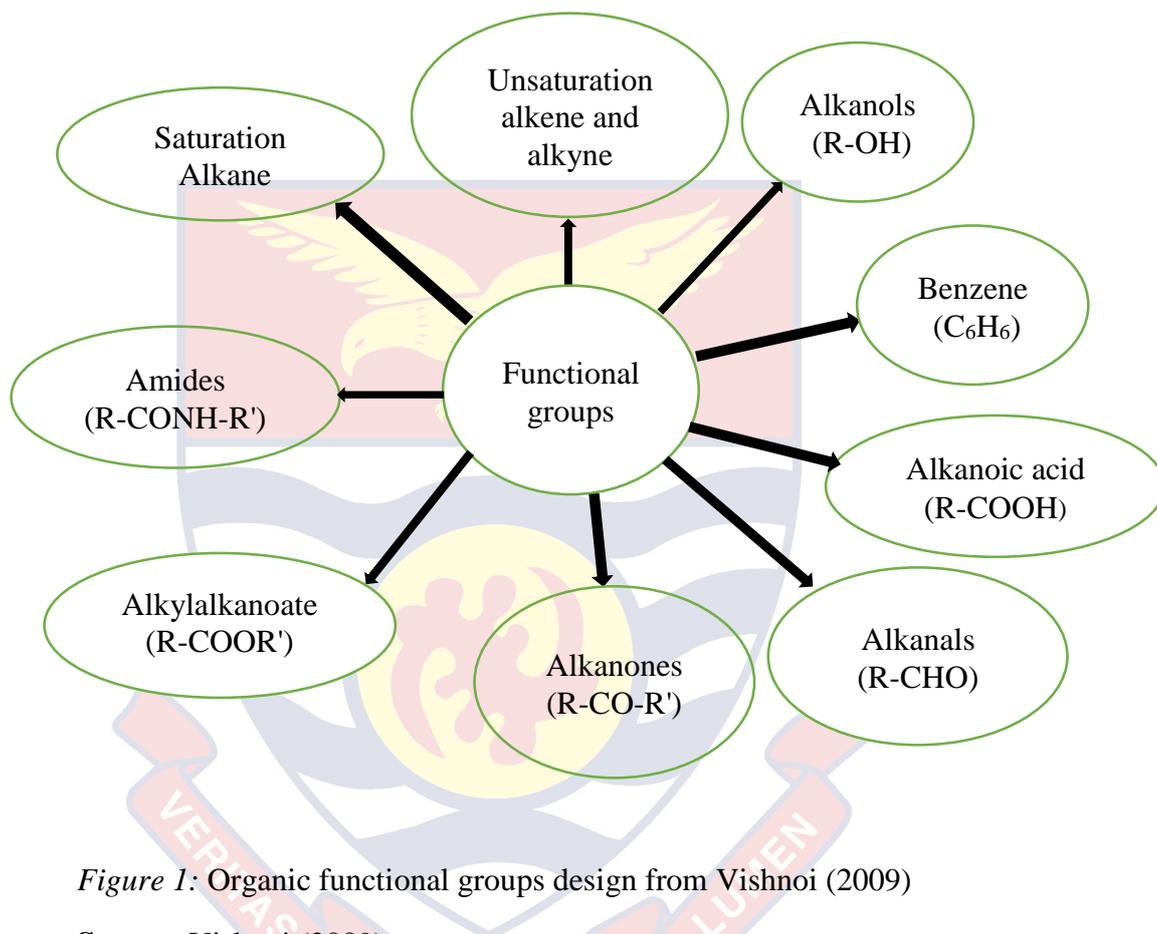


Figure 1: Organic functional groups design from Vishnoi (2009)

Source: Vishnoi (2009)

For this reason, alkanes do not give observable colour changes to purple colour of cold acidified or alkaline tetraoxomanganate(VII) (KMnO_4) solution. Alkanes are also unreactive to bromine water ($\text{Br}_2/\text{H}_2\text{O}$) or bromine in tetrachloromethane (Br_2/CCl_4) (Atkins & Beran, 1992; Bettelheim et al., 2004; Fieser & Williamson, 1992).

Hydrocarbons that contain carbon-carbon double bond or carbon-carbon triple bond are called unsaturated hydrocarbons. Aliphatic

hydrocarbons that have carbon-carbon double bond as its functional group are the alkenes with general molecular formula C_nH_{2n} . Carbon atoms in alkenes are sp^2 hybridised with one σ (sigma) bond and the other, π (pi) bond. Aliphatic hydrocarbons that contain carbon-carbon triple bond as its functional group with general molecular formula C_nH_{2n-2} . Carbon atoms in alkyne are sp hybridized containing one σ (sigma) bond and the other two being π (pi) bonds. Both alkenes and alkynes mainly undergo addition reactions due to the presence of weak and reactive pi bonds in their molecules (Schmid, 1996).

There are two tests for determining unsaturation (alkenes and alkynes) organic compound: Baeyer's Test (Alkaline $KMnO_4$ Test) and Bromine Test (Atkins & Beran, 1992; Fieser & Williamson, 1992). In Baeyer's Test (Alkaline $KMnO_4$ Test), pink/purple colour alkaline tetraoxomanganate(VII) ($KMnO_4$) solution disappears, when alkaline $KMnO_4$ is added to the unsaturated hydrocarbon (Fieser & Williamson, 1992). The disappearance of pink/purple colour take places with the formation of brown precipitate of MnO_2 . This is due to change of oxidation state of manganese from +7 to +4. Purple colour of cold acidified tetraoxomanganate (VII) ($KMnO_4$) solution decolourizes, due to change of oxidation state of manganese from +7 to + 2 (Fieser & Williamson, 1992). In the Bromine Test, the red-brown colour of bromine in carbon tetrachloride (Br_2/CCl_4) or bromine water (Br_2/H_2O) solution disappears or turns colourless when it is added to an unsaturated organic compound (Atkins & Beran, 1992).

Alkanols are organic compounds with the hydroxyl functional group (-OH) and general molecular formula of $C_nH_{2n+1}OH$. Carbon atoms in

alkanols are sp^3 hybridized. There are three types of alkanols namely: primary ($R-CH_2OH$), secondary (R_2-CHOH), and tertiary (R_3COH). Alkanols react qualitatively with Ceric Nitrate test where the colour changes from yellow to red (Zumdahl & Zumdahl, 2003). Primary alkanols are a type of alkanols in which the functional carbon that is the carbon that carries the hydroxyl ($-OH$) functional group is covalently bonded to only one other carbon atom in the molecule. In primary alkanols, there are two primary hydrogen atoms, covalently bonded to the carbon bearing the $-OH$ in the molecule. These two hydrogen atoms are responsible for two successive oxidation reactions of the primary alkanol molecule ($R-CH_2OH$). During oxidation reaction of primary alkanols, the two hydrogens are lost in the presence of oxidizing agents such as acidified $KMnO_4$, $K_2Cr_2O_7$ or Chromic acid (H_2CrO_4) one at a time. An alkanal (aldehyde) is formed during the first oxidation reaction and subsequently alkanic acid is formed in the second oxidation reaction. Example: CH_3CH_2OH (ethanol) will form CH_3CHO (ethanal) and finally CH_3COOH (ethanoic acid). Primary alkanols changes the orange colour of potassium heptaoxodichromate (VI) ($K_2Cr_2O_7$) to green, which is due to change of oxidation state of chromium Cr^{6+} to Cr^{3+} (Bettelheim et al., 2004; Vishnoi, 2009). Secondary alkanols are a type of alkanols in which the functional carbon that is the carbon that carries the hydroxyl ($-OH$) functional group is covalently bonded to two other carbon atoms in the molecule. In secondary alkanols, there is only one hydrogen atom attached to the functional carbon in the molecule and is responsible for the oxidation reactions to form alkanone (ketone) molecule (R_2-CHOH). For example, 2-propanol ($(CH_3)_2CHOH$) will oxidize in the presence of an

oxidizing agent such as KMnO_4 or $\text{K}_2\text{Cr}_2\text{O}_7$ in oxidation reaction by losing the only hydrogen atom attached to the functional carbon to form 2-propanone (CH_3COCH_3) (Fieser & Williamson, 1992). Alkanols mostly primary and secondary alkanols react with iodine in basic solution (I_2/NaOH) in the presence of heat to produce yellow precipitate triiodomethane (CHI_3) in the iodoform test (Matthews, 2011).

Tertiary alkanols are a type of alkanols in which the functional carbon carrying the hydroxyl ($-\text{OH}$) functional group is covalently bonded to three other carbon atoms in the molecule. In tertiary alkanols, there is no hydrogen atom attached to the functional carbon in the molecule hence cannot undergo oxidation reaction. Examples are; 2-methylpropan-2-ol ($\text{CH}_3\text{COH}(\text{CH}_3)\text{CH}_3$), and 2-methylbutan-2-ol ($\text{CH}_3\text{CH}_2\text{COH}(\text{CH}_3)\text{CH}_3$) (Zumdahl & Zumdahl, 2003).

Oxidation of alkanols with acidified potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) and dilute H_2SO_4 . Primary alkanols are oxidized to aldehydes then further oxidation produces alkanolic acid and secondary alkanols are oxidized to ketones. The yellow solution of potassium dichromate turns green, due to changes in oxidation state of chromium from +6 (yellow) to +3 (green) (Ebbing & Gammon, 2005; Fessenden & Fessenden, 1994; Fieser & Williamson, 1992).

Aromatic hydrocarbons (arene) are organic compounds that contain one or more benzene rings. Although benzene, C_6H_6 , is an unsaturated hydrocarbon, it does not usually undergo addition reactions because the delocalised π (π) electrons of benzene are more stable than the localized π electrons; benzene does not react with Br_2 in carbon tetrachloride (Br_2/CCl_4)

as alkenes do (Bettelheim et al., 2004). The usual reactions of benzene are substitution reactions. However, the three double bonds in benzene ring are denatured or destroyed whenever benzene undergoes addition reaction by reacting with three moles of hydrogen molecules (hydrogenation reaction) in the presence of Nickel catalyst at high temperature (100-200°C) and high pressures (100 atm). These conditions are required as Palladium and Nickel are less reactive (Vishnoi, 2009). Benzene is also reduced in the presence of very active catalysts like Rhodium and Platinum at room temperature and modest pressure, due to reactive nature of these catalysts used. In both reactions cyclohexane is formed. The catalytic hydrogenation of benzene ring gives the cyclohexane ring since any intermediate unsaturated hydrocarbons formed are more easily reduced (Atkins & Beran, 1992; Bettelheim et al., 2004; Ebbing & Gammon, 2005).

The functional group in an alkanolic (carboxylic) acid is the carboxyl group (RCOOH) with general molecular formula of $C_nH_{2n+1}COOH$. Many alkanolic acids are synthesized by oxidizing primary alkanols with a strong oxidizing agent. For example, ethanol (CH_3CH_2OH) can be oxidised to acetic (ethanoic) acid (CH_3COOH) by using potassium permanganate (Bettelheim et al., 2004; Fessenden & Fessenden, 1994). A carboxylic acid also reacts with an alkanol in the presence of concentrated tetraoxosulphate(VI) acid (H_2SO_4) to form an ester (alkylalkanoate) and water molecules in esterification. This test is accompanied with sweet fruity smell (Fessenden & Fessenden, 1994). Alkanolic acid functional group can be tested qualitatively by reacting with aqueous Na_2CO_3 or $NaHCO_3$ to evolve CO_2 gas effervescence (Morrison & Boyd, 1992; Zumdahl & Zumdahl, 2003).

Aldehydes (alkanals) and ketones (alkanones) contain the carbonyl functional group (C=O). In an aldehyde the carbonyl group has at least one H atom attached to it as (-CHO). Aldehydes typically have strong odours, vanillin is responsible for the pleasant odour in vanilla beans; cinnamaldehyde produces the characteristic odour of cinnamon (Atkins & Beran, 1992; Ebbing & Gammon, 2005). In a ketone, the carbonyl group has two alkyl groups attached to it (R-COR') (Bettelheim et al., 2004). Ketones have useful solvent properties. For instance, acetone (2-propanone) is found in nail polish remover (Morrison & Boyd, 1992). Aldehydes and ketones are most often produced by the oxidation reactions of alcohols. For example, primary alcohol oxidises to form aldehydes while secondary alcohols oxidise to form ketones (Ebbing & Gammon, 2005; Fieser & Williamson, 1992; Vishnoi, 2009).

Both aldehydes and ketones will produce yellow (orange) precipitate when drops of Brady's reagent (2, 4-dinitrophenylhydrazine) is added to form 2, 4-dinitrophenylhydrazone (Fieser & Williamson, 1992). Aldehydes reduce the complex silver ion to silver metal to form silver mirror on the sides of the test tube. Ketones will not react with this reagent (Atkins & Beran, 1992; Bettelheim et al., 2004). In the Schiff's test, little amount of the carbonyl compound is added to the reagent. Aldehydes produce a deep violet-red colour immediately while with ketones, the appearance of the violet colour takes time (Vishnoi, 2009). In the Fehling's reagent/Benedict's test, formation of brick-red precipitate of copper (I) oxide indicates the presence of aldehyde. Ketones will not react with this reagent (Ebbing & Gammon, 2005; Vishnoi, 2009). Aldehydes and ketones can be reduced to produce

primary and secondary alkanols respectively in the presence of reducing agents such as sodium borohydride or tetrahydridoborate(III) (NaBH_4) in ethanol or lithium aluminiumhydride or tetrahydridoaluminate(III) (LiAlH_4) in ether (Atkins & Beran, 1992).

An ester (alkylalkanoates) is a compound formed from a chemical reaction between a carboxylic acid, RCOOH and an alcohol, $\text{R}'\text{-OH}$ in the presence of concentrated sulphuric acid and heat. The general structure of ester is RCOOR' (Fesseden & Fessenden, 1994; Schmid, 1995). Most esters have sweet, fruity smell that is in contrast to the often pungent odours of the parent carboxylic acid (Fieser & Williamson, 1992). Esters hydrolyses to produce alkanol and alkanolic acids (Fesseden & Fessenden, 1994).

Amides (RCONH_2) are derived from carboxylic acids ($-\text{COOH}$) by the replacement of the hydroxyl group ($-\text{OH}$) with an amino ($-\text{NH}_2$) group. Amines are normally reduced using a reducing agent like LiAlH_4 (lithium tetrahydridoaluminate (III)) to produce an amine (Ege, 1999). The amide functional group can be detected qualitatively by reacting the solution containing amide with an aqueous sodium hydroxide (NaOH) with heat leading to evolution of pungent smell gas called ammonia (NH_3) which is basic by nature (Morrison & Boyd, 1992).

Conceptual Understanding and Its Implications on Teaching and Learning

Concepts are the construction of the human mind (Konicek-Moran & Keeley, 2015). Concepts are ideas, notions or thoughts that can be regarded as the emerging image of the mental process (Lakpini, 2006). It may be a product of some intuitive re-appraisal; the only problem is that a concept could be

concrete, abstract or even blurred. Concepts as a summary of the essential characteristics of a group of ideas (Lawson, Alkhoury, Benford, Clark, & Falconer, 2000).

Cognitive scientist Carey (2000) states that concepts are complex representational structures. Moreover, concepts can be constructed directly by generalizing from experience. In some cases, concepts are difficult to demonstrate. Within a particular representational structure, concepts help students to clarify ideas that are more complex. Concepts act as building blocks of more complex or even abstract representations. In science, students are continuously required to identify hidden concepts, define adequate quantities and explain underlying laws and theories using high-level reasoning skills (Konicek-Moran & Keeley, 2015). Thus, students are involved in the process of constructing models that help them better understand the relationships and differences among the science concepts.

The main goal of science education is teaching for conceptual understanding (Konicek-Moran & Keeley, 2015), a phenomenon which is complex (Nieswandt, 2007). It combines an understanding of single concepts such as sunlight, Chlorophyll, water, carbon dioxide or of a more complex concept such as chemical energy, which following certain rules and models, combines multiple individual concepts, resulting in a new concept. Learning a new concept is integration of knowledge into an existing knowledge framework (conceptual growth) or fundamental reorganization of existing knowledge to fit the new concept into the framework (conceptual change) (Treagust & Duit, 2008). Then, Conceptual understanding of science concept

is students' ability to apply the learned scientific concepts to scientific phenomena in an everyday life (Nieswandt, 2007).

It involves understanding of the principles that govern a domain and of the interrelations between units of knowledge in a domain (Rittle-Johnson, Siegler, & Alibali, 2001). And in chemistry, it is related to the ability to explain chemical phenomena through the use of macroscopic, molecular and symbolic levels of representation (Wu, Krajcik, & Soloway, 2001). It is known that when relationships are formed between these three levels of representation, students understand and learn more in chemistry (Sanger, Phelps, & Fienhold, 2000). At the macroscopic or phenomenal level properties can be seen and measured. At the submicroscopic level, molecular structures of the particles cannot be seen, whereas the symbolic level is the way a substance is represented by its chemical formula (Wu et al., 2001). Researchers have been arguing the necessity of learning at macroscopic, microscopic and symbolic levels (Gabel 1998; Johnstone 1993).

According to Kang and Howren (2004), conceptual understanding requires students to arrange facts and ideas into a significant concept of science. These facts and concepts form webs to help students make connections between the concepts of science and their experiences. It enables students to connect instinctive ideas with scientific ones, which result, to significant connections rather than just memorization of facts (Grove & Bretz, 2012). Conceptual understanding refers to what learners know and understand about a concept that is the generalizations learners can develop about the nature or properties of that concept (Mills, 2016).

Mills (2016) reiterated that students who understand a subject conceptually do not depend on memorisation approach rather they formulate ideas while learning; ask questions continually based on their state of understanding; and transform and reconstruct their knowledge structures. Although science educators have drawn attention to strengthen conceptual understanding of scientific concepts and processes, lots of teachers still fail to implement instructional strategies that guarantee assistance to learners. Hence, many students leave science classrooms with misconceptions even after instructions (Nicoll, 2001; Taber & Watts, 2000). Meaningful science learning requires conceptual understanding rather than memorization (Adadan, Trundle, & Irfing, 2010). Meaningful learning requires knowledge to be constructed by the learner, not transmitted from the teacher to the students (Jonassen, Peck, & Wilson, 1999).

Instructional strategies that sort to promote conceptual change requires time and effort on the part of the learner (Adadan et al., 2010). However, the practice of science instruction has emphasised on memorising a lot of science concept (Chin, 2004). Students who are excellent at memorising facts and definitions often engage in literal understanding (Konicek-Moran & Keeley, 2015). These students might not have been able to understand basic concepts that provide explanatory evidence for ideas about phenomena (Chelowinski, 2009). The important learning process is student's ability to think through all arguments on their 'own' and 'construct' further knowledge upon already understood concepts (Jia, 2010).

Chiu (2005) agreed that students do not grasp fundamental ideas covered in classroom teaching instructions. Even some of the best students

give the right answers but only using correctly memorised words but reveal their failure to understand fully the underlying concepts when questioned more closely. Without clear conceptual understanding and an awareness of learners' meta-cognition, they resort to more rote memorisation (Grove & Bretz, 2012). According to Martine and Rijlaarsdam (2006), learning of scientific concepts is more than a cognitive process as it is blended with interest and attitude towards learning, thus a learner is believed to understand scientific concepts only when the learner can explain every day phenomena by seeking connections among various pieces of information or applying the newly learned information to everyday life.

Chemistry students are not exempted to this trend. Lyons (2006) reported that numerous key chemistry concepts and processes are in the domain of misconceptions. This is because teachers predominantly use knowledge-based instruction rather than conceptual-based learning. For students to favourably deal with the complexity of key chemical concepts and processes, the teachers need to use student-centered instructional approaches in teaching (Olam, Olorantegbe & Orimogunje, 2010). That is, students need to navigate and coordinate between these interrelated variables in solving chemistry problems using complex reasoning.

Akkuzu and Uyulgan (2016) indicated that students are unable to adequately conceptualise chemistry content, such as intramolecular and intermolecular bonds, acidity and basicity, oxidation and reduction and determination of molecular structures, these were due to their inability to transfer knowledge acquired in those concepts to learning of organic chemistry. In order to promote students' understanding of functional groups

to prevent related misconceptions, Akkuzu and Uyulgan recommended that fundamental chemistry concepts should be reinforced, and students' current knowledge and the new information to be learned should be emphasized in activity-based lessons.

Asghar, Huang, Elliot, and Skelling (2019) revealed among other things that, teachers who use well developed assessment questioning to inform instruction help to facilitate development of a deeper understanding of accepted scientific concepts in students. When teachers develop and adapt specific activity-oriented teaching strategies, students' alternative conceptions will be addressed (Fatoke & Olaoluwa, 2014; Hanson, 2017; Morgil & Yoruk, 2006). Asghar et al. (2019) made recommendations based on the findings of the study that, teachers should;

- a. elicit students' prior knowledge about natural and scientific phenomena (Cornelius-Ukpepi & Enuokoha, 2013; Hailikari, Katajavuori, & Lindblom Ylanne, 2008)..
- b. choose appropriate inquiry-based activities to address students' alternative conceptions (Bradley, Ulrich, Maitland, & Jones, 2002; Hanson & Wolfskill, 2000; Kiboss, Ndirungu, & Wekesa, 2004).
- c. provide opportunities to help students apply their emerging scientific understandings and technological models.

Garnett, Garnett, and Hackling (1995) revealed among others that, lack of important needed knowledge, students' inability to visualize particles of matter, students' preconception from their prior world view, rote learning application of concepts, and general instructional strategies are the major factors that lead to students' developing alternative conceptions. Garnett et al.

concluded that, students' experience difficulties with the abstract nature of chemistry concepts.

Chemistry teachers should place greater emphasis on discourse regarding students' conceptions, use of appropriate teaching intervention strategies, encouraging students to reflect on their understandings and the provision of opportunities for students to experience chemistry at the macroscopic, submicroscopic and symbolic levels to help students eliminate alternative conceptions in chemistry concepts.

Moe (2011) indicated that, misunderstandings and misconceptions are mostly introduced when students encounter new scientific concepts. This implies that teachers should always know students pre-existing knowledge before they introduce new concepts (Adu-Gyamfi, Ampiah, & Agyei, 2020). Conceptual understanding of a concept is not solid until the learner is able to provide a relevant application within a specific content and discipline. Learning probes (inquiry) mostly necessitate students' deeper reflection on science concepts they are introduced to, and better their ways of understanding of that concepts (Moe, 2011). Moe recommended that;

1. inquiry-based curriculum and instruction should be designed to give more opportunities for students to reflect on their own inquiry processes.
2. science students should be trained to develop the skill of asking investigative questions.
3. in-service or pre-service professional development workshop should be organized for teachers to prepare them to teach science concept through science inquiry (Moe, 2011).

According to Kim, Goh, Chia, and Treagust (2002), even though students in experimental and control groups had misconceptions about qualitative analysis, the control group had much higher degree of misconception than the experimental group. That is most students from the control group were unable to relate the theory learnt to the practical aspects of qualitative analysis. With the use of qualitative analysis teaching package (QATP) students in the experimental group scores were significantly higher than those instructed with the traditional teaching method. Kim et al concluded that QATP was a well-structured and comprehensive, and that students taught using the package gained a greater understanding of qualitative analysis. Chemistry teachers should use more rigorous experimental instructional teaching strategies to teach qualitative analysis for development of conceptual understanding by students (Aregawi & Meressa, 2017; Hofstein & MamlokNaaman, 2007; Kim et al., 2002; Okebukola, 2006; Pareek, 2015; Shamuganathan, John, & Karpudewan, 2016; Tafa, 2012).

Mills (2016) substantiated conceptual understanding as a process of improving students' understanding and retention of concepts. When learning is individually constructed into the schemata, it becomes more meaningful and retained. In addition, conceptual understanding when achieved aides in knowledge transfer that needs to occur between theoretical concepts and practical. Science teaching should be focused on conceptual understanding to improve students' ability to reinforce connections and organize knowledge (Mills, 2016).

Boo (1994) indicated that for chemistry students to make sense of procedures, reactions and results in qualitative analysis practical work, they

need to apply content knowledge in topics such as acids, bases and salts, oxidation reduction reactions, reactivity of metals and periodicity. Boo revealed that chemistry students have difficulties in understanding chemical concepts and reactions that underpins qualitative analysis.

Effects of Teachers' Content Knowledge on their Students' Learning

Johnston (2005) opined that what is simple to the chemistry teacher, may not be so for the learner. Teachers with a better understanding of their learners' cognition, should be better able to adapt their lessons to facilitate a more holistic understanding of the content (Azuka, Durujaiye, Okwuoza, & Jekayinka, 2013; Ogembol, Otanga, & Yaki, 2015; Unanma, Abugu, Dike, & Umeobika, 2013).

Teaching and learning process of science depends on the nature and structure of the discipline. In fact, Ferguson & Bodner (2008) asserted that teachers should understand the nature of their content, and that teachers' understanding of that will influence the way they teach, and consequently the way their learners learn the content (Childs & Sheehan, 2009; Gabel, 1998; Simsek, 2009, Tatli & Ayas, 2013). Hence, the nature of the content also influences the way the subject is taught and learnt. Therefore, innovative learning strategies could be used by teachers at all levels of chemistry education to enhance students' learning of chemistry (Eybe & Schmidt, 2004). Teachers' deep and strong content knowledge is a necessary tool in a constructivist classroom (Adu-Gyamfi, Ampiah & Appiah, 2018; Aregawi & Meressa, 2017; Grayson, Anderson, & Crossley, 2001; Özkaya, Üce, Saricayir, & Sahin, 2006). This is because those teachers could provide students with opportunities to develop deep understanding of concepts,

internalize the concepts, and develop complex cognitive structures for connections to other bodies of knowledge. Taber (2011) reiterated that, good number of students make meaning of concepts in more or less similar ways as they are taught by their teachers. Therefore, in order to investigate what is being learnt it is equally important to know the teacher's knowledge of a specific content.

Jurišević, Glažar, Pučko, and Devetak (2008) found that teachers undergoing training in the colleges and universities have conceptual difficulties with regards to learning of chemistry, and this greatly influence their future teaching of chemistry concepts. Chemistry teachers' difficulties in chemistry concepts are potentially transferable to their students which mostly results in learners' misconceptions about chemistry (Chavan, 2017).

Omwirhiren and Ubanwa (2016) indicated that students' misconceptions in organic reactions were due to many factors including teacher-centered teaching methods employed by teachers, teachers' inadequate knowledge in the content, and lack of use of instructional materials in their teaching. Omwirhiren and Ubanwa recommended that, teaching of organic chemistry should start as early as SS1 so as to allow full coverage of its content and hence familiarise the students with organic chemistry concepts thereby reducing misconception in organic chemistry, and also teaching and learning of organic chemistry in SS should be strengthened to provide a good foundation for students.

Unlike conceptual understanding, conceptual misunderstanding involves conceptions that are 'wrong and flawed' (Gurel, Eryılmaz, & McDermott, 2015) and in conflict with scientific knowledge or claims. These

conceptions may be termed alternate conceptions, misconceptions, preconceptions, alternative frameworks, children's science, or naive conceptions (Adu-Gyamfi & Ampiah, 2019; Coştu, Ayas, & Niaz, 2012). It is proven that chemistry is a difficult subject for many students because chemistry topics are generally related to structures of matter. Chemistry curricula incorporate many abstract concepts that are important as further chemistry concepts cannot be understood if these underpinning concepts are not sufficiently grasped by the students (Sirhan, 2007). Moreover, learning requires much intellectual thought because the content is filled with many abstract concepts which are meaningfully linked (Nakhleh, 1992). This implies that, chemistry teachers should be well equipped with the subject matter in order to help teach students true conception and avoid misconceptions (Arokoyo & Amadi, 2018; Delmang & Gongden, 2016; Senthamarai, Sivapragasam & Senthilkumar, 2015).

Explanation helps learners develop awareness of their prior knowledge by revising their beliefs after becoming aware of gaps in their understanding (Williams & Lombrozo, 2012). Misconceptions in chemistry are as a result of lack of information, incorrect instructional strategies, and misconceptions of teachers about content, and prior experiences and understanding of students (Taber, 2002).

Many researchers have identified students' difficulties in understanding chemical concepts (Adu-Gyamfi & Ampiah, 2019; Adu-Gyamfi et al., 2015; 2017; Agung & Schwartz, 2007; Othman, Treagust & Chandrasegaran, 2008; Pınarbaşı & Canpolat, 2003). For this reason, students develop scientifically inaccurate conceptions about chemistry. Their knowledge of chemistry is,

therefore, incomplete and incoherent (Kozma & Russell, 1997). Many students, in fact, merely memorize chemistry concepts without actually learning them (Niaz & Rodriguez, 2000). This situation is an indication of why some students never come to like chemistry. Nevertheless, other factors such as teachers also play a significant role during the instructional process as they influence students' attitudes towards chemistry. Improve attitude of students can affect their performance (Sakiz, Pape & Hoy., 2012; Yara, 2009).

The findings of Adu-Gyamfi et al. (2018) showed among others that, teachers found problematic in teaching redox reactions due to their inability to select an appropriate instructional strategy for teaching the concept and teachers' insufficient knowledge in the subject matter. Adu-Gyamfi et al. based on the findings of the study concluded among others that, chemistry teachers used weak and unstructured instructional strategy to teach redox reactions and teachers' also lacked specific pedagogical content knowledge for teaching redox reactions. Chemistry teachers should select and use most appropriate and convenient structured instructional strategies when teaching since this enhances learners' conceptual understanding eliminating misconceptions (Adu-Gyamfi et al., 2018). The review does far point to the fact that, teachers' content knowledge has effects on their students' learning and understanding of chemistry concepts.

Factors Influencing Students' Conceptual Understanding and Difficulties

Other studies reports showed that, organic chemistry concepts are difficult for students (Adu-Gyamfi et al., 2017; Bhattacharyya & Bodner 2005; Childs & Sheehan, 2009; Johnstone, 1991; O' Dwyer & Childs, 2010; Sirhan, 2007). However, their reason of difficulties in chemistry may differ from one

person to the other. According to Johnstone (1991), the difficulty of organic chemistry for students is due to abstract nature of the concepts and the how the concepts are represented. Simsek (2009) indicated the teaching methods employed by teachers in their teaching and teachers' lack of specific pedagogical content knowledge and weak teaching instructional strategies contribute to students' difficulties (Adu-Gyamfi et al., 2018; Justi & Gilbert, 2002; Sakiz, Pape & Hoy, 2012; Uyulgan & Akkuzu, 2016). O' Dwyer and Childs (2010) reported that teachers' lack of their learners' prior knowledge, misconceptions, and students' attitudes and approach to learning and students' difficulties arise from complex nature of the concepts, bulky content, teacher-centered teaching, and, lack of students' and teachers' motivation (Ferguson & Bodner, 2008); and teachers' lack of content knowledge, and students' attitudes and approach to learning (Sirhan, 2007).

According to Mahajan and Singh (2005), the perceived factors such as instructional laboratory lessons, students' prior knowledge, and time constraint contribute to students' success in conceptualizing organic chemistry. The most popular method employed by instructors is the traditional-lecture method where instructors try to transfer knowledge directly to students using chalk and board, followed by demonstration method using models. According to Mahajan and Singh (2005), instructors gave the following among others as reasons for students' poor performance in organic chemistry at the undergraduate level:

1. Students lacks conceptual understanding of organic chemistry concepts making them very complicated.
2. Time constraints due to students' academic workload.

3. Instructional activity-oriented methods during teaching and learning (Adeogun, 2001; Arokoyo & Amadi, 2018; Ngwenya, 2015).
4. The students resort to memorisation rather than comprehension of organic chemistry concepts and hence, their inability to apply these concepts in other disciplines.

The instructors also gave the following among others as suggestions that will help improve organic chemistry teaching and learning in the SADC region (Mahajan & Singh, 2005):

1. Teachers' teaching organic should strive hard to complete within stipulated time or the time allocated for teaching organic chemistry should be increased.
2. More teaching and learning resources should be provided to facilitate and promote students' conceptual understanding of organic chemistry concepts.
3. The lecturers must consider student's prior knowledge and current topic when teaching to help students understand new concepts.
4. Learners should be actively involved during teaching and learning processes through question and answer technique.

According to Coll (2014), students consider organic chemistry concepts as very difficult to teach and learn and have the potential to be hindrance to their study of chemistry as a discipline. Several factors contribute to students' poor performance, including students' own preparedness, teacher's content knowledge and preparedness, environmental/social factors, and language (Ferguson & Bodner, 2008). The prominent causes were identified as poor conceptual foundation, students'

disinterest, incompetent teachers, large class sizes and psychological fear for chemistry. Furthermore, Adu-Gyamfi et al. (2018) reiterated that voluminous nature of chemistry content, students' quality, teachers' content knowledge of concept and choice of instructional strategies are issues that prevent effective instruction of chemistry concepts.

Constructivist Theory of Learning

Constructivism is a learning theory founded on the premise that, by learners reflecting on their experiences, they construct their own understanding of the world they live in (Penner, 2001). According to Taber and Watts (1997), constructivist theory of learning acknowledges that the individual learner actively constructs knowledge and learners actively do so to make sense of the world by interpreting new information. Learners are able to generate their own mental models, by making use of their experiences. Constructivist learning theory explains how students actively construct their own knowledge based on their pre-existing knowledge (Bryant, Kastrup, Udo, Hislop, Shefner, & Mallow, 2013; Henriques, 2002; Kozma, 2003).

The constructivist views the learner as an active agent in the knowledge acquisition process, making meanings of information presented while the teacher act as a facilitator (Jia, 2010; Phillips, 2007). Learning is an active sense making process, which occurs within the mind of the learner who construct a meaningful representation of new information available (Phillips, 2007). As a result, instruction aimed at transmitting knowledge directly from the instructor to the student will be ineffective and be discouraged. Instead, learners must be encouraged to build their own structure based upon their existing knowledge and understanding (Johnston,

2005). Constructivist learning strives to expose students to real situations that elicit their conceptual knowledge and promote self-directed development of applicable knowledge. This is an active process fostered by autonomous and cooperative learning strategies (Eilks, Prins, & Lazarowitz, 2013).

There are different theories under constructivism (Phillips, 2007). These include cognitivism by Piaget, social constructivism by Vygotsky, individual-centered radical constructivism position of Von Glasersfeld and group centered social constructivist position of Palincsar (1998). However, all such of constructivist theories share common features of the learner being at the central position in constructing and building meaningful knowledge. The theory underpinning this study is cognitive constructivism.

Cognitive Constructivism

Jean Piaget set forth the first theory of cognitive constructivism (Swan, 2005). Piaget posited that individual learner has the cognitive ability to construct meanings for themselves. In this theory, individual learner largely relies on oneself other than others. According to Piaget (1985), learners interpret new experiences based on their existing schemata through a process of assimilation and accommodation. Piaget posited that people construct new knowledge by assimilating it with their internal representations of the world. Accommodation occurs by reframing one's view of the world, in order to allow new experiences to fit and assimilation on other hand occurs when one modifies or changes new information to fit into his/her schemas (what he/she already knows). It keeps the information or experience and adds to what already exists in his minds (Grayson, Anderson, & Crossley, 2001).

Cognitive psychologists, especially Jerome Bruner and David Ausubel (Oliver, 2002) are concerned with how learning occurs and what type of knowledge is stored. Under the cognitive approach, learning is centered on the learner rather than on the content to be learned.

Cognitive theorists are not only in agreement that the learner's acquisition of sound, stable, and well organised bodies of knowledge is the long-term objective of education, but also believe and insist that these bodies of knowledge, once acquired, becomes the most significant factor that influences retention of new content material learned and promotes meaningful learning as well. Hence, control over meaningful learning can most be experienced effectively by identifying and manipulating significant cognitive structure variables (Ausubel, 1973). Von Glasersfeld (1989) reiterated that individuals as learners actively build their own knowledge within the persons thinking framework, and social interactions learners have among themselves as students and as learners as well.

Ausubel (1973) posited that, individual learner based on student's hierarchical cognitive structures actively organises all knowledge uniquely. The most significant piece of instruction from the teacher as a facilitator is to provide cognitive bridges which makes it possible for learners to incorporate new knowledge; which are usually in the form of advance organisers such as graphs, concept maps, or photographs of the phenomenon under study. In the course of achieving meaningful learning outcome, new information is linked with already existing concepts within the learners cognitive structures through an active interactive process upon which the new information slightly changes; and then incorporated henceforth.

Social Constructivism

Lev Vygotsky's theory of social constructivism had ideas that align better with current research (von Glasersfeld, 1993). To the social constructivists, knowledge is also a human product, and is constructed socially and culturally (Kukla, 2000). Individuals create meaning through their interactions with each other and their environment within which they live in. Social constructivists view learning as a social process, which does not only take place within an individual, nor is it a passive development of behaviours learners that are shaped by the learners external forces (McMahon, 1997). Meaningful learning occurs when individuals are actively engaged in social activities. Vygotsky's theory is centered on zone of proximal development (ZPD) (van Lier, 2000). Vygotsky professed that when someone is in this zone, which is a small range of time, a knowledgeable person (teacher) must share what they know with the novice (learner). During this stage, the learner becomes the most impressionable and vulnerable to learning new information (Vygotsky, 1978).

In contrast to cognitive constructivist theory, which considers learning to be internal assimilation and accommodation of information by learners, social constructivist uses social interaction as the framework for learners to learn and develop (Chelowinski, 2009). Social constructivist theory, maintains that learners in response to interactions with their environment structurally and internally formulate knowledge. Vygotsky asserted that social constructivist theory maintains that language and culture are the basic frameworks through which humans experience, communicate, and understand reality (as cited in Chelowinski, 2009). An explanation for interest

in social dimensions of cognition is that social and cultural factors greatly influence cognition is the perspective that thought, learning, and knowledge acquisition are not only influenced by social factors but also are social phenomena. From this perspective, cognition is a collaborative process (Palincsar, 1998).

The strengths of constructivism lie in the construction of knowledge and what that mean for students and teachers in their teaching and learning activities, the role of the teacher is to facilitate teaching process in the classroom other than as a knowledge giver since knowledge acquisition is mostly not directly transferred from one individual to another.

von Glasersfeld (1989) emphasized that, educators should consciously accept the fact that knowledge is constructed in action and must actively be constructed by individual learners; learner-dominated instruction where teachers function as facilitators must be encouraged. Knowledge is not attained but constructed by learners. This implies that learning involves negotiation and interpretation by the learner during the learning process. According to Von Glasersfeld, (1989), what learners learn is not a direct copy of what the learner observe within their immediate environments but emanates from their own thinking, reflection and processing of information (Steele, 2005). The very fundamental function of a teacher is to enable and encourage learners to think out-of-the-box by making their own connections that result in valid internalized meanings unique to them. In this regard, learners through exploratory activities enable them to embark on their own investigation and arrive at their own conclusions as to what happens in their immediate environment (Martin, 2003).

Core Ideas of Constructivism and Learning

According to Taber (2006), constructivist-learning theorists, have some basic core ideas that are subscribed to by all constructivist theorists.

Here are some of these core ideas upheld by constructivist;

1. Knowledge acquisition must actively be constructed by the learner, but not imposed on learner.
2. During learning situation, learners have with them pre-existing ideas about many phenomena, which are either temporal or unstable; well developed; or rooted deeply within the mental structures of the learner.
3. Learners mostly have their own individual worldviews, but there are some similarities and common patterns in their ideas of which these ideas are accepted socially and culturally.
4. Some of these ideas possessed by learners are often in contrast with scientifically accepted ideas and some of these ideas become persistent and very hard to be changed by learners.
5. Teachers as facilitators take learner's pre-existing ideas in order to alter or challenge them.

Constructivism in the Classroom

Watson (2001) highlighted that the principles mostly adhered to by constructivists within their classroom are:

1. Constructivist teachers employ interactive and substantial materials mostly to obtain raw data from their learners (Hofstein, & Mamlok-Naaman, 2007; Lee & Fraser, 2001).

2. The teacher to constrain lesson plans, shift instructional strategies and modify content entertains responses from students.
3. Teachers enquire about the understanding of concepts by the students before introducing new information about new concepts.
4. Students are encouraged to work in teams, get involved in group discussions and dialogue with their colleague learners.
5. Constructivist teachers encourage speaking and verbal communication on the part of the students asking thoughtful, and open-ended questions and even learners are encouraged to raise their difficulties and problems.
6. Constructivist teachers inquire about amplification of learner's initial responses. Insufficient knowledge or incomplete learning prove out to be a hindrance to learners' learning, hence acquiring information about the initial responses and then elaborating upon those responses are very essential in order to enhance learning.
7. Teachers employ instructional strategies that facilitate learners' understanding and knowledge that might stimulate contradictions to their preliminary hypotheses and then persuade dialogue (Hofstein, & Lunetta, 2002; Jagodzinski & Wolski, 2015; Tatli, & Ayas, 2011).
8. Students are always given enough time to analyse questions, seek answers and explanations before their responses are taken from them.
9. Teachers provide enough time for learners to build relationships and generate metaphors among themselves.

In the constructive perspective, new knowledge is acquired based on the learners prior or existing knowledge that learners bring to learning

situations. Learners obtain different information from many sources, but in building their own knowledge, they connect information to prior knowledge and experiences, organise it, and construct meaning out of them. What learners already possess within their mental structures influences what they attend to, how they organise them, and how they integrate new constructions to expand their knowledge base.

According to Brooks and Brooks (1993); Larson and Keiper (2007), a constructivist teacher should have the classroom focused mainly on real life problem solving situations, problem-based learning, independent minded investigation, and the pursuit of personal interests, simulation, discussion collaborative learning, think-pair share, and the utilisation of higher-order thinking skills.

Additionally, Potvin (2017) opined that educators should come to realization that knowledge cannot be passed directly from neither a teacher nor book to a learner, nor is it simply discovered in the real world by learners. All learners must make conscious effort to construct new knowledge for themselves. Instruction guided by the constructivist learning theories promotes learner engagement in learning environment (Swan, 2005).

An experimental study conducted by Kim (2005) sought to investigate the effects of a constructivist teaching approach on learners' achievements, self-concept, and learning strategies. The experimental group had instruction of constructivist approach while the control group had instruction with the conventional teaching approach. The results showed that constructivist teaching approach placed learners at the centre during teaching and learning

process and the teacher acted as a facilitator and this was more effective than the conventional teaching approach (Ultanir, 2012).

Bhutto and Chhapra (2013) indicated that, constructivist teaching approach is more compatible with how learners gain knowledge whenever conducive environment is created for the lesson. The study also showed that, constructivist practices enabled the teacher to have more interactive teaching schemes which placed the learner at the center during learning processes. The study concluded that, effectiveness of teaching strategies employed by teachers strengthened and contributed to learners understanding of concepts taught.

Misconceptions should be of great interest during teaching and learning because they represent what the learner has conceptualized to be correct at that moment in time but scientifically inaccurate (Nakhleh, 1992).

The general agreement among educators is that what a learner knows is not a function of detached observation but instead created through interaction of the learner's worldview since knowledge acquired and reality are subjective in nature (Bransford, Brown, & Cocking, 2000; Brooks & Brooks, 1993; Larson & Keiper, 2007). A typical constructive classroom environment is participatory-oriented (Adu-Gyamfi et al., 2020) and designed to promote hands-on and minds-on activity learning for all learners similar to those encountered in the real world. This type of teaching and learning environment should focus on authentic tasks similar (Adu-Gyamfi et al., 2020) to what people see in every day practice and to on-the-job experiences that would benefit all learners (Larson & Keiper, 2007).

Phillips (2007) reported that, in line with the constructivist belief that new knowledge must be formed using prior knowledge, teachers should also be aware of learners' misconceptions, incomplete comprehension, and preconceptions. Teachers must address these beliefs to aid learners achieve higher learning and conceptual understanding. Failure to do so could result in learners' misunderstanding and not learning what teacher originally intends to communicate to them (Özkaya, Üce, Saricayir, & Sahin, 2006). Phillips further elaborated that, it would be difficult to teach scientific concepts specifically chemistry concepts without a firm grounding in the idea that learners actively construct their own knowledge based on their pre-existing knowledge and their own processes of making meanings out of information they obtain.

Conceptual Framework of the Study

The framework in Figure 2 was designed as a guide to the study. It was used to indicate the factors influencing the teaching and learning of organic qualitative analysis concept in the SHS. Teaching and learning of organic qualitative analysis concept are influenced by factors such as teachers' factors, challenges and students' factors. Teachers' factors' like content knowledge and instructional strategies. Challenges like teaching and learning resources and nature of organic chemistry content. Students' factors' such as prior knowledge (conception) and alternative conception affect their learning of OQA concept. From literature, teachers' deep and strong content knowledge and student's prior knowledge are important factors that help teachers and students respectively during teaching and learning of chemical

concepts such as OQA. These factors are necessary tools that affect the way students will conceptualise OQA concept (Adu-Gyamfi et al., 2018).

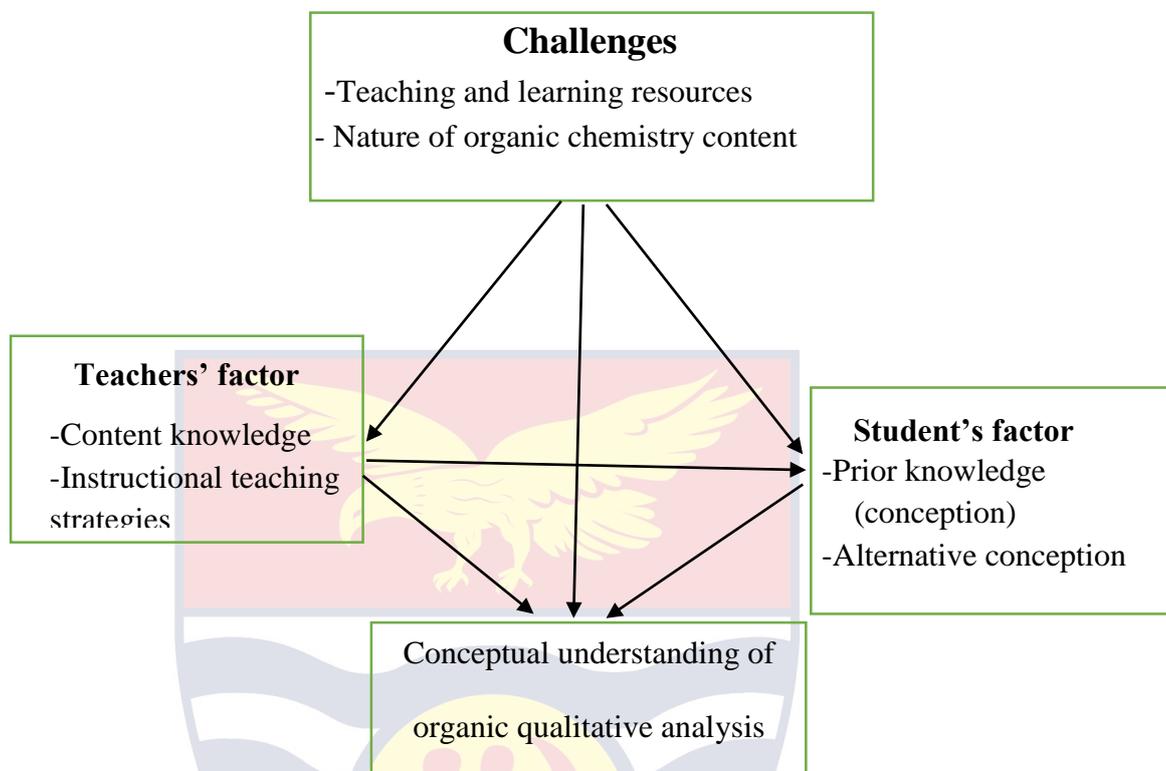


Figure 2: Conceptual framework on the teaching and learning of OQA concept

Source: Author's construct (Anim-Eduful, 2020).

Summary of Reviewed Literature

The literature review looked at both the theoretical and empirical aspects of the study under investigation as:

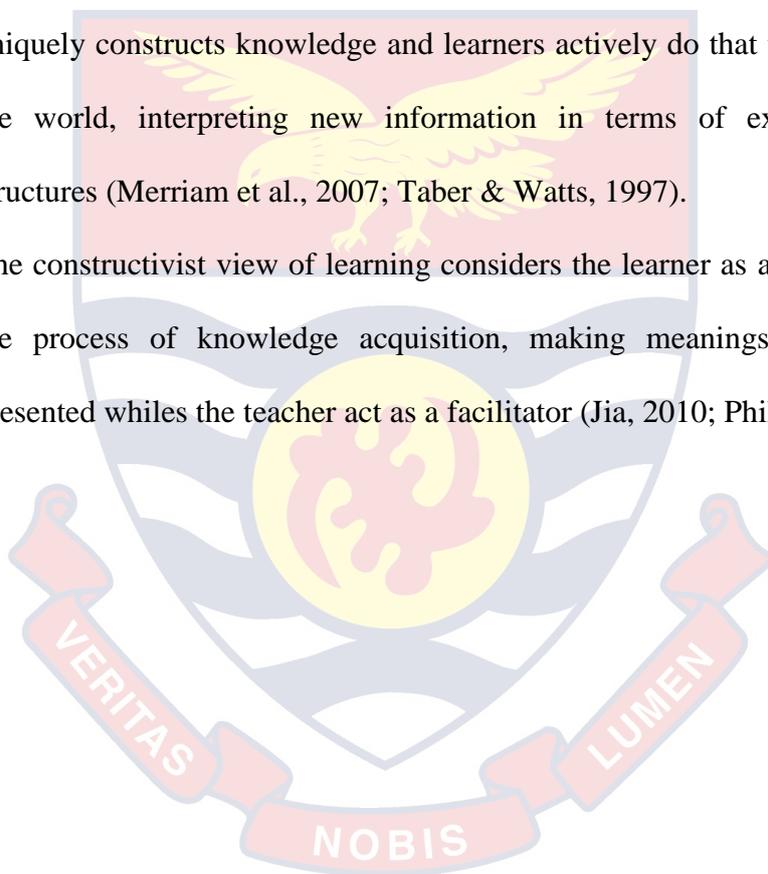
1. Students' have difficulties in understanding chemical concepts (Adu-Gyamfi & Ampiah, 2019; Adu-Gyamfi et al., 2015; 2017).
2. Compounds obtained from living things like sugars, proteins, amino acids, urea, vitamins and antibiotics are classified as organic (Bettelheim et al., 2004; Ebbing & Gammon, 2005).

- Adequate conceptual understanding of organic chemistry concepts are prerequisite for many professional programmes in human care (Hanson, 2017).
- Quantitative analysis finds the amount of each element or group present while qualitative analysis finds the type of each element or group present in a given sample of solution (Matthews, 2011).
- The qualitative organic analysis is basically functional group detection studied under aliphatic hydrocarbons; saturated (alkanes) and unsaturated (alkenes and alkynes). Aromatic hydrocarbons (benzene), alkanols, carbonyl compounds made up of alkanals (aldehydes) and alkanones (ketones), amides, carbohydrates (reducing sugars and non-reducing sugars) and proteins (MOE, 2010).
- Functional groups give organic compounds their characteristic chemical properties or groups of atoms in organic molecules that are particularly reactive and have characteristic properties (Atkins & Carey, 1990; Ebbing & Gammon, 2005; Fieser & Williamson, 1992).
- Alkanes do not give observable colour changes to purple colour of cold acidified or alkaline tetraoxomanganate(VII) (KMnO_4) solution. Alkanes are also unreactive to bromine water ($\text{Br}_2/\text{H}_2\text{O}$) or bromine in tetrachloromethane (Br_2/CCl_4) (Atkins & Beran, 1992; Bettelheim et al., 2004; Fieser & Williamson, 1992).
- Both alkenes and alkynes mainly undergo addition reactions, and decolourizes pink/purple colour acidified tetraoxomanganate(VII) (KMnO_4) solution and red-brown colour of bromine in carbon tetrachloride (Br_2/CCl_4) or bromine water ($\text{Br}_2/\text{H}_2\text{O}$) solution (Atkins & Beran, 1992; Fieser & Williamson, 1992).

9. Oxidation reaction of primary and secondary alkanols in the presence of acidified KMnO_4 or $\text{K}_2\text{Cr}_2\text{O}_7$ produces alkanal (aldehyde) and alkanones (ketones) respectively (Bettelheim et al., 2004, Vishnoi, 2009).
10. Benzene does not react with neither Br_2 in carbon tetrachloride (Br_2/CCl_4) nor tetraoxomanganate(VII) (KMnO_4) solution (Bettelheim et al., 2004).
11. Alkanoic acid functional groups are tested qualitatively by reacting with aqueous Na_2CO_3 or NaHCO_3 to evolve CO_2 gas effervescence (Morrison & Boyd, 1992; Zumdahl & Zumdahl, 2003).
12. Aldehydes (alkanals) and ketones (alkanones) contain the carbonyl functional group ($\text{C}=\text{O}$). Both aldehydes and ketones will produce yellow (orange) precipitate when drops of Brady's reagent (2, 4-dinitrophenylhydrazine) is added to form 2, 4-dinitrophenylhydrazone (Fieser & Williamson, 1992).
13. Aldehydes reduce the complex silver ion to silver metal to form silver mirror on the sides of the test tube. Ketones will not react with this reagent (Atkins & Beran, 1992).
14. Aldehydes produce a deep violet-red colour immediately whiles with ketones, the appearance of the violet colour takes time (Vishnoi, 2009).
15. Alkanals and alkanones are reduced to produce primary and secondary alkanols respectively in the presence of sodium borohydride or tetrahydridoborate (III) (NaBH_4) in ethanol or lithium aluminiumhydride or tetrahydridoaluminate (III) (LiAlH_4) in ether (Atkins & Beran, 1992).
16. Alkanoic acids also react with an alkanol in the presence of concentrated tetraoxosulphate(VI) acid (H_2SO_4) to form an ester (alkylalkanoate) and water molecules in esterification which is accompanied with sweet fruity smell (Fessenden & Fessenden, 1994).

17. Esters hydrolyse to produce alkanol and alkanoic acids (Fesssedden & Fessenden, 1994).
18. The amide functional group can be detected qualitatively by reacting the solution containing amide with an aqueous sodium hydroxide (NaOH) with heat leading to evolution of pungent smell gas called ammonia (NH₃) which is basic by nature (Morrison & Boyd, 1992).
19. The ultimate goal of science teaching is for conceptual understanding (Konicek-Moran & Keeley, 2015), and meaningful science learning requires conceptual understanding rather than memorisation (Adadan, Trundle & Irfing, 2010).
20. Teachers should always know students pre-existing knowledge before they introduce new concepts (Adu-Gyamfi et al., 2020).
21. Chemistry teachers should use more rigorous experimental instructional teaching strategies to teach qualitative analysis for development of conceptual understanding by students (Aregawi & Meressa, 2017; Hofstein & Mamlok-Naaman, 2007).
22. Teachers' deep and strong content knowledge is a necessary tool in a constructivist classroom because they provide students with opportunities to develop deep understanding of concepts, internalize the concepts, and develop complex cognitive structures for connections to other bodies of knowledge (Adu-Gyamfi et al., 2018).
23. Use of most appropriate and convenient structured instructional strategies when teaching enhances learners' conceptual understanding and designed and developed specific pedagogical content knowledge also enhance teachers' delivery (Adu-Gyamfi et al., 2018; Chittleborough & Mamiala, 2008).

24. Factors such as instructional laboratory lessons, students' prior knowledge, teacher content knowledge, and time constraint contribute to students' success in conceptualizing organic chemistry (Mahajan & Singh, 2005).
25. Length of content, quality of students', teachers' knowledge of concept and instructional strategies are issues that prevent effective instruction of chemistry concepts (Adu-Gyamfi et al., 2018).
26. Constructivist theory of learning acknowledges that each individual learner uniquely constructs knowledge and learners actively do that to make sense of the world, interpreting new information in terms of existing cognitive structures (Merriam et al., 2007; Taber & Watts, 1997).
27. The constructivist view of learning considers the learner as an active agent in the process of knowledge acquisition, making meanings of information presented while the teacher act as a facilitator (Jia, 2010; Phillips, 2007).



CHAPTER THREE

RESEARCH METHODS

This chapter provides detailed description of the methodology used in this study. This includes the research design, population, sample and sampling technique, research instruments, data collection procedure, and data processing and analysis. The chapter provides information on how the reliability and validity of the instruments were determined. Data collected with the research instruments were used to determine the chemistry teachers' and students' level of conceptual understanding and their difficulties in conceptualising organic qualitative analysis.

Research Design

This study made use of explanatory sequential mixed methods design. This approach combines both quantitative and qualitative methods of research. This mixed methods research was a systematic integration of quantitative and qualitative methods in a single study for purposes of obtaining a better picture and an in-depth understanding (Creswell, 2012) of teachers' and students' conceptual understanding on organic qualitative analysis. Mixed methods in this research acknowledged that all methods have inherent biases and a weakness; that using a mixed methods approach increased the possibility of the data collected being richer, more meaningful, and more importantly, being useful in answering the research questions (Creswell, 2014) on teaching and learning of organic qualitative analysis. This design was highly popular and implied collecting and analysing first, quantitative data and then, qualitative data in two consecutive phases within one study (Ivankova, Creswell, & Stick, 2006). By the use of cross-sectional survey, this explanatory sequential mixed

method design provided the study with both quantitative data (from a diagnostic test) and qualitative data (from interviews and observations) on chemistry teachers' and students' conceptual understanding in organic qualitative analysis. This design started with the collection and analysis of quantitative data. The first phase was followed by the subsequent collection and analysis of qualitative data. This phase of the study was designed so that it follows from the outcome of the first phase (Creswell & Clark, 2011) as presented in Figure 3.

Quantitative Stage

A cross-sectional survey was used to collect data from SHS 3 chemistry students and teachers from public schools in Central Region of Ghana. Diagnostic test developed by the researcher was used to collect the quantitative data by seeking the students' and teachers' level of understanding and difficulties in organic qualitative analysis. The quantitative data collected using the diagnostic test for both teachers and students provided an overview of their conceptual understanding and difficulties in organic qualitative analysis. The quantitative data was analysed to provide information for the second stage of the explanatory sequential design.

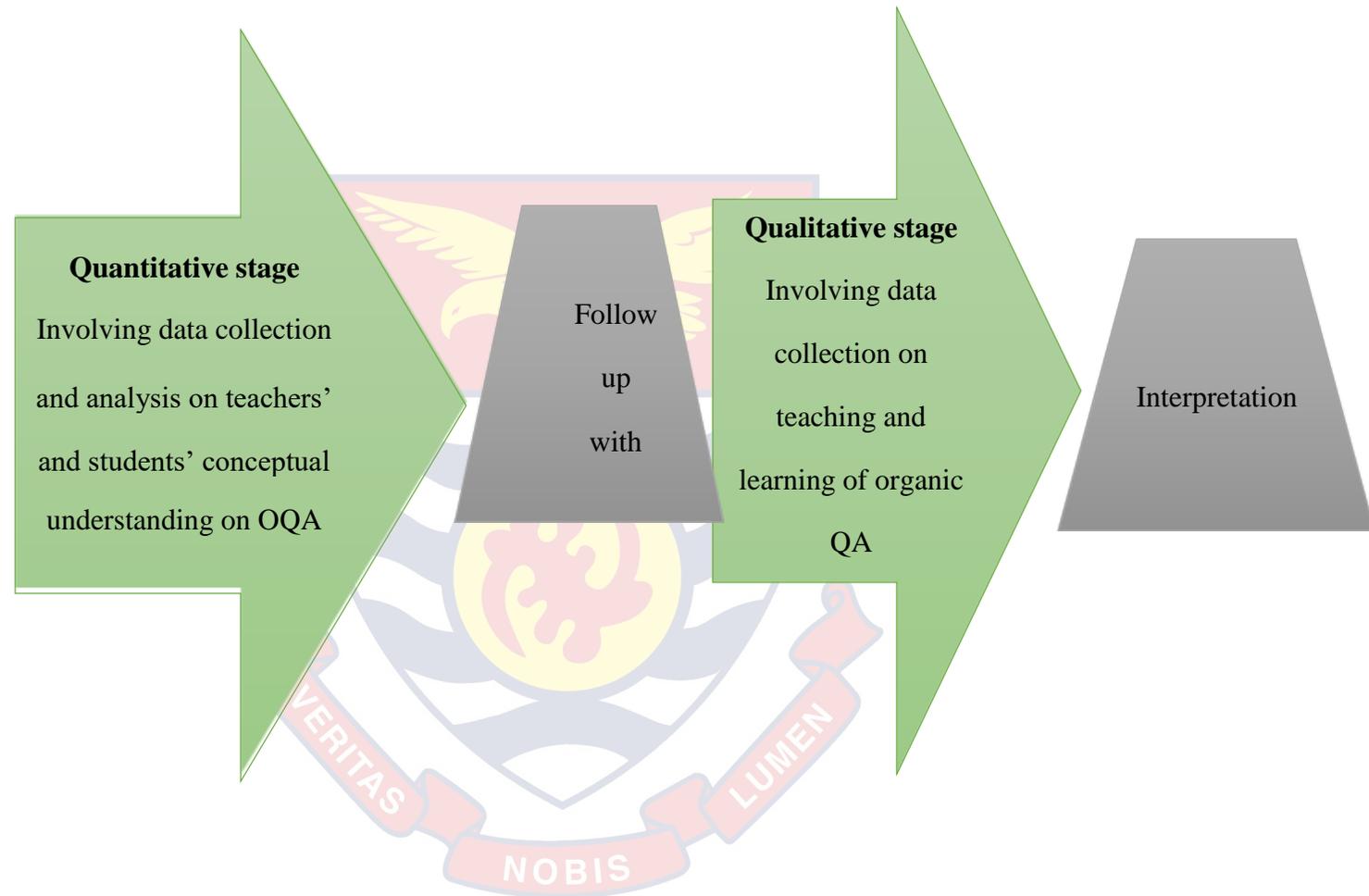


Figure 3: Explanatory sequential mixed methods design adapted from Creswell (2014).

Source: Creswell (2014).

Qualitative Stage

Qualitative stage was used to collect qualitative data from SHS 3 chemistry students through interviews. This was based on their general performance in the diagnostic test administered to them by the researcher. The purpose was to help ascertain the learning difficulties, problems, and students' expectations before and after lessons on organic qualitative analysis. Qualitative stage was also used to collect qualitative data from chemistry teachers using interviews. This was also based on the diagnostic test administered to them. The purpose was to explore teachers' problems and their intentions for teaching organic qualitative analysis. The qualitative data collected from both chemistry teachers and students were refined and explained to explore participants' views in more depth on teaching and learning of qualitative analysis. Based on the teacher interviews an observation checklist was designed. The purpose was to have an instrument for case studies on teaching of QA in some selected schools.

Interpretation Stage

Quantitative data collected using the diagnostic test from both teachers and students were analysed and emerging issues about teachers' and students' conceptual understanding and difficulties discussed. The conceptual levels of teachers were compared to that of their students and the findings discussed to inform the definition of the problem with teaching and learning of organic qualitative analysis. This was followed with the use of the qualitative findings to explain the findings from the quantitative stage of the study. This was important because the qualitative findings gave better explanation to chemistry

teachers' and students' conceptual understanding and difficulties on organic qualitative analysis.

Population

There were 68 public SHS in Central Region in 2019/2020 academic year. Of the 68 schools, chemistry teachers and students from 55 schools that offer chemistry as an elective subject were used for the study. There were three male single-sex schools, three female single-sex schools, and 49 co-educational schools. Central Region was chosen for the study due to the school-types, proximity and researcher's familiarity within the area. It was estimated that, there were 120 SHS students at each level (SHS 1, 2 and 3) in all the 55 schools. This means that there were 6,600 chemistry students at each level making the total number of 19,800 chemistry students in all the 55 schools in the Central Region in 2019/2020 academic year. The target population for this study was all SHS 3 students offering elective chemistry for 2019/2020 academic year. This was because the SHS 3 chemistry students have studied the needed fundamentals of organic chemistry in the second year as stipulated in the MOE (2010) chemistry syllabus, and they were in a better position to contribute to the study.

With respect to the chemistry teachers it was estimated that, there were three chemistry teachers at each level (SHS 1, 2 and 3) teaching the subject. This implied that there were nine chemistry teachers in each school making a total of 495 teachers in all the 55 schools within Central Region. All chemistry teachers who have once taught organic chemistry were used for the study. This was because their experiences immensely contributed to the study.

Sampling Procedure

The sample selection process involved multi-stage sampling technique. In the first stage of the process of sampling, a stratified random sampling technique was used to classify the schools into Metropolitan schools, Municipal schools and District schools. This gave 10 Metropolitan schools, 16 Municipal schools, and 42 District schools. Stratified random sampling was used to stratify the 55 schools offering chemistry into categories of schools as Classes A, B and C to form three strata. Schools were classified into A, B, and C categories basically due to availability of infrastructure and teaching and learning resources. Class A schools have a better share of these characteristics than class B schools likewise Class B schools have more than Class C schools. These classes of schools were stratified into single-sex and co-educational schools. Stratified sampling followed by simple random sampling to select two schools from each stratum. There were six Class A schools made of three males single-sex and three females single-sex. There were 18 Class B schools and 31 Class C schools which were all co-educational. Simple random sampling procedure was used to select two out of the six Class A schools, two out of the 13 Class B schools and two out of the 32 Class C schools. In all, six public schools participated in this study as shown in Table 1. Simple random sampling was used to select 50 SHS 3 students from male single-sex and also 50 from the female single-sex schools. This implied that 50 males and 50 females making a total of 100 students selected from the single-sex schools participated in the study.

Table 1: Number of Senior High Schools Classified into Classes A, B and within Central Region

Class of schools	Number of schools	Type of schools	Sampled schools
Class A	6	single-sex	2
Class B	18	coeducational	2
Class C	32	coeducational	2

Source: Field survey (Anim-Eduful, 2020)

Stratified sampling procedures followed by convenient sampling were used to select 163 students (50.3% males and 49.7% females) from the four selected coeducational schools. This implied that a total of 163 students (82 males and 81 females) from the four co-educational schools. In all, a total of 263 SHS students (132 males and 131 females) were involved in this study. Of the 263 students, 38% were from class A, 24% from class B and 38% from class C.

Purposive sampling technique was used to select all chemistry teachers in the schools to participate in the study. Purposive sampling techniques was applied to select one teacher each from four schools for the interviews and lesson observations. This is because teachers in other two schools at the time of data collection, were not teaching but revising with their students, hence their inability to organise a lesson for observations. Any teacher selected for interviews and lesson observations was teaching chemistry and was willing to participate in the research. This is because the purpose of the lesson observations was to determine whether the teacher interviewed practices what he/she professed during the one-on-one interview with the researcher. In all, 47 teachers were involved in the study from the six schools.

Data Collection Instruments

Diagnostic tests, interviews, and observations were the main research instruments for the study. These were:

1. Organic Qualitative Analysis Diagnostic Test for Students (OQADTS)
2. Organic Qualitative Analysis Diagnostic Test for Teachers (OQADTT)
3. Student Interview Guide on Organic Qualitative Analysis (SIGOQA)
4. Teacher Interview Guide on Organic Qualitative Analysis (TIGOQA)
5. Observation Checklist on Teaching Organic Qualitative Analysis (OCTOQA)

Diagnostic Tests

The diagnostic test (OQADTS and OQADTT) were in two sections (Appendices A and B). Section A sought for biodata of respondents: age, sex, class of school. Section B was made of nine two-tier four-option multiple choice test items. Students and teachers were required to correctly respond to each item by selecting one of the four options with a reason. The reason provided for selecting a particular option helped to explore conceptual understanding of students and teachers on the test. Two tests items were not multiple-choice but essay-type. The two items involved detection and analysis of functional group with organic reagents. Here, chemistry students' and teachers' conceptual understanding and difficulty in conceptualising functional group were explored. That is their ability to:

1. identify some organic functional groups like alkenes, alkynes, alkanols, benzene, alkanolic acids, and alkylalkanoates.
2. write observation that will be envisaged when known oxidising and reducing agents reacts with certain organic compounds.

Validity and reliability of OQADTS and OQADTT: The two diagnostic test items for students and teachers were similar and were constructed by the researcher. In the process of designing the test, the items were compared to standardised questions on functional group detections and organic reaction questions in chemistry textbooks and questions set by the WAEC for the West African Secondary School Certificate Examinations. The purpose of this was to ensure the content validity of the instrument. To also ensure face validity of the instrument, it was shown to two colleague chemistry teachers and a science education lecturer from the Department of Science Education, University of Cape Coast for an expert advice and critique on the content. This helped improve the quality of OQADTS and OQADTT items before they were pilot-tested with 30 students and 10 teachers from senior high schools in the Sekondi-Takoradi Metropolis of Western Region. This is because the schools for the pilot testing were considered to possess similar characteristic with the schools that were selected for the main study in Central Region. The pilot-testing of OQADTS and OQADTT helped determine the difficulty and discrimination indices of the test items, which in turn helped improve on the internal consistency of the instrument.

The pilot-tested items were subjected to item analysis, hence test items found too easy or too difficult were deleted. For OQADTS, Item 14 (an alkanol which undergoes complete oxidation reaction to produce alkanone) was modified into an alkanol which undergoes complete oxidation reaction to produce alkanone. Also, the same item for OQADTT was Item 20, which was modified as it was done in OQADTS. For OQADTS, Items 5, 7, 8, 9, 13, 17 and 18 were deleted. These items measured detections of benzene, alkanols,

amides, alkanolic acids, combustion reactions of hydrocarbons, alkene and aldehyde respectively. These items were deleted because they measured the same organic functional group intended to by other items and also, found in the essay test items. After deletion of those items, Kuder-Richardson (KR) 21 coefficient of reliability for OQADTS and OQADTT were calculated as 0.81 (Appendix F) and 0.74 (Appendix G) respectively. These (KR) 21 values indicated that the two diagnostic test items were reliable.

Interview Guides

Students and teachers involved in this study were interviewed using SIGOQA (Appendix C) and TIGOQA (Appendix D) respectively and this sought to determine from students and teachers experiences during teaching and learning of organic qualitative analysis. SIGOQA was a semi-structured interview guide. This was in two Sections, A and B. Section A was made of five items that sought to determine students' expectations and experiences before an organic qualitative chemistry lesson and Section B was made of four items that sought to determine whether students' expectations were met and experiences they have had after an organic qualitative lesson. This helped the researcher to delve deeper and obtain an in-depth understanding into processes students experience during their learning of QA. For the SIGOQA, there were nine items in all, where Items 1- 5 were the interview items before the lessons and Items 6- 9 were those after the lesson on organic qualitative analysis (Appendix C).

TIGOQA (Appendix D) was also a semi-structured interview guide type developed by the researcher for chemistry teachers and this sought to determine the teachers' experiences and expectations during their teaching of

organic qualitative analysis. TIGOQA was in two sections, A and B. Section A consisted of five items that sought determine teachers' experiences and expectations prior to an organic qualitative analysis lesson. Section B consisted of three items that sought to determine teachers' teaching experiences after an organic qualitative lesson. The purpose was to help the researcher to obtain in-depth understanding into teachers' experiences and best practices in teaching of organic QA. For the TIGOQA, there were eight items in all, where Items 1- 5 were used prior to lessons and Items 6- 8 used after the lesson on organic qualitative analysis.

Validity and reliability of TIGOQA and SIGOQA: TIGOQA and SIGOQA were given to an experienced chemistry educator from the Science Education Department, University of Cape Coast and two SHS colleague teachers to judge its content, and also cross check the items for honesty and clarity. The intent of these processes was to validate the interview guide, and suggestions from these experts helped improve the quality thereof. In using TIGOQA and SIGOQA, the basic areas were strictly adhered to as I moved from one teacher to another and same was done to the students. During the interviews, I made sure my personal views and experiences did not influence the views of teachers, recorded, and used only responses of teachers interviewed. I further avoided asking too many questions at a go and made it more interactive. Themes were generated from the views of teachers and students on teaching and learning of organic QA. The themes were given to some selected teachers to critique and later for a peer review. In attempt of reporting the views of teachers and students, sufficient data were provided under each theme for readers to make their own inferences.

Observation Checklist on Teaching Organic Qualitative Analysis (OCTOQA)

An observation checklist was designed (Appendix E) by the researcher after interactions with chemistry teachers to determine how they teach organic qualitative analysis. The intent of observation checklist was to confirm what teachers professed to do and what they actually practice in lessons on organic qualitative analysis, and also determine to what extent do these teaching practices influence on their students' conceptual understanding.

OCTOQA was in two sections, A and B. Section A sought to find out general information about teachers; sex, number of years in teaching chemistry, and duration for the lesson. Number of students in the class was also in Section A. Section B helped to explore how teachers teach organic QA to students in a lesson on organic QA. For the OCTOQA, there were 10 items in all, where Items 1-4 consisted of general information and Items 5-10 consisted of expectations in relation to the presence or other wise of what teachers professed to teach.

Validity and reliability of OCTOQA: To check for the validity of this instrument, a lecturer from Department of Science Education, University of Cape Coast, was given the checklist for expert vetting on the content and the constructs.

Suggestions and comments were used to modify the checklist. The researcher ensured that the outcome of the lessons through observation was neither understated nor overstated. The outcomes of observation were not pre-empted prior to the lessons.

Data Collection Procedures

An introductory letter from the Head of Science Education Department, University of Cape Coast was collected, and then the researcher visited the selected schools. Permission was then sought from the heads of the selected schools to undertake the study. The heads of Science Departments and heads of Chemistry Units were all briefed on the purpose of the study to establish a good rapport with the authorities and teachers for a smooth conduct of the study. The researcher first found out if chemistry teachers have covered enough on organic chemistry in each school. Selected schools that had not covered enough were exempted from the study. Other schools were made to replace those selected but exempted schools. This is because their students were not in a better position to contribute to the study. The administration of the research instruments was done by me in order to ensure that all rules of engagement were properly adhered to, especially the administration of the OQADTS and OQADTT. This helped to prevent possible malpractices so that true reflection of teachers and students were obtained. Quantitative data were collected using the diagnostic test for both teachers (OQADTT) and students (OQADTS). The quantitative data was analysed and emerging issues about teachers' and students' conceptual understanding and difficulties discussed. The conceptual levels of teachers were compared to that of their students and the findings discussed to inform the definition of the problem with teaching and learning of organic QA.

The quantitative data collection was followed with collection of qualitative data using interview (SIGOQA and TIGOQA) and observation checklist (OCTOQA). This was important because the qualitative findings gave better

explanation to chemistry teachers' and students' conceptual understanding and difficulties in organic QA. The teacher interviews informed the construction of OCTOQA. The OCTOQA was used to observe some selected lessons on organic QA. There were interactions with students and teachers before and after each lesson. The purpose was to find out the expectations and satisfaction of students and teachers before and after each lesson.

Data Processing and Analysis

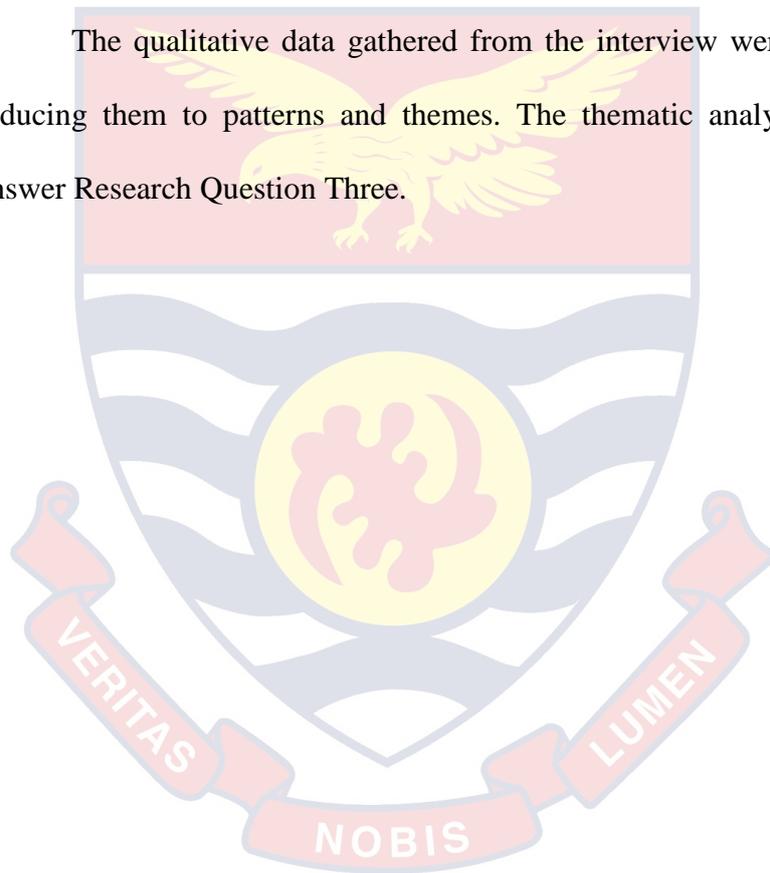
The items on diagnostic tests for both teachers and students scored a maximum of 2 marks. This gave a total of 18 marks for the nine items. Two essay type test items scored a total of 26 marks. In all, the diagnostic test for both teachers and students had a total score of 44 marks. Structure of level of understanding were adapted from previous studies in the area of conceptual understanding (Ültay & Çalik, 2016) and modified to suit this study. Students' and teachers' responses on both tiers correctly were awarded 2 marks; those who responded to one of the tiers (content or reason) correctly were awarded 1 mark; and those who responded to both tiers incorrectly were awarded 0. The three levels of conceptual understanding were;

1. Full scientific understanding is the first level that goes with correct content and reason responses,
2. Partial scientific understanding is the second level that goes with correct responses for either content or reason but not both, and
3. No scientific understanding is the third level that goes with incorrect responses for both content and reason.

Percentages, means, and standard deviations were used to answer the Research Question One. The independent-samples t-test was used to test for

the difference in general performance of chemistry teachers from their students. For Research Question Two, the reasons given by both teachers and students were open coded and constantly compared. I then made meaning of theirs and generated themes out of them. Sample statements from both teachers and students were used to support presentations under the themes. The explanations from teachers and students were grouped as alternative conceptions and factual difficulties.

The qualitative data gathered from the interview were transcribed by reducing them to patterns and themes. The thematic analysis was used to answer Research Question Three.



CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presented the results and discussion of the findings from the study on teachers' and students' conceptual understanding on OQA. The results are from the analyses of the data collected with QQADT for both teachers and students, interview guides, and observation checklist structured on teaching and learning of OQA. The results are presented using the research questions as a guide.

Research Question One: What different is chemistry teachers' level of conceptual understanding in organic qualitative analysis from their students?

Levels of Teachers' and Students' Conceptual Understanding on OQA

Research Question 1 sought explore how different teachers' level of conceptual understanding in OQA is from their students. To achieve this, similar OQA diagnostic test items were given to 263 SHS 3 students and 47 teachers. General performance of chemistry teachers and students on the OQA test were then compared. In general, teachers demonstrated partial scientific understanding and students, no scientific understanding on OQA test. This is because the mean scientific understanding of teachers on all items was 0.72 and that of students, 0.30. The results on levels of conceptual understanding of students on QQADST and that of teachers on QQADTT are presented in Tables 2 and 3 respectively.

Table 2: Levels of Students' Conceptual Understanding in Organic Qualitative Analysis (N= 263)

Item	Understanding level						M	SD
	No Scientific Understanding		Partial Scientific Understanding		Full Scientific Understanding			
	n	%	n	%	n	%		
hydrocarbons								
6	179	68.1	67	25.5	17	6.5	0.92	0.606
5	90	34.2	104	39.5	69	26.2	0.88	0.775
10	134	51.0	103	39.2	26	9.9	0.59	0.664
12	156	59.3	91	34.6	16	6.1	0.47	0.610
α 14B	208	79.1	0	0	55	20.9	0.42	0.815
β 14B	213	81.0	0	0	50	19.0	0.38	0.786
15 β	231	87.8	0	0	32	12.2	0.24	0.655
18	211	80.2	39	14.9	13	4.9	0.25	0.535
8	140	53.2	90	34.2	33	12.5	0.59	0.703
21	230	87.5	20	7.6	13	4.9	0.17	0.494
alkanols								
9	168	63.9	76	28.9	19	7.2	0.43	0.626
α 14D	223	84.8	0	0	40	15.2	0.30	0.720
β 14D	217	82.5	0	0	46	17.5	0.35	0.761
15 α	213	81.0	0	0	50	19.0	0.38	0.786
16	207	78.7	52	19.8	4	1.5	0.23	0.455
20	255	97.0	0	0	8	3.0	0.06	0.328
alkanoic acid								
11	101	38.4	120	45.6	42	16.0	0.78	0.704
13	156	59.3	96	36.5	11	4.2	0.45	0.576
α 14A	210	79.8	0	0	53	20.2	0.40	0.799

Table 2: (Continued)

α 14E	226	85.9	0	0	37	14.1	0.28	0.697	
β 14A	210	79.8	0	0	53	20.2	0.40	0.804	
β 14E	225	85.6	0	0	38	14.4	0.29	0.705	
19	242	92.0	0	0	21	8.0	0.16	0.534	
alkylalkanoates									
7	87	33.1	99	37.6	77	29.3	0.96	0.790	
α 14C β 14C	222	84.4	0	0	41	15.6	0.31	0.727	
15 γ	210	79.8	0	0	53	20.2	0.40	0.804	
	216	82.1	0	0	47	17.9	0.35	0.756	
Amides									
17	223	84.8	29	11.0	11	4.2	0.19	0.491	
Alkanals and alkanones									
22	257	97.7	5	1.9	1	0.3	0.03	0.183	

Source: Field data (Anim-Eduful, 2020)

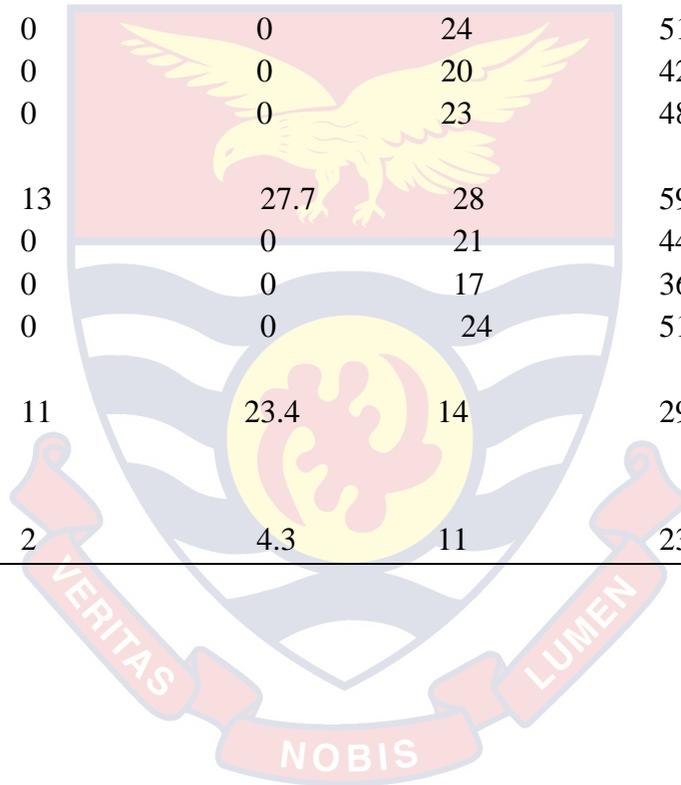
Table 3: Levels of Teachers' Conceptual Understanding in Organic Qualitative Analysis (N= 47)

Item	Understanding level						M	SD
	No Scientific Understanding		Partial Scientific Understanding		Full Scientific Understanding			
	n	%	N	%	n	%		
hydrocarbons								
6	12	25.5	10	21.3	25	53.2	1.28	0.852
5	6	12.8	13	27.7	28	59.6	1.47	0.718
10	5	10.6	17	36.2	25	53.2	1.43	0.683
12 α 14B	23	48.9	15	31.9	9	19.1	0.70	0.778
β 14B	22	46.8	0	0	25	53.2	0.89	1.005
15 β	25	53.2	0	0	22	46.8	0.94	1.009
18	23	48.9	0	0	24	51.1	1.02	1.011
	22	44.7	19	40.4	6	12.8	0.66	0.700
8	5	10.6	17	36.2	25	53.2	1.43	0.683
21	21	44.7	7	14.9	19	40.4	0.96	0.932
alkanols								
9	15	31.9	18	38.3	14	29.8	0.98	0.794
α 14D β 14D	23	48.9	0	0	24	51.1	1.02	1.011
15 α	26	55.3	0	0	21	44.7	0.89	1.005
16	18	38.3	0	0	29	61.7	1.23	0.983
20	24	51.1	17	36.2	6	12.8	0.62	0.709
	27	57.4	0	0	20	42.6	0.85	1.000
alkanoic acid								
11	7	14.9	19	40.4	21	44.7	1.30	0.720
13	17	36.2	13	27.7	17	36.2	1.00	0.860
α 14A	22	46.8	0	0	25	53.2	1.06	1.009

Table 3: (Continued)

α 14E	24	51.1	0	0	23	48.9	0.98	1.011
β 14A	23	48.9	0	0	24	51.1	1.02	1.011
β 14E	27	57.4	0	0	20	42.6	0.85	1.011
19	24	51.1	0	0	23	48.9	0.98	1.011
alkylalkanoates								
7	6	12.8	13	27.7	28	59.6	1.47	0.718
α 14C	26	55.3	0	0	21	44.7	0.94	1.009
β 14C	30	63.8	0	0	17	36.2	0.72	0.971
15 γ	23	48.9	0	0	24	51.1	1.02	1.011
amides								
17	22	46.8	11	23.4	14	29.8	0.83	0.868
alkanals and alkanones								
22	34	72.3	2	4.3	11	23.4	0.51	0.856

Source: Field data (Anim-Eduful, 2020)



To ascertain that propane readily dissolves in tetrachloromethane, Item 6 was used. From Table 2, 67(25.5%) of the students at a mean of 0.92 (SD=0.606) demonstrated partial scientific understanding that propane readily dissolves in tetrachloromethane. This indicates that 68.1% students had no scientific understanding and only 6.5% fully understood the concept. Further on this concept, results from Table 3 show that 21.3% of the teachers at a mean of 1.28 (SD=0.852) demonstrated partial scientific understanding that propane readily dissolves in tetrachloromethane. This indicates that 25.5% teachers had no scientific understanding and 53.2% had full understanding of the concept. Hence, teachers and their students have partial scientific understanding that propane readily dissolves in tetrachloromethane.

To ascertain that alkenes and alkynes are organic compounds that usually undergo addition reactions, Item 5 was used. From Table 2, 104 (39.5%) of the students at a mean of 0.88 (SD=0.775) demonstrated partial scientific understanding that alkenes and alkynes are organic compounds that usually undergo addition reactions. This indicates that 34.2% students had no scientific understanding and 26.2% fully understood the concept. Further on this concept, results from Table 3 show that, 27.7% of the teachers at a mean of 1.47 (SD=0.718) demonstrated partial scientific understanding that alkenes and alkynes are organic compounds that usually undergo addition reactions. This indicates that 12.8% teachers had no understanding and 59.6% had full scientific understanding of the concept. Hence, teachers, like their students, have partial scientific understanding that alkenes and alkynes are organic compounds that usually undergo addition reactions.

On Item 10, the results from Table 2 show that 103(39.2%) of the students at a mean of 0.59 (SD=0.664) demonstrated partial scientific understanding that ethene is an organic compound which decolorizes both Br_2/CCl_4 and acidified KMnO_4 . This indicates that only 9.9% had full scientific understanding and 51.0% had no understanding. Further on this concept, results from Table 3 show that, 36.2% of the teachers at a mean of 1.43 (SD=0.683) demonstrated partial scientific understanding. This indicate that 53.2% fully understood and 10.6% had no understanding. Hence, teachers, like their students, have partial scientific understanding that ethene is an organic compound that decolorizes both Br_2/CCl_4 and acidified KMnO_4 .

To ascertain that propene gives brown colour solution with alkaline potassium tetraoxomanganate(VII), Item 12 was used. From Table 2, the results show that 156(59.3%) of the students at a mean of 0.47 (SD=0.610) demonstrated no scientific understanding that propene gives brown colour solution with alkaline potassium tetraoxomanganate (VII). This indicates that 34.6% students partially understood while only 6.1% fully understood the concept. Also, on this concept results from Table 3 show that, 31.9% of the teachers at a mean of 0.70 (SD=0.778) demonstrated partial scientific understanding that propene gives brown colour solution with alkaline potassium tetraoxomanganate(VII). This indicates that 48.9% teachers had no understanding and 19.1% had full scientific understanding of the concept. Hence, teachers, unlike their students who have no understanding, have partial scientific understanding that propene gives brown colour solution with alkaline potassium tetraoxomanganate(VII).

On Item $\alpha 14B$, the results from Table 2 show that 208(79.1%) of the students at a mean of 0.42 (SD=0.815) demonstrated no scientific understanding that propene is formed when propanol is dehydrated in the presence of concentrated tetraoxosulphate(VI) acid and heat. This indicates that 20.9% students had full scientific understanding. Also, on this same concept results from Table 3 show that, none of the teachers at a mean of 0.89(SD=1.005) demonstrated partial scientific understanding and 46.8% had no scientific understanding and 53.2% demonstrated full scientific understanding. Hence, teachers, unlike their students who have no scientific understanding, have no partial scientific understanding but full understanding that, propene is formed when propanol is dehydrated in the presence of concentrated tetraoxosulphate(VI) acid and heat.

To ascertain that an alkene functional group is present in propene, Item $\beta 14B$ was used. From Table 2, 213(81.0%) of the students at a mean of 0.38 (SD=0.786) demonstrated no scientific understanding and only 19.0% students fully understood that an alkene functional group is present in propene. Further on this concept, results from Table 3 show that, none of the teachers at a mean of 0.94 (SD=1.009) demonstrated partial scientific understanding. This indicates that, 46.8% teachers fully understood the concept and 53.2% teachers did not. Hence, teachers, unlike their students who demonstrate no scientific understanding, have no partial scientific understanding but full scientific understanding that an alkene functional group is present in propene.

From Table 2, on Item 15β results show that, as high as 231(87.8%) of the students at a mean of 0.24 (SD=0.655) demonstrated no scientific understanding and only 12.2% students fully understood the concept that

dehydration is the type of chemical reaction involved in the conversion of propanol to propene. Also, on this concept results from Table 3 show that, none of the teachers at a mean of 1.02 (SD=1.011) demonstrated partial scientific understanding and 51.1% fully understood and 48.9%, no scientific understanding that, dehydration is the type of chemical reaction involved in the conversion of propanol to propene. Hence, teachers, unlike their students who have no scientific understanding, demonstrate no partial understanding but full understanding that, dehydration is the type of chemical reaction involved in the conversion of propanol to propene.

To ascertain that 2-butyne is unsaturated and will decolorise bromine solution, Item 18 was used. From Table 2, 211(80.2%) of the students at a mean of 0.25 (SD=0.535) demonstrated no scientific understanding that 2-butyne is unsaturated and that it decolorises bromine solution. This indicates that 14.9% students partially understood and only 4.9% students fully understood the concept. Also, on this concept results from Table 3 show that, 40.4% of the teachers at a mean of 0.66 (SD=0.700) demonstrated partial scientific understanding on the concept. This indicates that 46.7% teachers had no scientific understanding and 12.8% had full scientific understanding of the concept. Hence, teachers, unlike their students who have no scientific understanding, have partial scientific understanding that, 2-butyne unsaturated and can decolorise bromine solution.

To ascertain that complete hydrogenation of benzene gives cyclohexane, Item 8 was used. From Table 2, the results show that 90(34.2%) of the students at a mean of 0.59 (SD=0.703) demonstrated partial scientific understanding that complete hydrogenation of benzene gives cyclohexane.

This indicates that 53.2% students had no scientific understanding and only 12.5% fully understood the concept. Further on this concept, results from Table 3 show that, 36.2% of the teachers at a mean of 1.43 (SD=0.683) demonstrated partial scientific understanding that complete hydrogenation of benzene gives cyclohexane. This indicates that 10.6% teachers had no scientific understanding and 53.2% had full scientific understanding of the concept. Hence, teachers and their students have partial scientific understanding that complete hydrogenation of benzene gives cyclohexane.

On Item 21, results from Table 2 show that, as high as 230(87.5%) of the students at a mean of 0.17 (SD=0.494) demonstrated no scientific understanding that either bromine solution or acidified KMnO_4 is used to distinguish between benzene and ethene. This indicates that only 7.6% students had partial scientific understanding and only 4.9% fully understood the concept. Further on this concept, results from Table 3 show that, 14.9% of the teachers at a mean of 0.96 (SD=0.932) demonstrated partial scientific understanding that either bromine solution or acidified KMnO_4 is used to distinguish between benzene and ethene. This indicates that 44.7% had no scientific understanding and 40.4% fully understood the concept. Therefore, teachers, unlike their students who have no scientific understanding, have partial scientific understanding that either bromine solution or acidified KMnO_4 is used to distinguish between benzene and ethane.

On Item 9, results from Table 2 show that, 168(63.9%) of the students at a mean of 0.43 (SD=0.626) demonstrated no scientific understanding that secondary alkanol undergoes complete oxidation reaction to produce an alkanone. This indicates that only 7.2% students had full scientific

understanding and 28.9% had partial scientific understanding of the concept. Further on this concept, results from Table 3 show that, 38.3% of the teachers at a mean of 0.98 (SD=0.794) demonstrated partial scientific understanding. This indicate that, 29.8% teachers fully understood and 31.9% had no scientific understanding of the concept. Hence, teachers, unlike their students who have no understanding, have partial scientific understanding that secondary alkanol undergoes complete oxidation reaction to produce an alkanone.

To ascertain that ethanol and propanoic acid are produced when ethylpropanoate undergoes acid hydrolysis, Item α 14D was used. From Table 2, the results show that, 223(84.8%) of the students at a mean of 0.30 (SD=0.720) demonstrated no scientific understanding. This indicates that, 15.2% teachers fully understood the concept that ethanol and propanoic acid can be prepared when ethylpropanoate undergoes acid hydrolysis. Further on this concept, results from Table 3 show that, none of the teachers at a mean of 1.02 (SD=1.011) demonstrated partial scientific understanding. This indicates that, 48.9% teachers had no scientific understanding and 51.1% had full understanding of the concept. Hence, teachers, unlike their students who have no understanding, have no partial scientific understanding but a full scientific understanding that, ethanol and propanoic acid are produced when ethylpropanoate undergoes acid hydrolysis.

On Item β 14D, results from Table 2 show that, 217(82.5%) of the students at a mean of 0.35 (SD=0.761) demonstrated no scientific understanding. This indicates that only 17.5% students fully understood that alkanol and alkanonic acid functional groups that are present when

ethylpropanoate undergoes acid hydrolysis. Further on this concept, results from Table 3 show that, none of the teachers at a mean of 0.89 (SD=1.005) demonstrated partial scientific understanding. This indicates that, 44.7% teachers fully understood the concept and 55.3% teachers had no scientific understanding of the concept. Hence, teachers, unlike their students who have no scientific understanding, have no partial scientific understanding but full scientific understanding that alkanol and alkanolic acid functional groups are present when ethylpropanoate undergoes acid hydrolysis than their students.

To ascertain that that oxidation is the type of chemical reaction involved in the conversion of propanol to propanoic acid, Item 15 α was used. From Table 2, 213(81.0%) of the students at a mean of 0.38 (SD=0.786) demonstrated no scientific understanding. This indicates that, only 19.0% students fully understood the concept that oxidation is the type of chemical reaction involved in the conversion of propanol to propanoic acid. Also, on this concept the results from Table 3 show that, none of the teachers at a mean of 1.23 (SD=0.983) demonstrated partial scientific understanding on the concept. This indicates that most (61.7%) teachers had full scientific understanding on and 38.3% teachers had no understanding on the concept. Hence, teachers, unlike their students who have no scientific understanding, demonstrated no partial scientific understanding but full scientific understanding that oxidation reaction occurs in the conversion of propanol to propanoic acid.

On Item 16, the results from Table 2 show that, 207(78.7%) of the students at a mean of 0.23 (SD=0.455) demonstrated no scientific understanding that an alkanol reacts with yellow-coloured potassium

heptaoxodichromate(VI) solution to change green. This indicates that 19.8% students demonstrated partial scientific understanding and 1.5% students fully understood the concept. Also, on this concept the results from Table 3 show that, 36.2% of the teachers at a mean of 0.62 (SD=0.709) demonstrated partial scientific understanding of the concept. This indicates that 12.8% teachers fully understood and 51.1% teachers demonstrated no understanding of the concept. Hence, teachers, unlike their students who demonstrate no scientific understanding, have partial scientific understanding that an alkanol reacts with yellow-coloured potassium heptaoxodichromate(VI) solution changes to green.

To ascertain whether students and teachers understand that, yellow precipitate is formed when an alkanol is treated with hot solution of iodine in sodium hydroxide, Item 20 was used. From Table 2, as high as 255(97.0%) of the students at a mean of 0.06 (SD=0.328) demonstrated no scientific understanding on the concept. This indicates that, as low as 3.0% of the students fully understood the concept that yellow precipitate is formed when an alkanol is treated with hot solution of iodine in sodium hydroxide. Further on this concept, results from Table 3 show that, none of the teachers at a mean of 0.85 (SD=1.000) demonstrated partial scientific understanding of the concept. This indicates that 57.4% teachers demonstrated no scientific understanding and 42.6% teachers had full understanding on. Hence, teachers, unlike their students who demonstrate no scientific understanding, demonstrate no partial scientific understanding but full scientific understanding that yellow precipitate is formed when an alkanol is treated with hot solution of iodine in sodium hydroxide.

To ascertain that hydrogen gas is liberated when alkanolic acid reacts with sodium metal, Item 11 was used. From Table 2, the results show that, 120(45.6%) of the students at a mean of 0.78 (SD=0.704) demonstrated partial scientific understanding that hydrogen gas is liberated when alkanolic acid reacts with sodium metal. This indicates that 38.4% students demonstrated no scientific understanding and 16.0% fully understood the concept. Further on this concept, results from Table 3 show that, 40.4% of the teachers at a mean of 1.30 (SD=0.720) demonstrated partial scientific understanding on the concept. This indicates that 14.9% teachers demonstrated no scientific understanding and 44.7% teachers demonstrated full scientific understanding on the concept. Hence, teachers like their students demonstrate partial scientific understanding that hydrogen gas is liberated when alkanolic acid reacts with sodium metal.

On Item 13, results from Table 2 show that, 156(59.3%) of the students at a mean of 0.45 (SD=0.576) demonstrated no scientific understanding that, complete oxidation of propanol in the presence of oxidising agent, such as potassium heptaoxodichromate(IV) and heat produces propanoic acid. This indicates that 36.5% students demonstrated partial scientific understanding and only 4.2% students fully understood the concept. Further on this concept, results from Table 3 show that, 27.7% of the teachers at a mean of 1.00 (SD=0.860) demonstrated partial scientific understanding on the concept. This indicates that 36.2% teachers demonstrated no scientific understanding and 36.2% fully understood the concept. Hence, teachers, unlike their students who demonstrate no scientific understanding, have partial scientific understanding that complete oxidation of propanol in the presence of oxidising

agent such as potassium heptaoxodichromate(IV) and heat produces propanoic acid.

To ascertain whether students and teachers understand that propanoic acid is produced when propanol undergoes oxidation reaction in the presence of acidified potassium dichromate(VI), Item α 14A was used. From Table 2, the results show that, as high as 210(79.8%) of the students at a mean of 0.40 (SD=0.799) demonstrated no scientific understanding on the concept. This indicates that, 20.2% fully understood the concept that propanoic acid is produced when propanol undergoes oxidation reaction in the presence of acidified potassium dichromate(VI). Further on this concept, results from Table 3 show that, none of the teachers at a mean of 1.06 (SD=1.009) demonstrated partial scientific understanding on the concept. This indicates that, 46.8% teachers demonstrated no scientific understanding and 53.2% had full scientific understanding on the concept. Hence, teachers, unlike their students who demonstrate no scientific understanding, have no partial scientific understanding but full understanding that propanoic acid is produced when propanol undergoes oxidation reaction in the presence of acidified potassium dichromate(VI).

On Item α 14E, the results from Table 2 show that, 226(85.9%) of the students at a mean of 0.28 (SD=0.697) demonstrated no scientific understanding and 14.1% teachers fully understood that, both ethanol and propanoic acid are produced when ethylpropanoate undergoes acid hydrolysis. This indicates that none of the students demonstrated any partial scientific understanding on the concept. Further on this concept, results from Table 3 show that, none of the teachers at a mean of 0.98 (SD=1.011) demonstrated

partial scientific understanding on the concept. This indicates that, 51.1% teachers demonstrated no scientific understanding and 48.9% fully understood the concept. Hence, teachers, unlike their students who demonstrate no scientific understanding, have no partial scientific understanding but full scientific understanding that both ethanol and propanoic acid are produced when ethylpropanoate undergoes acid hydrolysis.

To ascertain that an alkanolic acid functional group is present when propanol undergoes oxidation reaction in the presence of acidified potassium dichromate(VI), Item β 14A was used. From Table 2, the results show that, as high as 210(79.8%) of the students at a mean of 0.40 (SD=0.804) demonstrated no scientific understanding on the concept. This indicates that, 20.2% students fully understood the concept. Further on this concept, results from Table 3 show that, none of the teachers at a mean of 1.02 (SD=1.011) demonstrated partial scientific understanding on the concept. This indicates that, 48.9% teachers demonstrate no scientific understanding and 51.1% had full understanding on the concept. Hence, teachers, unlike their students who demonstrate no scientific understanding, have no partial scientific understanding but full scientific understanding that, an alkanolic acid functional group is present when propanol undergoes oxidation reaction in the presence of acidified potassium dichromate(VI).

On Item β 14E, the results from Table 2 show that, 225(85.6%) of the students at a mean of 0.29 (SD=0.705) demonstrated no scientific understanding and 14.4% students fully understood that, both alkanol and alkanolic acid functional groups are present when ethylpropanoate undergoes acid hydrolysis. This indicates that none of the students demonstrated partial

scientific understanding on the concept. Further on this concept, results from Table 3 show that, none of the teachers at a mean of 0.85 (SD=1.011) demonstrated partial scientific understanding on the concept. This indicates that 57.4 % teachers demonstrated no scientific understanding and 42.6% fully understood the concept. Hence, teachers, unlike their students who demonstrate no scientific understanding, have no partial scientific understanding but full understanding that both alkanol and alkanolic acid functional groups are present when ethylpropanoate undergoes acid hydrolysis.

To ascertain whether teachers and students understand that, carbon (IV) dioxide is evolved when propanoic acid reacts with sodium hydrogentrioxocarbonate(IV), Item 19 was used. From Table 2, the results show that, as high as 242(92.0%) of the students at a mean of 0.16 (SD=0.534) demonstrated no scientific understanding and only 8.0% students fully understood the concept. This indicates that none of the students demonstrated partial scientific understanding on the concept. Further on this concept, results from Table 3 show that, none of the teachers at a mean of 0.98 (SD=1.011) demonstrated partial scientific understanding on the concept. This indicates that, 51.1% teachers demonstrated no scientific understanding and 48.9% teachers fully understood the concept. Hence, teachers, unlike their students who demonstrate no scientific understanding, have no partial scientific understanding but full understanding that, carbon(IV) dioxide is evolved when propanoic acid reacts with sodium hydrogentrioxocarbonate(IV).

To ascertain whether teachers and students understand that, ethyl methanoate is an ester and sweet scented, Item 7 was used. From Table 2, the

results show that, 99(37.6%) of the students at a mean of 0.96 (SD=0.790) demonstrated partial scientific understanding on the concept. This indicate that 33.1% students demonstrated no scientific understanding and 29.3% fully understood that, ethyl methanoate is an ester hence is sweet scented. Further on this concept, results from Table 3 show that, 27.7% of the teachers at a mean of 1.47 (SD=0.718) demonstrated partial understanding on the concept. This indicates that, 12.8% teachers demonstrated no scientific understanding and 59.6% teacher fully understood the concept. Hence, teachers and their students demonstrate partial scientific understanding that ethyl methanoate is an ester hence is sweet scented.

On Item α 14C, results from Table 2, 222(84.4%) of the students at a mean of 0.31 (SD=0.727) demonstrated no scientific understanding and 15.4% students fully understood that ethylpropanoate is produced when propanoic acid reacts with ethanol. This indicates that, none of the students demonstrated partial scientific understanding on the concept. Further on this concept, results from Table 3 show that, none of the teachers at a mean of 0.94 (SD=1.009) demonstrated partial scientific understanding on the concept. This indicates that, 55.3% teachers demonstrated no understanding and 44.7% fully understood that, ethylpropanoate is produced when propanoic acid reacts with ethanol. Hence, teachers, unlike their students who demonstrate no scientific understanding, have no partial understanding but full scientific understanding that, ethyl propanoate is produced when propanoic acid reacts with ethanol.

To ascertain whether teachers and students understand that, alkyl alkanoate functional group is present in a product formed from chemical reaction between propanoic acid and ethanol, Item β 14C was used. From

Table 2, the results show that 210(79.8%) of the students at a mean of 0.40 (SD=0.804) demonstrated no scientific understanding and only 20.2% students fully understood the concept. This indicates that, none of the students demonstrated partial scientific understanding on the concept. Further on this concept, results from Table 3 show that, none of the teachers at a mean of 0.72 (SD=0.971) demonstrated partial scientific understanding on the concept. This indicates that 63.8% teachers demonstrated no scientific understanding and 36.2% teachers fully understood the concept. Hence, teachers, unlike their students who demonstrate no scientific understanding, have no partial understanding but full understanding that, alkyl alkanoate functional group is present in a product formed from chemical reaction between propanoic acid and ethanol.

On Item 15 γ , results from Table 2 show that, 216(82.1%) of the students at a mean of 0.35 (SD=0.756) demonstrated no understanding and 17.9% fully understood that, the type of chemical reaction involved in the conversion of propanol to ethylpropanoate is esterification. This indicates that, none of the students demonstrated partial scientific understanding on the concept. Further on this concept, results from Table 3 show that, none of the teachers at a mean of 1.02 (SD=1.011) demonstrated partial scientific understanding on the concept. This indicates that, 48.9% teacher demonstrated no scientific understanding and 51.1% teachers fully understood the concept. Hence, teachers, unlike their students who demonstrate no understanding, have no partial understanding but full scientific understanding that, the type of chemical reaction involved in the conversion of propanol to ethylpropanoate is esterification.

On Item 17, results from Table 2, 223(84.8%) of the students at a mean of 0.19 (SD=0.491) demonstrated no scientific understanding that ammonia gas is evolved when amide is warmed with dilute sodium hydroxide solution. This indicates that only 4.2% teachers had full scientific understanding and 11.0% teachers partially understood the concept. Also, on this concept, results from Table 3 show that, 23.4% of the teachers at a mean of 0.83 (SD=0.868) demonstrated partial scientific understanding on the concept. This indicates that, 46.8% teachers demonstrated no scientific understanding and 29.8% teachers had full understanding on the concept. Hence, teachers, unlike their students who demonstrate no scientific understanding, have partial scientific understanding that ammonia gas is evolved when amide is warmed with dilute sodium hydroxide solution than their students.

To ascertain whether teachers and students have understanding that ammoniacal silver nitrate or Fehling's solution is used to distinguish between alkanals and alkanones, Item 22 was used. From Table 2, the results show that, as high as 257(97.7%) of the students at a mean of 0.03 (SD=0.183) demonstrated no understanding. This indicates that only 1.9% teachers had partial scientific understanding and as low as 0.3% students fully understood the concept. This indicates that, none of the students demonstrated partial understanding on the concept. Also, on this concept, results from Table 3 show that, only 4.3% of the teachers at a mean of 0.51 (SD=0.856) demonstrated partial understanding on the concept. This indicates that 72.3% teachers demonstrated no scientific understanding and 23.4% teachers had fully understood the concept. Hence, teachers, unlike their students who demonstrate no understanding, have partial understanding that, either

ammoniacal silvernitrate or Fehlings solutions can be used to distinguish between alkanals and alkanones.

To further explore the general level of conceptual understanding of teachers and their students on OQA, means were calculated out of the scores awarded for demonstration of full scientific understanding, partial scientific understanding, and no scientific understanding. The mean scores of teachers in the diagnostic test was 21.60 (SD=11.515) with minimum and maximum scores of 1 and 40 respectively out of the total score of 43 marks. The mean scores of students in the diagnostic test was 8.89 (SD=7.218) with minimum and maximum scores of 1 and 37 respectively out of the total score of 43 marks. These means implied that, two-thirds majority of the teachers demonstrated their conceptual understanding by scoring marks ranging between 10.09 and 33.12 out of the total score of 43 marks and two-thirds majority of their students demonstrated their conceptual understanding by scoring marks ranging between 1.67 and 16.18 out of a total score of 43 marks. To able to explore whether differences exist in the conceptual understanding of teachers and their students on OQA, the means were compared using the independent-samples t-test. The results of the t-test analysis are presented in Table 4.

Table 4: Independent-Samples t-test Results on Teachers' and Students' Level of Conceptual Understanding on Organic Qualitative Analysis

Category	N	Mean	SD	t	df	p
Teacher	47	21.60	11.515	-10.023	308	0.001*
Student	263	8.89	7.218			

* Significant, $p < 0.05$

Source: Field data (Anim-Eduful, 2020)

The independent-samples t-test was used because when the homogeneity of variance assumption was checked using Levene's test, and it was insignificant ($p = 0.001$). This means that the variances for the teachers and students are not the same thus equal variances not assumed. The results of the independent-samples t-test was used to test whether there was statistical significant difference in the conceptual understanding of students and teachers on OQA. The results from Table 4 show that there was statistical significant difference between the mean scores of students and teachers on the OQA concept. This is because mean score of teachers ($M = 21.60$, $SD = 11.515$) was higher to the students ($M = 8.89$, $SD = 7.218$, $t(308) = -10.023$, $p = 0.001$).

Results of the study indicate that students demonstrate no scientific understanding on organic functional groups detections as compared to teachers who demonstrate partial scientific understanding. Students' demonstration of no scientific understanding on OQA could be that they hardly spend time to learn on their own but only trust the information giving by their teachers (Mahajan & Singh, 2005), who themselves have partial understanding, leading

to rote learning (Stieff, 2007) of organic chemistry with little or no conceptual understanding (Bhattacharyya & Bodner, 2005) and then, they (students) finding it difficult to apply their previous knowledge and experiences on OQA (Smith & Ragan, 1999). Students demonstrate no scientific understanding, possibly because their teachers themselves could not demonstrate full understanding on OQA but partial understanding and that, teacher content knowledge is one of the factors that contributes to weak student conceptual understanding (Ferguson & Bodner, 2008). This no scientific understanding of students on OQA confirms the work of Bhattacharyya and Bodner (2005) that students demonstrate low conceptual understanding in organic chemistry even at the university level. Teachers demonstrating partial understanding on OQA may find it difficult to help students to relate the new information on OQA to previous experiences. If teachers have partial knowledge, then it would be difficult for them to influence their students develop full conceptual understanding (Sadler et al., 2013) on OQA using appropriate instructional strategies. Teachers and their students demonstration of low level of conceptual understanding on OQA is not only limited to hydrocarbons but nonhydrocarbons (such as alkanols, alkanolic acids, alkylakanoates, amides, alkanals, and alkanones) as well. This low level of conceptual understanding on detection of saturation and unsaturation means that teachers are not addressing the targeted specific objectives of the curriculum (MOE, 2010), where students are to test for saturation and unsaturation using acidified and alkaline purple $KMnO_4$, Br_2/H_2O . Teachers may not only have problems with enacting the curriculum (MOE, 2010) with appropriate pedagogical knowledge but may have problems of content knowledge of that they are

supposed to teach to students. This is also evident as teachers and their students have low conceptual understanding of test of benzene using cold dilute $KMnO_4$, Br_2/H_2O or $Br_2/CHCl_3$ and to test for alkanals and alkanones using 2, 4-dinitrophenylhydrazine, Fehling's or Benedict's solution and Tollen's reagent (ammoniacal silver nitrate). Teachers could be just transferring information (Jonassen et al., 1999) on organic chemistry from textbooks to their students with no meaningful learning from both sides. Teachers and their students may have not sufficient mental models (Konicek-Moran & Keeley, 2015) of OQA. This is because, teachers and their students have low or no conceptual understanding that, alkanols change yellow heptaoxidochromate(VI) solution green. Though there is statistical significant difference in the conceptual understanding of teachers and their students with teachers being on the high side however, since teachers demonstrate partial scientific understanding they could not have impact full scientific understanding to their students. Hence, the students involved in this study are true reflection of their teacher concept knowledge on OQA.

Research Question Two: How are teachers' alternative conceptions and factual difficulties on organic qualitative analysis different from their students?

Alternative Conceptions and Factual Difficulties on OQA

Research Question Two sought to unearth the difficulties chemistry teachers and students have in conceptualising organic qualitative analysis. To achieve this, teachers' and students' difficulties on OQA were categorized into alternative conceptions and factual difficulties. However, there were no alternative conceptions and factual difficulties provided by teachers and

students in some of the test items. Generally, the items on the diagnostic tests were very difficult to students with an index of 0.35 but moderately difficult to their teachers with an index of 0.66 with associated alternative conceptions and factual difficulties in most instances.

Item 5 was less difficult to students with an index of 0.63. Of the 263 students, 37.64% students' explanations were alternative conceptions and 1.90% explanations were of the factual difficulties category. The evidence of alternative conceptions and factual difficulties is:

Alternative conceptions: (i) alkenes and alkynes have very strong bonds hence undergo condensation reaction. An excerpt is: "*alkenes and alkynes undergo condensation reaction because the bonds which hold them is very strong*" (Student, 134).

(ii) alkenes are less reactive than alkynes and thus, undergo elimination and substitution reaction respectively. An excerpt is: "*alkynes are less reactive than alkenes and as a result undergo substitution reaction and elimination reaction respectively*" (Students, 65).

Factual difficulties: (i) alkenes and alkynes undergo addition reaction because of the carbon bond. An excerpt is: "*alkenes and alkynes have c-c bonds in them hence they undergo addition reaction to form products*" (Students, 53).

(ii) alkenes and alkynes undergo addition reactions to produce alkanols. An excerpt is: "*alkenes and alkynes undergo addition reaction because their end products are ethanol*" (Student, 164).

However, the concept was less difficult to teachers with an index of 0.87. Of the 47 teachers, none of them demonstrated any alternative conceptions but 27.66% teachers' explanations were in the category of factual

conceptions relating to alkenes and alkynes undergoing addition reactions. The evidence of factual difficulties in a teacher's explanations is:

Factual difficulties: (i) hydrocarbons undergo addition reaction. An excerpt is: “alkenes and alkynes are hydrocarbons hence undergo addition reactions” (Teacher, 23).

Item 6 was very difficult to students with an index of 0.32. Of the 263 students, 1.14% students' explanations were alternative conceptions and 24.33% were in the category of factual difficulties. The evidence of alternative conceptions and factual difficulties is:

Alternative conceptions: propane is unsaturated organic compound and contains only carbon-carbon bonds. An excerpt is “Propane is unsaturated compound because it contains c-c bonds that decolourizes both bromine in tetrachloromethane (Br_2/CCl_4) and acidified potassium tetraoxomanganate (VII) ($KMnO_4$) solutions” (Student, 216).

Factual difficulties: propane is a polar molecule hence dissolves in polar solvent. An excerpts is; “Propane is a polar molecule hence will readily dissolve in a polar organic solvent such as tetrachloromethane solution” (Student, 119).

However, the concept was lesson difficult to teachers with an index of 0.74. Of the 47 teachers, equal proportion (14.93%) of teachers' explanations were alternative conceptions and factual difficulties relating to the fact that propane readily dissolves in tetrachloromethane but not alkene and alkyne molecules. The evidence of alternative conceptions and factual difficulties is:

Alternative conceptions: alkenes and alkynes are polar compounds and thus, decolorize polar tetrachloromethane. An excerpt is: *alkenes and alkynes are polar compounds thus decolorize polar tetrachloromethane*” (Teacher, 6).

Factual difficulties: alkenes and alkynes usually undergo addition reaction because the pi bonds in the carbon-carbon double and triple bonds are very strong to break by tetrachloromethane solution. An excerpt is: *“alkenes and alkynes undergo addition reactions because pi bonds in the carbon-carbon double and triple bonds are strong hence unreactive to polar tetrachloromethane*” (Teacher, 42).

Item 8 was difficult to students with an index of 0.43. Of the 263 students, 31.79% students’ explanations were alternative conceptions and 3.04% were in the category of factual difficulties. The evidence of alternative conceptions and factual difficulties is:

Alternative conceptions: (i) benzene undergoes addition and oxidation reactions to produce benzoic acid. An excerpt is: *“... benzene undergoes addition and oxidation reactions to form benzoic acid because the process involves addition of an acid to benzene*” (Student, 86).(ii) benzene undergoes hydrogenation and acid oxidation to form benzoic acid. An excerpt is: *“benzene is hydrogenated to produce cyclohexane and then acid oxidation forming benzoic acid*” (Student, 23).

Factual difficulties: (i) benzene is hydrogenated to produce hexane. An excerpt is:

“hexane is produced when benzene is hydrogenated” (Student, 61).

(ii)benzene undergoes hydrogenation to produce cyclohexane through hydrogen atom elimination. An excerpt is: *benzene undergoes hydrogenation*

to produce cyclohexane removing hydrogen atom from a compound” (Student, 239). However, the concept was less difficult to teachers with an index of 0.87. Of the 47 teachers, an equal proportion (25.37%) teachers’ explanations were categorised into alternative conceptions and conceptual difficulties. The evidence of alternative conceptions and factual difficulties is:

Alternative conceptions: hydrogenation of benzene produces cycloalkane compounds. An excerpt is: “benzene hydrogenate to produce cyclohexane because benzene is a cyclic compound with double bonds between each other carbon atoms” (Teacher, 31).

Factual difficulties: some teachers simply mentioned that, benzene hydrogenates to form hexane with no scientific explanation. An excerpt is: “complete hydrogenation of benzene produces hexane” (Teacher, 24).

Item 10 was difficult to students with an index of 0.47. Of the 263 students, 38.78% students’ explanations were alternative conceptions and 0.76% in the category of conceptual difficulties relating to the fact that, ethene decolorizes both Br_2/CCl_4 and acidified KMnO_4 . The evidence of alternative conceptions and factual difficulties is:

Alternative conceptions: (i) ethane changes Br_2/CCl_4 and acidified purple KMnO_4 to orange as it is saturated hydrocarbon. An excerpt is: “ethane is saturated hydrocarbon because of the carbon-carbon bonds within it molecules, it will change bromine in tetrachloromethane (Br_2/CCl_4) colour to orange” (Student, 65).

(ii) saturated hydrocarbons decolorize acidified potassium tetraoxomanganate (VII) (KMnO_4) solutions. An excerpt is: “saturated organic compound changes colour of bromine in tetrachloromethane (Br_2/CCl_4) and acidified

potassium tetraoxomanganate (VII) (KMnO₄) solutions to pale green ...”

(Student, 125). (iii) ethane decolorizes both Br₂/CCl₄ and acidified KMnO₄.

An excerpt is: “*ethane changes the colours of Br₂/CCl₄ and acidified KMnO₄ colourless*” (Student, 59).

Factual difficulties: (i) some students only mentioned that ethene decolorizes both Br₂/CCl₄ and acidified KMnO₄ and were unable to explain why this is possible. An excerpt is: “*colours of Br₂/CCl₄ and acidified KMnO₄ changes to colourless by ethene*” (Student, 72).

However, the concept was less difficult to teachers with an index of 0.89. Of the 47 teachers, an equal proportion (36.17%) of teachers’ explanations were alternative conceptions and factual difficulties respectively relating to the fact that, ethene decolorizes both Br₂/CCl₄ and acidified KMnO₄. The evidence of alternative conceptions and factual difficulties is:

Alternative conceptions: (i) ethane is saturated hence decolorizes Br₂/CCl₄ and acidified KMnO₄. An excerpt is: “*ethane is an alkane and being saturated molecule changes (Br₂/CCl₄) and acidified (KMnO₄) solutions white ppt*” (Teacher, 25). (ii) propane to decolorize Br₂/CCl₄ and acidified KMnO₄. An excerpt is: “*propane changes Br₂/CCl₄ and acidified KMnO₄ to colourless*” (Teacher, 12).

Factual difficulties: some of the teachers could only restate that ethene changes (Br₂/CCl₄) and acidified (KMnO₄) solutions with no justification for the process. An excerpt is: “*... ethene is the compound as it changes colour of (Br₂/CCl₄) and acidified (KMnO₄) solutions*” (Teacher, 39).

Item 12 was very difficult to students with an index of 0.35. Of the 263 students, 34.60% students’ explanations were in the category of alternative

conceptions with no factual difficulties relating to the fact that, propene gives brown colour solution with alkaline potassium tetraoxomanganate(VII). The evidence of alternative conceptions is:

Alternative conceptions: (i) 2-propanone gives brown colour solution with alkaline potassium tetraoxomanganate(VII). An excerpt is: “*colour of alkaline potassium tetraoxomanganate(VII) solution changes to brown upon reaction with 2propanone*” (Student, 14).

(ii) propanal produces brown colour solution with alkaline potassium tetraoxomanganate(VII). An excerpt is: “*colour of alkaline potassium tetraoxomanganate(VII) solution changes to brown upon reaction with propanal*” (Student, 48).

Also, the concept was difficult to teachers with an index of 0.51. Of the 47 teachers, 31.91 teachers’ explanations were alternative conceptions with no factual difficulties relating to the fact that propene gives brown colour solution with alkaline potassium tetraoxomanganate(VII). The evidence of alternative conceptions is:

Alternative conceptions: (i) propane reacts with alkaline potassium tetraoxomanganate (VII) to give brown colour. An excerpt is: “*propane reacts with alkaline potassium tetraoxomanganate (VII) to give brown colour*” (Teacher, 27). “*propane reacts with alkaline potassium tetraoxomanganate (VII) solution to give brown colour because oxidation states of Manganese reduces from +7 which is purple colour to +2 which is brown colour*” (Teacher, 19).

Item 18 was extremely difficult to students with an index of 0.19. Of the 263 students, 12.93% students’ explanations were alternative conceptions

and 1.90% were in the category of factual difficulties relating to the fact that, 2-butyne is unsaturation thus decolorises bromine solution. The evidence of alternative conceptions and factual difficulties is:

Alternative conceptions: (i) 2-butyne is an alkane hence decolorizes bromine solution. An excerpt is: “*alkanes such as 2-butyne changes colour of bromine solution to colourless*” (Student, 58).

Factual difficulties: (i) some of the students did not know that 2-butyne is an unsaturated hydrocarbon. An excerpt is: *I think 2-butyne is not a hydrocarbon but an amide and thus, decolorises bromine solution*” (Student, 153).

Also, this concept was moderately difficult to teachers with an index of 0.53. Of the 47 teachers, 19.15% teachers’ explanations were alternative conceptions and 21.28% were factual difficulties relating to the fact that, 2-butyne is unsaturation thus decolorises bromine solution. The evidence of alternative conceptions and factual difficulties is:

Alternative conceptions: (i) 2-butyne is an alkane thus decolorises bromine solution. An excerpt is: “*alkane such as 2-butyne decolorizes bromine solution*” (Teacher, 19).

Factual difficulties: some teachers did not know that 2-butyne is an unsaturated hydrocarbon. An excerpt is: (i) *alkanoic acid decolorises bromine solution. An excerpt is: “2-butyne contains alkanoic functional group acid hence, changes colour of bromine solution to colourless*” (Teacher, 35).

Item 21 was extremely difficult to students with an index of 0.11. Of the 263 students, 7.22% students’ explanations were alternative conceptions and 0.38% were factual difficulties relating to the fact that, bromine solution

or acidified KMnO_4 is a solution used to distinguish between benzene and ethene. The evidence of alternative conceptions and factual difficulties is:

Alternative conceptions: (I) the reagent is concentrated H_2SO_4 for substitution on benzene and addition reaction with ethene. An excerpt is: “benzene (C_6H_6) reacts through substitution reaction with concentrated H_2SO_4 to produce $\text{C}_6\text{H}_5\text{NO}_2$ whiles ethene reacts to form an alkane” (Student, 239).

Factual difficulties: (i) benzene is reactive to oxidizing agents such as acidified KMnO_4 . An excerpt is: “benzene strongly react with oxidizing agents to give different colour when react with acidified KMnO_4 as compared to colourless colour of ethene” (Student, 211).

Also, the concept was moderately difficult to teachers with an index of 0.55. Of the 47 teachers, 19.15% teachers’ explanations were alternative conceptions and 2.13% were factual difficulties relating to the fact that, bromine solution or acidified KMnO_4 is used to distinguish between benzene and ethene. as the evidence of alternative conceptions and factual difficulties is:

Alternative conceptions: (i) bromine atom is used to distinguish between benzene and ethene. An excerpt is: “benzene and ethene is differentiated using bromine atom” (Teacher, 3).

Factual difficulties: (i) some teachers did not know that indicators are not reagents for organic qualitative analysis but that of titration. An excerpt is: “benzene changes phenolphthalein from colourless to pink but ethene is unreactive to phenolphthalein” (Teacher, 8).

Item 9 was difficult to students with an index of 0.34. Of the 263 students, 27.76% teachers’ explanations were alternative conceptions and

1.14% were factual difficulties relating to the fact that, secondary alkanol undergoes complete oxidation reaction to produce an alkanone. The evidence of alternative conceptions is:

Alternative conceptions: (i) secondary alkanols with two (–OH) groups present on the carbon containing the –OH group oxidize to form alkanone. An excerpt is:

“secondary alkanols oxidizes to form ketones because in secondary alkanols there are two –OH groups and two hydrogen atoms attached to the carbon containing the OH hence resulting in the formation of a ketone” (Student, 238).

(ii) the structure of secondary alkanols with two hydroxyl groups oxidize to alkanones. An excerpt is: *“... alkanols have two structural formulae so undergo complete oxidation reaction to form ketones”* (Student, 262).

Factual difficulties: (i) some students did not know that primary alkanol oxidizes to form alkanone but aldehydes. An excerpt is: *“alkanones are produced when primary alkanols oxidise”* (Student, 227).

(i) some of the students did not know that, tertiary alkanols do not oxidize to form alkanone. An excerpt is: *“alkanones are formed when tertiary alkanols when they oxidize”* (Student, 172).

However, the concept was less difficult to teachers with an index of 0.68.

Of the 47 teachers, 38.30% teachers' explanations were alternative conceptions with no factual difficulties relating to the fact that, secondary alkanol undergoes complete oxidation to produce an alkanone. The evidence of alternative conceptions is:

Alternative conceptions :(i) the presence of the two hydroxyl groups on secondary alkanols oxidise completely to produce ketones. An excerpt is: “*secondary alkanols undergo complete oxidation to produce alkanone because in secondary alcohols there are two hydroxyl (-OH) groups present hence forming an alkanone*” (Teacher, 12).

Item 16 was very difficult to students with an index of 0.22. Of the 263 students, 19.77% students’ explanations were alternative conceptions with no factual difficulties relating to the fact that, alkanol reacts to change yellow potassium heptaoxodichromate(VI) solution to green. The evidence of alternative conceptions is:

Alternative conceptions: alkanols reacts with potassium heptaoxodichromate (VI) solution to change colour to yellow. An excerpt is: “*alkanols react with acidified $K_2Cr_2O_7$ to give an observable yellow precipitate colour*” (Student, 30).

Also, this concept was very difficult to teachers with an index of 0.43. Of the 47 teachers, 21.28% teachers’ explanations were alternative conceptions and 14.89% were factual difficulties relating to the fact that, alkanol reacts with yellow colour potassium heptaoxodichromate(VI) solution and changes it to green. The evidence of alternative conceptions and factual difficulties is:

Alternative conceptions: (i) alkanols react with yellow potassium heptaoxodichromate(VI) solution to form white precipitate. An excerpt is: “*alkanol react with yellow colour of potassium heptaoxodichromate(VI) solution to form white precipitate*” (Teacher, 5).

Items 11 was moderately difficult to students with an index of 0.62. Of the 263 students, 45.63% students’ explanations were in the category of

alternative conceptions without factual difficulties relating to the fact that, hydrogen gas is liberated when alkanolic acid reacts with sodium metal. The evidence of alternative conceptions is:

Alternative conceptions: (i) an amide reacts with sodium metal to liberate hydrogen gas. An excerpt is: "hydrogen gas is liberated when amides reacts with sodium metal" (student, 75).

(ii) carbonyl groups react with sodium metal to liberate hydrogen gas. An excerpt is: *"hydrogen gas is liberated when alkanones reacts with sodium metal" (student, 75).*

(iii) the presence of carbon-oxygen double bond in alkanolic acids liberate hydrogen gas in the presence of sodium metal. An excerpt is: *"... an alkanolic acid because, the alkanolic contains carbon double bond oxygen and carbon double bond -OH, the hydrogen in OH breaks and form the hydrogen gas" (student, 172).*

However, the concept was less difficult to teachers with an index of 0.83. Of the 47 teachers, 40.43% teachers' explanations were alternative conceptions without any factual difficulties in relating to the fact that, hydrogen gas is liberated when alkanolic acid reacts with sodium metal. The evidence of alternative conceptions is: *Alternative conceptions: (i) black precipitate is*

formed when alkanolic acid react with sodium metal. An excerpt is: "propanoic acid reacts with sodium metal to produce black precipitate" (Teacher, 16).

(ii) carbonyl group reacts with sodium metal to liberate hydrogen gas. An excerpt is: *"hydrogen gas is liberated when alkanals reacts with sodium metal" (Teacher, 32).*

Item 13 was very difficult to students with an index of 0.38. Of the 263 students, 36.50% students' explanations were alternative conceptions without any factual difficulties relating to the fact that, complete oxidation of propanol in the presence of suitable oxidizing agent produces propanoic acid. The evidence of alternative conceptions is:

Alternative conceptions: (i) complete oxidation of propanol produces propanone.

An excerpt is: *“propanone is produced when propanol is completely oxidized”* (student, 126).

(ii) complete oxidation of propanol produces propylpropanoate. An excerpt is: *“propylpropanoate is evolved when propanol is completely oxidized”* (Student, 208).

(iii) alkylalkanoate (RCOOR^1) is produced when propanol is completely oxidized. An excerpt is: *“complete oxidation of propanol produces propylpropanoate this because there is propanol in the propylpropanoate which occurred during the oxidation reaction”* (Student, 72).

However, the concept was moderately difficult to teachers with an index of 0.64. Of the 47 teachers, 27.66% teachers' explanations were alternative conceptions without any factual difficulties relating to the fact that, complete oxidation of propanol produces propanoic acid. The evidence of alternative conceptions is:

Alternative conceptions: complete oxidation of propanol produces propylpropanoate. An excerpt is: *“propylpropanoate is produced when propanol oxidizes completely”* (Teacher, 32).

Item 7 was moderately difficult to students with an index of 0.65. Of the 263 students, 36.50% students' explanations were alternative conceptions and 1.14% factual difficulties relating to the fact that, the sweet scent associated with alkylalkanoate functional group detection. The evidence of alternative conceptions and factual difficulties is:

Alternative conception: alkylalkanoates are sweet scented as they are formed from alkanoic acids. An excerpt is: "*ethylmethanoate is sweet scented because it has the reagent of alkanoic acid ...*" (Student, 161).

Factual difficulties: (i) some of the students did not know that sodium ethanoate is a salt but not an ester. An excerpt is: "*sodium ethanoate is an ester so is sweet scented*" (Student, 19).

(ii) some of the students did not know that methanamide is not an ester. An excerpt is: "*I think it is methanamide which is an ester so sweet scented*" (Student, 11). However, the concept was less difficult to teachers with an index 0.85. Of the 47 teachers, 27.66% teachers' explanations were in the category of factual difficulties without any alternative conceptions relating to the fact that, the sweet scent associated with alkylalkanoate functional group detection. The evidence of factual difficulties is:

Factual difficulties: (i) some teachers did not know that methanamide is not an ester. An excerpt is: "*methanamide is an ester so is sweet scented*" (Teacher, 32). (ii) some teachers did not know that sodium ethanoate is not a salt but an ester. An excerpt is: "*sodium ethanoate is an ester so is sweet scented*" (Teacher, 17).

Item 17 was extremely difficult to students with an index of 0.15. Of the 263 students, 10.27% students' explanations were alternative conceptions

and 0.76% were factual difficulties relating to the fact that, ammonia gas is evolved when amide is warmed with dilute sodium hydroxide solution. The evidence of alternative conceptions and factual difficulties is:

Alternative conceptions: nitrogen gas is evolved when amide reacts with dilute sodium hydroxide solution. An excerpt is: “amide reacts with dilute sodium hydroxide solution to liberate nitrogen gas” (Student, 52).

However, the concept was moderately difficult to teachers with an index of 0.51. Of the 47 teachers, 12.77% teachers’ explanations were alternative conceptions and 10.64% were factual difficulties relating to the fact that, ammonia gas is evolved when amide is warmed with dilute sodium hydroxide solution. The evidence of alternative conceptions and factual difficulties is:

Alternative conception: hydrogen gas is evolved when amide reacts with dilute sodium hydroxide solution. An excerpt is: “hydrogen gas is liberated when amide reacts with dilute sodium hydroxide solution” (Teacher, 41).

Item 22 was extremely difficult to students with an index of 0.01. Of the 263 students, 1.90% students’ explanations were factual difficulties without any alternative conceptions relating to the fact that, ammoniacal silver nitrate (Tollen’s reagent) or Fehling’s solutions is used qualitatively to distinguish between alkanals and alkanones. The evidence of factual difficulties is:

Factual difficulties: (i) some of the students did not know that phenolphthalein is an indicator but not a reagent used to distinguish between compounds containing carbonyl functional groups. An excerpt is: “phenolphthalein is used to distinguish between alkanals and alkanones, alkanals decolorises phenolphthalein but alkanones do not react” (Student, 144).

(ii) some of the students did not know that sodium hydroxide is an alkaline but a reagent used to distinguish between compounds containing carbonyl functional groups. An excerpt is: “*alkanals changes sodium hydroxide colour to pale green but alkanones do not*” (Student, 70).

Also, the concept was very difficult to teachers with an index of 0.28. Of the 47 teachers, an equal proportion (4.26%) teachers’ explanations were alternative conceptions and factual difficulties relating to the fact that, Tollen’s reagent or Fehling’s solutions is used qualitatively to distinguish between carbonyl functional groups. The evidence of conceptual difficulties is:

Factual difficulties: aldehydes react with Tollen’s reagent to form acidic solution.

An excerpt is: “*aldehyde like propanal ($\text{CH}_3\text{CH}_2\text{CHO}$) react with Tollen’s reagent to form acid solutions*” (Teacher, 16).

These conceptual difficulties could account for teachers and their students’ inability to demonstrate full scientific understanding on OQA but partial scientific understanding and no scientific understanding respectively. Not only is OQA difficult to students (Goh et al., 1987; Tsoi, 1994) but also difficult to teachers who teach the students. Students difficulties in detecting all functional groups either through the use of suitable organic reagents or the use of chemical reactions could be partly due to their insufficient knowledge on organic chemistry (Coll & Treagust, 2001; Nicoll, 2001), their inability to identify chemical structures of organic compounds and give correct names of these organic compounds (Adu-Gyamfi et al., 2017). The results showed that even though most of the students are unable to identify most organic chemical

reactions, the very few who were able failed to state and explain clearly functional groups present in those compounds. Hence, students are unable to give correct chemical structures of organic compounds undergoing chemical reactions. Teachers also have similar factual difficulties and alternative conceptions but not as high as that of the students. Alternative conceptions seem to be a common phenomenon with students in relation to chemical concepts globally and same can be said with organic qualitative analysis. However, teachers in this study are demonstrating alternative conceptions and other factual difficulties on OQA and that could be a contributing factor to students' alternative conceptions. Teachers being a contributing factor to students' alternative conceptions is a confirmation of the fact that conceptual misunderstanding (a category of alternative conceptions) is based on teacher's inability to use chemistry lessons to help students challenged their preconceived notions and nonscientific beliefs they bring to the classroom (Adu-Gyamfi & Ampiah, 2019).

Teachers' demonstration of wide range of factual difficulties and alternative conceptions just as their students could be their basis of conceptual difficulties and partial level of conceptual understanding on OQA. The alternative conceptions and factual difficulties of teachers could be partly due to difficult nature of OQA (Stieff, 2007). Organic chemistry is known to be difficult to students, and these teachers likely had difficulties learning the content at the SHS and even at the university hence their difficulties in teaching their students. Nature of the content influences the way the subject is taught and learnt (Tatli & Ayas, 2013). This implies that teachers' difficulties in conceptualizing difficult content are potentially transferable to their

students, which mostly results in learners' alternative conceptions about the concepts (Chavan, 2017).

Teachers' alternative conceptions and factual difficulties could be partly due to teachers' weak content knowledge. Teachers' deep and strong content knowledge is a necessary tool in students' learning (Adu-Gyamfi et al., 2018; Aregawi et al., 2017). Good numbers of students make meaning of concepts in similar ways as their teachers (Taber, 2011) who teach them. Teachers' understanding of science content influence the way they teach, and consequently the way their learners learn the content (Childs & Sheehan, 2009; Greenbowe & Schroeder, 2008; Simsek, 2009, Tatli & Ayas, 2013). Teachers weak content knowledge could partly be due to teachers' factual difficulties: which are teachers' conceptions developed from false ideas learnt at the early ages and have remained unchallenged; lack of preparation before teaching the content; not specializing in chemistry at the university level; lack of frequent teaching of organic chemistry and OQA content to students.

Therefore, the study shows that what students learn is equally dependent on the teacher's knowledge of that specific content. The results show that, teachers' just as their students also have little knowledge about organic reagents needed to test for the various functional groups, and give exact colour changes that occurs during these functional groups detections. This is because, teachers just as their students also failed to provide names and explain reagents needed to detect for these functional groups. For instance, both students and teachers have factual difficulties distinguishing between saturation and unsaturation, primary and secondary alkanols, alkylalkanoates, amides, and alkanals and alkanones. The results further show that teachers just

as their students have factual difficulties and alternative conceptions in identifying the name of particular chemical reaction such as oxidation, dehydration and esterification. This implies that not only students have conceptual difficulties in providing and predicting final product in organic reactions with reasons (Tang et al., 2010) but their teachers who teach them also have conceptual difficulties as well.

This study also confirms that teachers who do not have adequate and sufficient understanding of scientific concept can misrepresent the content to their students, causing them to have misunderstandings (Ball et al., 2008). This confirms earlier works (Goh et al., 1987; Tsoi, 1994) that, qualitative analysis is a difficult concept when it comes to students' learning of chemistry and this could be the presence of alternative conceptions and factual difficulties teachers and their students have on OQA. These learning difficulties of students in OQA could be attributed to low level of teachers' conceptual understanding on OQA. The results from this study does not only reaffirms works of (Adu-Gyamfi et al., 2017) that students have difficulties identifying chemical structures of organic compounds and functional groups of these organic compounds, teachers who teach students these concepts also have similar difficulties as alternative conceptions and factual difficulties.

Research Question Three: What accounts for teachers' and students' problems on teaching and learning of organic qualitative analysis?

Factors Accounting for Problems of Teaching and Learning OQA

Research Question Three sought to find out what account for SHS teachers' and students' problems on teaching and learning of OQA. To achieve this, observations were made from four teachers to explore how

lessons on OQA were carried out. Teachers and students were also interviewed before and after the lessons. Three themes that emerged from the interviews and observations as:

1. Teaching and learning resources; which are the laboratory space, reagents, and equipment needed to facilitate the practical-based teaching of OQA.
2. Practical-based instruction: which explains how teaching is done using participatory-driven pedagogical approach to enhance students learning of chemical concepts.
3. Organic Chemistry Curriculum Content; which explains how students and teachers perceive the content of OQA in relation to the curriculum.

Teaching and Learning Resources

Adequate teaching and learning resources was one of the major factors that came up during the interviews and lesson observation that account for teachers and students' problems of teaching and learning of OQA. Examples of those resources are boiling and test tubes, bromine in tetrachloromethane solution (Br_2/CCl_4), ammonia in silver nitrate ($\text{NH}_3/\text{AgNO}_3$), potassium dichromate solution $\text{K}_2\text{Cr}_2\text{O}_7$, Benedict's solution and Fehling's solution. When asked whether teachers have introduced organic chemistry and OQA to their students, all the four teachers responded affirmative, and even added that they were almost finishing the concepts. Excerpts are:

... yes I have, I started some weeks ago ... for functional group detections, I have finished but not the entire organic chemistry. You see.... those functional group detections are the major concepts students need in the whole organic...

and also some reactions of them. We are almost finishing them in class, and I will try and do the practical works too.... (Adama, a Teacher from School A).

...yes ooo sir but theoretical, I mean without practical works” (Ameyaw, a Teacher).

“longtime my brother, just that these students from their responds in class shows they do not understand them completely so I have to go back and forth just for them to comprehend them” (Akuako, a Teacher from School C).

“yes sir, we are on it, at the tail end like esters, amides and the rest. Gradually gradually we will finish because WASSCE is just few weeks from now” (Agyabeng, a Teacher from School D).

Thereafter, students were asked before the lesson observation if they have been introduced to organic chemistry and OQA. Excerpts of my interactions with four of the students are:

Researcher: Have you been introduced to OQA?

Student: “yes please but it looks very confusing and this makes me reluctant learning it” (School C, Student 3).

Student: “yes sir, it’s very difficult and complicated to understand” (School B, Student 1).

Student: No, eeh yes sir. Is it not detections of functional groups like alkanes, alkenes and ... alkanols?

Researcher: Yes.

Student: “yes we have done them but not in the laboratory, no practical works. I have not been learning them frequently because I don’t understand” (School A, Student 2).

Student: “yes sir, in fact yes. I like learning them but I have difficulties”

(School C, Student 2)

During my lesson observation in these schools, I observed that organic chemistry and OQA have been introduced to students by their respective teachers but without practical activities. This was confirmed during a lesson observation by the teachers. Excerpts are:

“from here (that is after treating them in class) we will do these test practically in the laboratory for you to observe and experience these organic reagents and their respective reactions with these functional groups” (Kpodo, a Teacher). *“if we finish these functional group detections I will try if we can do the real practical works in the lab”* (Agyabeng, a Teacher).

Teacher problem of teaching OQA to the understanding of students, in part is laboratory space. Some schools did not have space solely as chemistry laboratory.

Excerpts to support this statement are:

... because we do not have a laboratory... and rely mainly using ‘normal’ approach in classroom (Adama, a Teacher from School A).

Not only are schools not having laboratory space but the basic chemicals and reagents are absent in them. Teachers only manage the learning environment using images and illustration to help students to learn OQA. Excerpts are:

“the chemicals and the reagents are not usually available and I am left with teaching through normal illustration and sometimes too, I print out pictures of these organic chemicals like $KMnO_4$ and $K_2Cr_2O_7$ (Adama, a Teacher)

“... because in this whole school the only organic chemical we have in that room called laboratory is ethanol and even that, it’s been there for more than

a year and rest of the chemicals are all inorganic salts and solutions” (Ameyaw, a Teacher). *“we have some of the reagents like the $KMnO_4$ and bromine solution to test for saturation and unsaturation functional groups but unfortunately those higher functional groups like alkanols, alkanolic acids, aldehydes and ketones we do not have reagents like the $K_2Cr_2O_7$, Fehling’s and Benedict’s solution, and this one*

Tollen’s reagent to test for those functional groups” (Kpodo, a Teacher from School B).

Some schools even use outdated chemicals and reagents in teaching OQA to students. This was identified as not giving students the best experience on OQA. An excerpt is:

“... even the few chemicals we use for the inorganic practical works, the chemicals are expired, some as far as four and even five years, so doing practical lessons are very difficult for me especially been the only chemistry for the three streams” (Agyabeng, a Teacher from School D).

The willingness of teachers to have the necessary chemicals and reagents, and equipment was there but teachers cannot fund and require external support.

Excerpts are:

“Massa, to be frank with you, ...you know those chemicals are very expensive and our salary is not enough to purchase those chemicals myself for the school, there’s nothing I can do” (Adama, a Teacher).

The availability of the chemical, reagents, and equipment would go a long way to enhance effective teaching and learning of OQA. An excerpt is:

“Senior for me, I think if I get these organic reagents and compounds, it will go a long way to help, I strongly believe it will really help to teach very well” (Agyabeng, a Teacher).

Students interviewed confirmed the view point of their teachers that their schools were not having adequate chemicals and reagents for teaching OQA. Excerpts to amplify this point is:

“sir, we are always given examples of reagents on the chalkboard that these reagents are used to detect organic functional groups and we become confused because we have not seen these reagents before. Sometimes he asks us to distinguish between primary, secondary and tertiary alkanols, and also aldehydes and ketones on the board and this makes learning of these many functional groups confusing” (School B, Student 1).

“we have not seen those reagents before so learning something without seeing is very difficult. Always I have to image and memorize things like the colour changes” (School C, Student 1).

My interactions with one of the students is:

Researcher: How do you understand OQA?

Student: sir, OQA is abstract.

Researcher: what do you mean by OQA is abstract?

Student: it is too difficult and complicated. Is also too many and confusing.

Researcher: Can you explain further?

Student: hmm sir, those functional groups are too many and the reagents ... very confusing. About two or three reagents can be used to detect one functional group, sir how is that possible. Meanwhile we do not see these reagent ooo; always they are written on the board for us. I have

only seen those used to detect alkane, alkene and alkyne that is the KMnO_4 but those of Benedict's and Fehling's we have not, these things make learning of qualitative analysis very difficult (School B, Student 2).

Practical-based Instruction

The approach to teaching and learning (that is the instruction) of OQA was seen as a key factor contributing to students' difficulties on learning OQA. All the four teachers involved in lesson observations and interviews were worried of the instructional approaches they used to teach the concept. The teachers opined that the right approach to teaching OQA was practical-based instruction where students interact directly with chemicals, reagents, and equipment to detect functional groups in the laboratory. Excerpts to support this assertion are:

"we need students in the laboratory to actively use the chemicals and reagents. It makes qualitative analysis easier" (Akuoko, a Teacher).

"For me continuous practical lessons should be able to help them understand" (Akuoko, a Teacher from School C).

"I use practical lessons in teaching organic qualitative analysis lessons just to ensure my students understand. We have some of the reagents but not all" (Kpodo, a Teacher).

The inadequacy of teaching and learning resources has brought up the use of variety of instructional approaches instead of practical-based to help students learn OQA.

“as for me I use multi-based methods of teaching where I use a lot of teaching techniques like lecture method, participatory approach to teach ...” (Adama, a Teacher).

Some teachers use the expository approach to teach OQA to students. Excerpts to amplify this assertion are:

I most times teach by the normal chalkboard illustration and sometimes too, I print out pictures of these organic chemicals like $KMnO_4$ and $K_2Cr_2O_7$ and show them to my students during teaching of OQA” (Adama, a Teacher).

In other instances, teachers used models and animations to teach OQA to students. Excerpts are:

“... I teach this topic mostly using organic models and videos (animations) to my students because we do not have the needed chemicals or the reagents to detect these functional groups” (Agyabeng, a Teacher).

“Hmmm, I will say lack of organic chemicals and reagents for practical lessons make students learning organic qualitative analysis difficult because it cannot be learnt from books for understanding looking at it nature ... But I expect students to understand it when I do my best using the models and animations” (Akuoko, a Teacher).

“My brother, I have been teaching this subject for 9 years and year after year most of my students find this particular topic difficult because of it nature but I try my best as I told you, I use the models and practical lessons to try for them to understand but frankly speaking it has not been easy for me” (Kpodo, a Teacher).

Students from Schools A, B, and D corroborated their teachers' assertion that, teachers do not use practical-based instruction on OQA to help students overcome their learning difficulties. Excerpts are:

“Teaching a more confusing topic like organic qualitative analysis theory theory theory without practical lessons it makes it very difficult for us to learn and understand” (School A, Student 4).

“I think he should use something which is visible so that we see and feel it, something like practical lessons. For me, I understand things if I see and do it myself and more often, that way I will understand it better” (School D, Student 3). Students explained that their difficulty is that, they force it when learning OQA as teachers barely use practical-based approach in teaching the concept.

An excerpt is:

“Organic Qualitative Analysis is difficult because our teacher teaches it without doing practical work and so I try to capture it, and when studying I force myself that it should be this then I take it like that whether I have seen it before or not. So learning it becomes very confusing” (School B, Student 2).

My interactions with some teachers and students prior to some lesson observations are:

Researcher: What would you expect if you were learning Organic Qualitative Analysis today?

“Sir, I will expect him to explain in details for us to understand and also he should use models and animations, which will help me understand because seeing objects stick more than hearing” (school D, Student 3).

Researcher: Sir, what should I expect from this lesson on Organic Qualitative Analysis today?

Teacher: It will be the usual chalkboard illustrations with marker but I will involve the students.

Researcher: Please, can you explain further?

Teacher: I will review their previous knowledge before I continue today's business. I will also take my time and explain in details for them to understand since we cannot do practical lessons due to lack of reagents. Indeed, in this teacher's lessons, there was no opportunity provided for students to interact with materials but responding to teacher questions and following marker (chalk) board illustrations.

There were other observations I made in other schools which could account for students' conceptual difficulties on OQA. For instances,

In Adama's lesson, he had no lesson plan as a guide, no models, no experiments, and no review of students' previous knowledge and experiences but he actively involved students (in responding and solving sample questions) during his teaching and explained OQA concepts in detailed to the students.

Thereafter the lesson, I had an interaction with Adama. An extract is:

Researcher: Did the lesson go as expected?

Adama: It was very successful.

Researcher: Please, can you explain further?

Adama: Even though I did not teach it as a practical lesson, I was able to explain it well to my students and gave examples of compounds that contain these functional groups. However, the only thing is that, at the beginning I forgot to review their previous knowledge as I promised but I think it was successful.

Researcher: What would have done differently another time?

Adama: I will do more explanations and give more examples of compounds containing ethanol, esters and alkanolic acid functional groups, and review their previous knowledge which is very important.

A student from School A interviewed after the lesson made this comment:

“Sir the lesson was successful because I really understood what he taught, he explained those functional groups well..... but, sir, like I will understand more if we have done practical works, that one I will see and perform by myself” (School A, Student 3).

With respect to Kpodo from School B, he reviewed students' previous knowledge and experiences by actively involving students during the teaching and explained OQA concepts in details but all happened without students interacting with materials in a practical-based approach as he promised before the lesson. An extract of our interaction is:

Researcher: Sir, welcome back from the lesson.

Teacher: Thank you.

Researcher: Did the lesson go as expected?

Kpodo: It was very very successful.

Researcher: Please, can you explain further?

Kpodo: Ok, you were there so you saw everything, I involved my students, explain those functional group and their reactions to them very well and even gave them notes they needed. From their responses and contribution towards the lesson, it went well.

Researcher: Oh okay, but sir before the lesson you promised to teach detections of those functional groups through experiments.

Kpodo: Yes, I did promise but initially I thought I could get some of the reagents like the Tollen's reagent and the dichromate ($K_2Cr_2O_7$) for the aldehydes and the alkanols but I couldn't find on the shelves. Also the taps are not flowing as you can see (*as he opened one of the taps in the laboratory*). But all the same, the students understood them without the experiments ooo. You you..... saw it yourself. I am not justifying though, but

Researcher: Ok, sir. What would have done differently another time?

Kpodo: Obviously practical work ... I think practical works will help than the theory teaching. Next time I will get these reagents down before we start the lesson.

Student from School B interviewed after the lesson made this comment: "*the lesson was very successful, I really understood those functional groups but I thought we will do experiments ooo*" (School B, Students 3).

With respect to Akuoko, a teacher from School C, he taught OQA with experiments, involved students throughout the practical process. An extract of our interaction after the lesson is:

Researcher: Did the lesson go as expected?

Akuoko: I think so, as you saw it yourself.

Researcher: What would have done differently another time?

Akuoko: I will control the class well because you could see that, at the later part some of the reagents especially the acidified permanganate was contaminated so few were not getting the required results.

Researcher: How did that happened sir?

Akuoko: Some of the students were putting many droppers in the reagents instead of using the only dropper in it. Sometimes it happens due to their numbers.

From School C, students corroborated their teacher's assertion that some reagents got contaminated;

"Sir, as for the lesson it was very successful because it is our first organic practical work we have done ... the only problem was that some of my mates were rushing so they ended up putting different droppers in the same reagent bottle and they got contaminated. That was why me for instance, I was not getting the right colour changes expected but overall I have enjoyed organic practical work" (School C, Student 2).

"Sir so this purple $KMnO_4$ colour disappearance is very simple like that, is really nice and simple. I think we should do more experiments so that organic becomes simple and easier for us" (School C, Student 3)

With respect to Agyabeng, a teacher from School D, he taught OQA by reviewing students' previous knowledge and experiences, involved students and also gave detailed explanation of the concepts by giving more examples available in their immediate environment but with no animations or models as promised. An extract of our interaction is:

Researcher: Sir, Did the lesson go as expected?

Agyabeng: Yes, sir, it was successful.

Researcher: Please, can you explain further?

Agyabeng: Responses and contributions from the students really informed me that. *Researcher*: Sir, you did not use the animations and models as promised earlier?

Agyabeng: hmmm, I forgot them, I really forgot ... but I will do my best to use them in our next meeting.

From School D, students called for teachers to use animals and models to teach OQA if there is inadequacy of conventional materials. This approach, students opined that could help in overcoming their learning difficulties. Excerpts are: “... *Sir, I understood what he taught because he explained those functional groups very well but I was expecting visual something like animations or videos. I remember when he taught us hybridization he showed us videos and it was nice and simple. That even helped us to understand it. I think he should use that and it will help us*” (School D, Student 3).

“*Sir, I understood, is better than before, but I think this topic is kind of difficult so he should use animations or videos and even he can use some small round round balls (they meant ball-and –stick models) that can also help us understand. I have seen one on a television before*” (School D, Student 4).

From the four lessons observed, it was only in school C that the teacher employed what he planned prior to the lesson, the other three teachers did not practice what they professed. These practices affected students' level of conceptualizing OQA as students commented.

Organic Chemistry Curriculum Content

Another factor that was both mentioned by teachers and students that account for their problems in conceptualising OQA in relation to teaching and learning is the nature of chemistry curriculum and the time the content is supposed to be taught. The content of OQA was abstract and voluminous. An excerpt is:

“My brother, I have been teaching this subject for 9 years and year after year most of my students find this particular topic difficult because of its nature (i.e., OQA is plenty in the syllabus) but I try my best as I told you, I use the models and practical lessons to try for them to understand but frankly speaking it has not been easy for me” (Kpodo, a Teacher).

Though the content is voluminous, teachers preferred to teach it at the tail of the 3-year SHS programme. This is because the examination council sets few questions on it. An excerpt is:

“... because in the WASSCE final examination, WAEC mostly bring more of the inorganic substances than the organic, I hardly teach the OQA early, so I put them at the tail end of the year (SHS 3) because few questions come from that aspect (organic)” (Adama, a Teacher).

OQA is taught at the end of the 3-year SHS programme to help students overcome the learning difficulties. However, this strategy was only good for high achievers. An excerpt is:

“... so that it does not become difficult for them and we have no option. Moreover, we can never complete the whole chemistry syllabus so to me, this strategy mostly helps those who are good academically. The only disadvantage is that, sometimes

I finish but in a rush manner” (Adama, a Teacher).

Most students interviewed corroborated with the teacher from (School A) who asserted that nature and time of teaching chemistry contributed to their difficulties in conceptualizing OQA.

“Organic Qualitative Analysis is very tedious, difficult and complicated to study and understand” (School B, Student, 4)

“Organic Qualitative Analysis is very lengthy, difficult and confusing and this makes us very reluctant to learn that particular topic in organic chemistry” (School C, Student, 1).

“Organic Qualitative Analysis is very abstract, difficult and complicated. I think is above us, it should be learnt at the University level especially those who will be reading pure Chemistry thus should be taken away from our syllabus” (School D, Student 2).

“... Sir, for me organic chemistry should be started from Form 1 through to Form 3 especially the qualitative analysis so that we understand. They are voluminous and abstract to understand, and the teacher also waited till final year just before the COVID 19 break he started bombarding us with these functional group detections. I become confused anytime I start learning it” (School A, Student 2).

“... is like all the chemistry teachers reserve organic chemistry as the last topic to teach, and because of limited time to write WASSCE, they (teachers) rush and put everything together on us to learn. Because chemistry is also voluminous I sometimes memorize them trying to understand but it does not stick. I sometimes put my chemistry book aside and pick another subject and read just because I don't get it” (School C, Student 2).

“last minutes you see teachers rushing to teach this confusing topic especially those alkenes, alkynes, alkanols ... me I cannot learn under pressure ooo, you will not even understand it. Sir, please was it like that during your time? She laughs...” (School C, Student 3).

Findings from the interviews showed that, teachers admitted adequate teaching and learning resources help students comprehend OQA concept but

insufficient of these teaching and learning resources (Ngwenya, 2015) interrupts teachers' teaching and subsequently hinders students' learning of OQA. In some of the schools, teaching and learning resources were available but teachers hardly use them in the teaching of OQA. This, then becomes problem of attitude but not availability. Teachers are, therefore, encouraged to use teaching and learning resources as they help students to conceptualize OQA and other concepts in organic chemistry (Swan, 2005).

It is serious if teachers do not practice what they say with respect to the use of teaching and learning resources in their lesson. This is an indication that teachers normally proclaim best teaching practices in theory but practice different things during teaching. This attitude of teachers is serious especially as OQA concept is abstract by nature makes students have difficulties in learning OQA. This attitude of teachers practicing something different from what they profess to do could be that teachers just have theoretical knowledge about teaching and learning resources and their importance and how best to use them in an instruction but are unable to practice it effectively.

The findings from lesson observation brought to bear that, even though teaching and learning of OQA concept should be practical oriented, teaching and learning transpired without practical works. This is partly due to either unavailability of learning resources or learning resources available but teacher refusal to use them. Finding of this study reaffirms (Ajayi & Ogbaba, 2017) that teaching and learning resources effectively enhance students understanding of scientific concept. Teachers lack of specific pedagogical content knowledge and weak teaching instructional strategies (Adu-Gyamfi et al., 2018; Sakiz et al, 2012; Uyulgan & Akkuzu, 2016) are problems that result

to students' difficulties in conceptualizing OQA. In addition, teachers' weak teaching instructional strategies resulted students' to develop scientifically inaccurate conceptions about functional group detections (Adu-Gyamfi & Ampiah, 2019; Adu-Gyamfi et al., 2015; 2017). The study has contributed to the literature that not only is organic chemistry difficult to students but OQA is also difficult to students to learn and their teachers have conceptual difficulties in a concept they are to teach to students.



CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter highlights the summary of the key findings, conclusion, and recommendations on teachers' and students' conceptual understanding on OQA. The conclusions and recommendations in this chapter are based on the key findings from the study. The chapter ends with some suggestions made for future study.

Summary

This study investigated teachers' and students' conceptual understanding of OQA in SHS in Central Region of Ghana as there were consistent reports over the years by WAEC chief examiner on students' weaknesses on OQA. To achieve the purpose of the study an explanatory sequential mixed methods design was used for collecting and analysing both quantitative and qualitative data for the study.

OQADTT and OQADTS instruments were used to collect the quantitative data. SIGOQA, TIGOQA and OCTOQA instruments were also used to collect the qualitative data from teachers and students.

A multi-stage sampling technique was employed to select 263 SHS 3 students from six SHS and 47 chemistry teachers from 16 SHS. OQA lessons were observed in four schools. Data from the diagnostic tests, interviews, and observation checklist were analysed using frequencies, percentages, means, standard deviations, and themes. Other analytical tool employed in the study was independent-samples t-test. Sample statements from teachers and students during the interviews and lesson observation were used to support the themes.

Key findings

1. The findings from the exploration of teachers' and students' level of conceptual understanding on OQA are:
 - a. Students were at the no scientific understanding level of learning OQA. Students' level of understanding was very interesting to note. This is because students demonstrated no scientific level of conceptual understanding that, propene is formed when propanol is dehydrated in a reaction called dehydration; propene contains an alkene functional group; 2-butyne is unsaturated that decolorises bromine solution; complete hydrogenation of benzene gives cyclohexane; bromine solution or acidified KMnO_4 is used to distinguish between benzene and ethene; secondary alkanol undergoes complete oxidation reaction to produce an alkanone; ethanol and propanoic acid are produced when ethylpropanoate undergoes acid hydrolysis; alkanol and alkanonic acid functional groups are present when ethylpropanoate undergoes acid hydrolysis; oxidation reaction occurs in the conversion of propanol to propanoic acid; yellow precipitate is formed when an alkanol is treated with hot solution of iodine in sodium hydroxide; complete oxidation of propanol in the presence of oxidizing agent such as potassium heptaoxodichromate(IV) and heat produces propanoic acid; propanoic acid is produced when propanol undergoes oxidation reaction in the presence of acidified potassium dichromate(VI); both ethanol and propanoic acid are produced when ethylpropanoate undergoes acid hydrolysis; an alkanonic acid functional group is present when propanol undergoes oxidation reaction in the presence of acidified potassium dichromate(VI); both alkanol and alkanonic acid functional groups are present when ethylpropanoate undergoes acid

hydrolysis; carbon(IV) dioxide is evolved when propanoic acid reacts with sodium hydrogentrioxocarbonate(IV); ethyl propanoate is produced when propanoic acid reacts with ethanol; alkyl alkanoate functional group is present in a product formed from chemical reaction between propanoic acid and ethanol; the type of chemical reaction involved in the conversion of propanol to ethylpropanoate is esterification; ammonia gas is evolved when amide is warmed with dilute sodium hydroxide solution than their students; and either ammoniacal silvernitrate or Fehlings solutions can be used to distinguish between alkanals and alkanones.

b. Students had partial level of conceptual understanding that, propane readily dissolves in tetrachloromethane; propene gives brown colour solution with alkaline potassium tetraoxomanganate(VII); alkenes and alkynes are organic compounds that undergo addition reactions; ethene is an organic compound that decolorizes both Br_2/CCl_4 and acidified KMnO_4 ; hydrogen gas is liberated when alkanolic acid reacts with sodium metal; and ethyl methanoate is an ester and sweet scented;

c. Teachers were at the partial level of scientific understanding on OQA. This is because teachers only had full level of conceptual understanding that propene compound contain the alkene functional group; ethanol and propanoic acid are produced when ethylpropanoate undergoes acid hydrolysis; alkanol and alkanolic acid functional groups are present when ethylpropanoate undergoes acid hydrolysis; oxidation reaction occurs in the conversion of propanol to propanoic acid; yellow precipitate is formed when an alkanol is treated with hot solution of iodine in sodium hydroxide; propanoic acid is produced when propanol undergoes oxidation reaction in the presence of

acidified potassium dichromate(VI); both ethanol and propanoic acid are produced when ethylpropanoate undergoes acid hydrolysis; an alkanolic acid functional group is present when propanol undergoes oxidation reaction in the presence of acidified potassium dichromate(VI); both alkanol and alkanolic acid functional groups are present when ethylpropanoate undergoes acid hydrolysis; carbon(IV) dioxide is evolved when propanoic acid reacts with sodium hydrogencarbonate(IV); ethylpropanoate is produced when propanoic acid reacts with ethanol; alkyl alkanolate functional group is present in a product formed from chemical reaction between propanoic acid and ethanol; the type of chemical reaction involved in the conversion of propanol to ethylpropanoate is esterification;

d. Teachers demonstrated partial level of conceptual understanding that, propane readily dissolves in tetrachloromethane; alkenes and alkynes are organic compounds that undergo addition reactions; ethene decolorizes both Br_2/CCl_4 and acidified KMnO_4 ; propene gives brown colour solution with alkaline potassium tetraoxomanganate(VII); propene is formed when propanol is dehydrated in the presence of concentrated tetraoxosulphate(VI) acid and heat; dehydration is the type of chemical reaction involved in the conversion of propanol to propene; 2-butyne is unsaturated and can decolorize bromine solution; complete hydrogenation of benzene gives cyclohexane; either bromine solution or acidified KMnO_4 is used to distinguish between benzene and ethane; secondary alkanol undergoes complete oxidation reaction to produce an alkanone; an alkanol reacts with yellow-coloured potassium heptaoxodichromate(VI) solution to change green; hydrogen gas is liberated when alkanolic acid reacts with sodium metal; complete oxidation of propanol

in the presence of oxidizing agent such as potassium heptaoxodichromate(IV) and heat produces propanoic acid; ethyl methanoate is an ester and sweet scented; ammonia gas is evolved when amide is warmed with dilute sodium hydroxide solution than their students; and either ammoniacal silver nitrate or Fehlings solutions can be used to distinguish between alkanals and alkanones.

e. There was statistical significant difference in the levels of scientific understanding of students and teachers on the organic qualitative analysis diagnostic test. This is because mean score of teachers ($M = 21.60$, $SD = 11.515$) was higher to the students $M = 8.89$, $SD = 7.218$, $t(308) = -10.023$, $p = 0.001$).

2. The findings from the examination of teachers' and students' alternative conceptions and factual difficulties on OQA are:
 - a. The test on organic qualitative analysis was very difficult to students. This is because the calculated difficult index was 0.35.
 - b. The test on organic qualitative analysis was moderately difficult to teachers. This is because the calculated difficult index was 0.66.
 - c. Students were full of alternative conceptions on OQA. That, alkenes are less reactive than alkynes and thus, undergo elimination and substitution reaction respectively; propane is unsaturated organic compound and contains only carbon-carbon bonds; benzene undergoes hydrogenation and acid oxidation to form benzoic acid; ethane changes Br_2/CCl_4 and acidified purple $KMnO_4$ to orange as it is saturated hydrocarbon; propanal produces brown colour solution with alkaline potassium tetraoxomanganate(VII); 2-butyne is an alkane hence decolorizes bromine solution; the reagent is concentrated H_2SO_4 for substitution on benzene and addition reaction with ethene; secondary

alkanols with two ($-OH$) groups present on the carbon containing the $-OH$ group oxidise to form alkanone; alkanols reacts with potassium heptaoxodichromate(VI) solution to change colour to yellow; *an* amide reacts with sodium metal to liberate hydrogen gas; complete oxidation of propanol produces propylpropanoate; alkylalkanoates are sweet scented as they are formed from alkanolic acids; and nitrogen gas is evolved when amide reacts with dilute sodium hydroxide solution.

- d. Students showed factual difficulties on OQA that, alkenes and alkynes undergo addition reaction because of the carbon bond; propane is a polar molecule hence dissolves in polar solvent; benzene undergoes hydrogenation to produce cyclohexane through hydrogen atom elimination; some students only mentioned that ethene decolorizes both Br_2/CCl_4 and acidified $KMnO_4$ and were unable to explain why this is possible; some of the students did not know that 2-butyne is an unsaturated hydrocarbon; benzene is reactive to oxidizing agents such as acidified $KMnO_4$; some of the students did not know that, tertiary alkanols do not oxidize to form alkanone; some of the students did not know that sodium ethanoate is a salt but not an ester; and some of the students did not know that phenolphthalein is an indicator but not a reagent used to distinguish between compounds containing carbonyl functional groups.
- e. Teachers demonstrated alternative conceptions on OQA that, alkenes and alkynes are polar compounds and thus, decolorize polar tetrachloromethane; ethane is saturated hence decolorises Br_2/CCl_4 and acidified $KMnO_4$; propane reacts with alkaline potassium tetraoxomanganate (VII) to give brown colour; 2-butyne is an alkane thus decolorizes bromine solution; bromine atom

is used to distinguish between benzene and ethene; the presence of the two hydroxyl groups on secondary alkanols oxidise completely to produce ketones; alkanols react with yellow potassium heptaoxodichromate(VI) solution to form white precipitate; complete oxidation of propanol produces propylpropanoate; and hydrogen gas is evolved when amide reacts with dilute sodium hydroxide solution.

- f. Teachers showed factual difficulties on OQA that, hydrocarbons undergo addition reaction; alkenes and alkynes usually undergo addition reaction because the pi bonds in the carbon-carbon double and triple bonds are very strong to break by tetrachloromethane solution; some teachers simply mentioned that, benzene hydrogenates to form hexane with no scientific explanation; some of the teachers could only restate that ethene changes (Br_2/CCl_4) and acidified (KMnO_4) solutions with no justification for the process; alkanolic acid decolorizes bromine solution; some teachers did not know that indicators are not reagents for organic qualitative analysis but that of titration; some teachers did not know that methanamide is not an ester; and aldehydes react with Tollen's reagent to form acidic solution.
3. The findings from the exploration of what account for teachers' and students' problems on teaching and learning of OQA are:
 - a. Teachers and their students asserted that the schools were with little or no laboratory space, reagents, and other equipment needed for teaching and learning of OQA.
 - b. Teacher and their students asserted that practical-based instruction was the best approach to teaching and learning of OQA but was not the practice in the schools.

- c. Teachers and their students asserted that in the absence of adequate chemicals and reagents, models and animations could be used to help students overcome their learning difficulties on OQA but these were also absent in the schools.
- d. Teachers and students asserted that the content of the chemistry curriculum on OQA is voluminous and abstract in nature and needed more time but teachers usually introduced the concept in the final year of the SHS programme.

Conclusion

The study has shown that, qualitatively teachers, unlike their students who demonstrated no scientific understanding level on learning organic qualitative analysis, demonstrated partial level of scientific understanding on organic qualitative analysis. The study has added to the literature that not only are students with low level of conceptual understanding on organic qualitative analysis but their teachers do and that the low level of scientific understanding among students could be attributed to the weak content knowledge of their teachers. In addition, teachers' level of scientific understanding was statistically significantly different from their students' level of scientific understanding on organic qualitative analysis.

The study has shown that, organic qualitative analysis was difficult to teachers and their students. The teachers' and their students' difficulties were qualitatively seen as alternative conceptions and factual difficulties. The alternative conceptions and factual difficulties were seen under various functional groups as saturated and unsaturated hydrocarbons, alkanols, alkanonic acids, alkylalkanoates, alkanones and aldehydes, and amides.

Students' alternative conceptions were that of conceptual misunderstanding as teachers share most of these alternative conceptions. The study has added to the literature that alternative conceptions exist in the area of organic qualitative analysis as there are in other areas of chemistry.

The study has shown that not only were teachers and their students having conceptual difficulties in organic qualitative analysis but there were other factors accounting for problems of teaching and learning of the concept. The problems of teaching and learning of organic qualitative analysis were associated with teaching and learning resources, practical-based instruction, and chemistry curriculum content. Teachers and their students agreed that practical-based instruction could be the solution to the conceptual difficulties students have on organic qualitative analysis. And that where there is challenge in procuring chemicals and reagents for teaching and learning organic qualitative analysis through practical-based instruction which is absent in the selected schools, the use of models is the solution.

Recommendations

The following recommendations are made based on the findings of the study:

- a. As teachers demonstrated partial scientific conceptual understanding on OQA, the Ministry of Education through the Ghana Education Service should liaise with the teacher education universities to organise short courses for teachers to help them upgrade their content knowledge in chemistry.

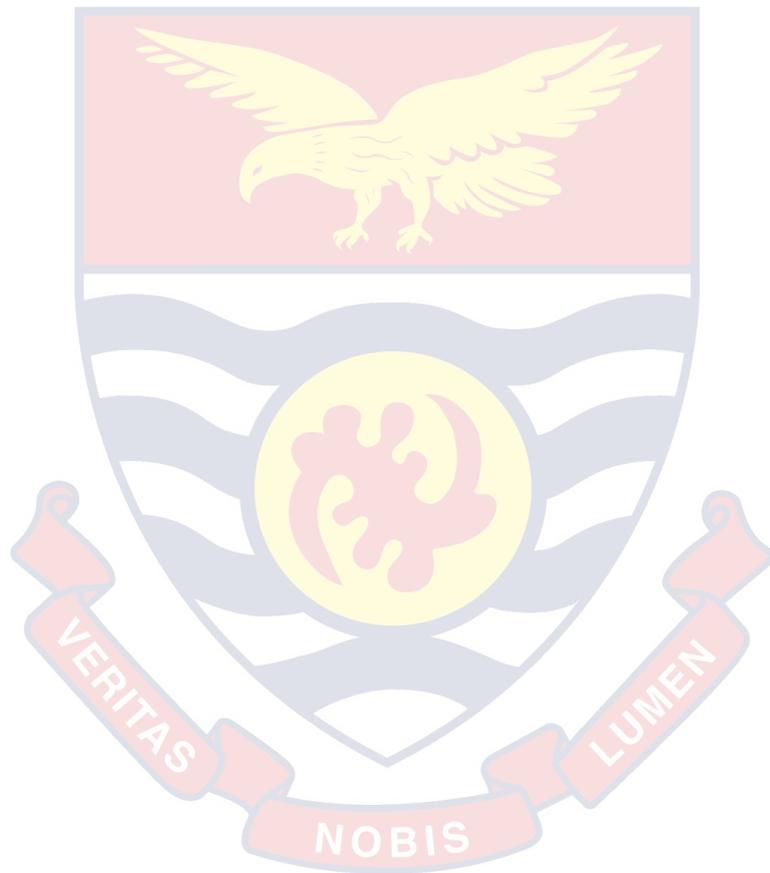
- b. As students' factual difficulties and alternative conceptions existed in the area of OQA, chemistry teachers should select and use conceptual change approaches in teaching chemistry.
- c. As teachers' factual difficulties and alternative conceptions existed on OQA, chemistry educators and researchers should design and develop instructional strategies that challenge alternative conceptions among teachers.
- d. The Ministry of Education should provide the selected schools with well-equipped laboratories for effectively teaching of OQA to students as the schools lack laboratory space, reagents, and other equipment.
- e. The Inspectorate Division of Ghana Education Service should monitor chemistry teachers and insist on the use of approaches recommended by the curriculum planners for teaching qualitative analysis as teachers barely teaching OQA to students through practical-based teaching.

Suggestion for Future Research

The study explored chemistry teachers' and students' conceptual understanding of OQA. The study, however, did not intervene in helping students to develop scientific conception on OQA concept with ease. It is therefore, recommended that future research should consider the use of interventions in the teaching and learning of OQA concept to enhance students' conceptual understanding.

Also, the study explored what contribute to teacher problems in teaching OQA. However, the study did not consider other factors such as professional qualification, academic qualification, teaching and classroom assessment practices.

It is, therefore, recommended that further research on the impact of professional and academic qualification, teaching and classroom assessment practice on teacher difficulties on OQA.



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APPENDICES

APPENDIX A

ORGANIC QUALITATIVE ANALYSIS DIAGNOSTIC TEST FOR STUDENTS

This diagnostic test seeks to find out students' conceptual understanding and difficulties in organic qualitative analysis. Please kindly read carefully and provide responses in the spaces provided. Your responses will be treated as confidential. Thus your identity is not required. You are therefore entreated to respond to the items to the best of your ability since your performance will be used purposely for research. You will be given 50 minutes to respond to the items after which your paper will be collected.

SECTION A

Biodata:

1. School type: Single sex [] Mixed School []
2. Class A school [] Class B school [] Class C school []
3. Sex: Male [] Female []
4. Age:years

SECTION B

Kindly select one among the alternatives and give reason for the one selected in the spaces provided.

5. Alkenes and alkynes are organic compounds that usually undergo.....reactions.
 - A. addition
 - B. condensation

- C. elimination
- D. substitution

Give reason:

.....

.....

6. The compound that will readily dissolve in tetrachloromethane is

.....

- A. $\text{CH}_3\text{CH}_2\text{CH}_3$
- B. $\text{CH}_3\text{CH}_2\text{OH}$
- C. CH_3OH
- D. HCl

Give reason:

.....

.....

7. Which of the following compounds is sweet scented?

- A. Ethanoic acid
- B. Ethylmethanoate
- C. Methanamide
- D. Sodium methanoate

Give reason:

.....

.....

8. A complete hydrogenation of benzene gives

- A. cyclohexane
- B. cyclohexene

- C. hexane
- D. hexene

Give reason:

.....
.....

9. An alkanol which undergoes complete oxidation reaction to produce an alkanone is likely to be a

- A. primary alkanol
- B. quaternary alkanol
- C. secondary alkanol
- D. tertiary alkanol

Give reason:

.....
.....

10. An organic compound which decolourizes both Br_2/CCl_4 and acidified KMnO_4 is

- A. C_2H_4
- B. C_2H_6
- C. C_3H_8
- D. C_4H_{10}

Give reason.....

.....

11. Which of the following functional group will liberate hydrogen gas when reacts with sodium metal?

- A. $-\text{CONH}_2$

- B. . -CHO
- C. -CO-
- D. -COOH

Give reason.....

12. The compound that will give brown colour solution with alkaline potassium tetraoxomanganate (VII) is

- A. $\text{CH}_3\text{CH}_2\text{CH}_3$
- B. CH_3COCH_3
- C. $\text{CH}_3\text{CH}_2\text{CHO}$
- D. $\text{CH}_3\text{CH}=\text{CH}_2$

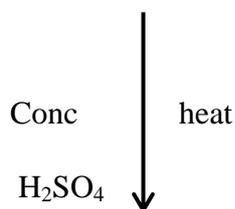
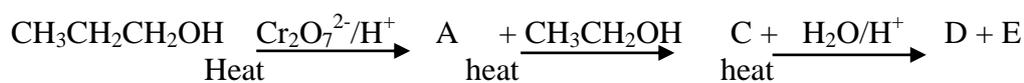
Give reason.....

13. The compound to be produced when propanol is completely oxidized in the presence of oxidizing agent such as potassium heptaoxodichromate (IV) and heat is

- A. propanol
- B. propanone
- C. propanoic acid
- D. propylpropanoate

Give reason.....

Consider the following reaction scheme below, and use them to answer the below questions 14(α) and (β).



B

14. Give the

(α) chemical formula of each of the compounds A, B, C, D and E

.....

.....

.....

.....

.....

(β) functional groups presence in A, B, C, D and E

.....

.....

.....

.....

.....

15. Identify the type of chemical reaction involved in the conversion of



(α) A

.....

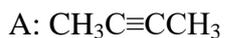
(β) B

.....

(γ) C

.....

Consider the following chemical structures below, and use them to answer questions 16 to 22.



16. Write your observation when the compound B reacts with acidified potassium heptaoxodichromate(VI) solution.

a. Identify the functional group responsible for this.

b. Give reason.....

.....

17. Write your observation when the compound D is warmed with dilute sodium hydroxide solution.

a. Identify the functional group responsible for this.

Give reason.....

.....

18. Write your observation when the compound A react with bromine solution.

a. Identify the functional group responsible for this.

Give reason.....

.....

19. Write the observation when compound C is treated with sodium hydrogen trioxocarbonate(IV) $[\text{NaHCO}_3]$

.....

20. Write the observation when compound B is treated with hot solution of I_2 in NaOH solution.

.....
.....

State the reagent that can be used to distinguish between the following pairs of organic compounds in organic qualitative analysis.

21. C_6H_6 and $CH_2=CH_2$

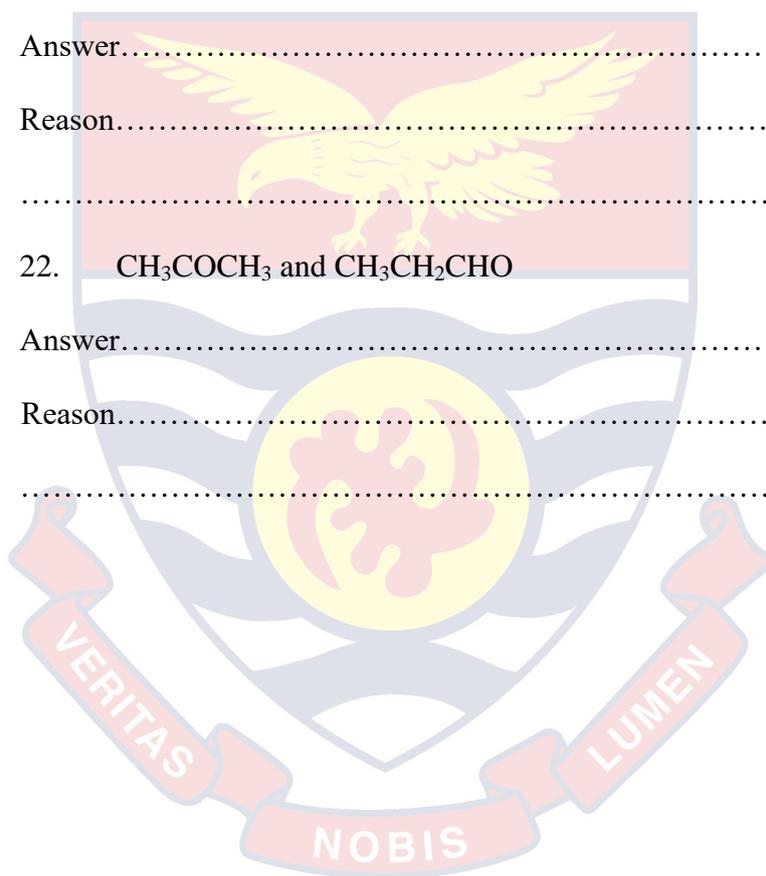
Answer.....

Reason.....

22. CH_3COCH_3 and CH_3CH_2CHO

Answer.....

Reason.....



APPENDIX B

ORGANIC QUALITATIVE ANALYSIS DIAGNOSTIC TEST FOR TEACHERS

This is a study, which seeks to investigate the conceptual understanding of chemistry teachers' and their students' with regard to organic qualitative analysis. You are kindly requested to complete all the items in this section by either ticking (✓) or filling in the appropriate answer in the spaces provided. Your responses would be treated with the strictest confidentiality, and only for research purposes.

Please read through the items as carefully as possible and offer your candid opinion.

SECTION A: General information

This section seeks information about you and your school. Kindly fill the space provided or tick (✓) the brackets following the options.

1. Name of School.....

2. Gender Male [] Female []

3. Age:

20 – 30yrs [] 31 – 40yrs []

41-50 yrs. [] Over 50 yrs []

4. Teaching experience

0 – 5yrs [] 6 – 10yrs []

11-15 yrs [] 16-20yrs [] Over 20 yrs []

4. Highest level of academic qualification

First degree []

Second degree []

PhD []

5. Professional qualification

UTDBE []

PGDE []

B.Ed. []

M.Phil []

Others, specify.....

5. Area of specialty (write your major Subject)

.....

SECTION B

Please carefully read the following statements and indicate by ticking whether you agree or not, and kindly give reason for your response.

6. Alkenes and alkynes are organic compounds that usually undergo.....reactions.

- A. addition
- B. condensation
- C. elimination
- D. D. substitution

Give reason:

.....
.....

7. The compound that will readily dissolve in tetrachloromethane is

- A. $\text{CH}_3\text{CH}_2\text{CH}_3$
- B. $\text{CH}_3\text{CH}_2\text{OH}$
- C. CH_3OH
- D. HCl

Give reason:

.....
.....

8. Which of the following compounds is sweet scented?

- A. Ethanoic acid
- B. Ethylmethanoate
- C. Methanamide
- D. Sodium methanoate

Give reason:

.....
.....

9. A complete hydrogenation of benzene gives

- A. cyclohexane
- B. cyclohexene
- C. hexane
- D. hexene

Give reason:

.....
.....

10. An alkanol which undergoes complete oxidation reaction to produce an alkanone is likely to be a

- A. primary alkanol
- B. quaternary alkanol
- C. secondary alkanol
- D. tertiary alkanol

Give reason:

.....
.....

11. An organic compound which decolourizes both Br_2/CCl_4 and acidified KMnO_4 is

A. C_2H_4

B. C_2H_6

C. C_3H_8

D. C_4H_{10}

Give reason.....

.....

12. Which of the following functional group will liberate hydrogen gas when reacts with sodium metal?

A. $-\text{CONH}_2$

B. $-\text{CHO}$

C. $-\text{CO}-$

D. $-\text{COOH}$

Give reason.....

.....

13. The compound that will give brown colour solution with alkaline potassium Tetraoxomanganate (VII) is

A. $\text{CH}_3\text{CH}_2\text{CH}_3$

B. CH_3COCH_3

C. $\text{CH}_3\text{CH}_2\text{CHO}$

D. $\text{CH}_3\text{CH}=\text{CH}_2$

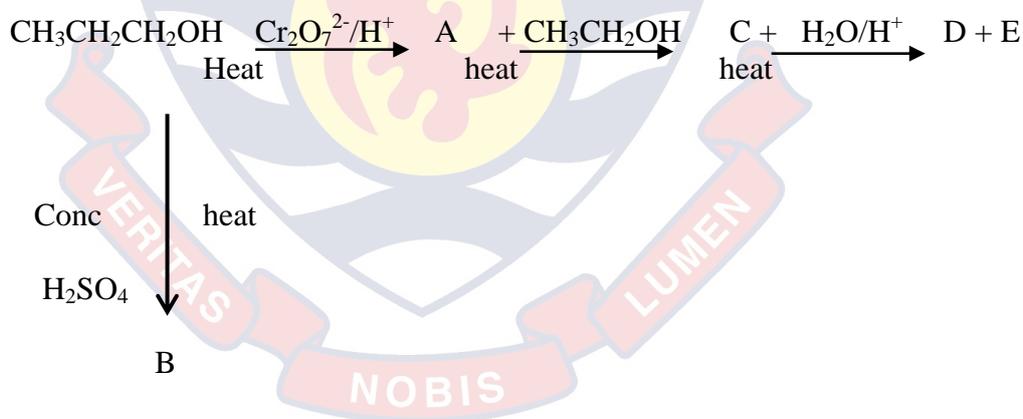
Give reason.....

14. The compound to be produced when propanol is completely oxidized in the presence of oxidizing agent such as potassium heptaoxodichromate (IV) and heat is

- A. propanol
- B. propanone
- C. propanoic acid
- D. propylpropanoate

Give reason.....

Consider the following reaction scheme below, and use them to answer the below questions 15(α) and (β).



15. Give the

(α) chemical formula of each of the compounds A, B, C, D and E

.....

(β) functional groups presence in A, B, C, D and E

.....
.....
.....
.....

16. Identify the type of chemical reaction involved in the conversion of

$\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ to

(α) A

.....

(β) B

.....

(γ) C

.....

Consider the following chemical structures below, and use them to answer questions 17 to 21.

A: $\text{CH}_3\text{C}\equiv\text{CCH}_3$

C: $\text{CH}_3\text{CH}_2\text{COOH}$

B: $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{OH}$

D: CH_3CONH_2

17. Write your observation when the compound B reacts with acidified potassium heptaoxodichromate(VI) solution.

c. Identify the functional group responsible for this.

d. Give reason.....

.....

18. Write your observation when the compound D is warmed with dilute sodium hydroxide solution.

- b. Identify the functional group responsible for this.
- c. Give reason.....
.....
19. Write your observation when the compound A react with bromine solution.

- b. Identify the functional group responsible for this.
- c. Give reason.....
.....

20. Write the observation when compound C is treated with sodium hydrogen trioxocarbonate(IV) [NaHCO₃]
.....
.....

21. Write the observation when compound B is treated with hot solution of I₂ in NaOH solution.
.....

State the reagent that can be used to distinguish between the following pairs of organic compounds in organic qualitative analysis.

22. C₆H₆ and CH₂=CH₂
Answer.....
.....

Reason.....
.....

23. CH₃COCH₃ and CH₃CH₂CHO
Answer.....
.....

Reason.....
.....

APPENDIX C

STUDENT INTERVIEW GUIDE ON ORGANIC QUALITATIVE ANALYSIS

This seeks to find out from students their experiences during learning of organic qualitative analysis. This will be in two, Sections A and B. Section A will be their learning experiences before organic chemistry lesson and Section B will be after organic QA lesson.

Section A (Before the lessons on organic QA)

1. Have you been introduced to organic chemistry?
2. Have you been learning organic qualitative analysis?
3. Identify some problems in learning organic qualitative analysis?
4. How does your teacher help you to overcome these problems?
5. If you are learning organic qualitative analysis today, what do you expect?

Section B (After the lessons on organic QA)

1. Where your expectations met during organic qualitative analysis lesson?
2. Can you provide details of meeting or not meeting your expectation?
3. Can you identify some problems associated with your learning of organic QA after this lesson?
4. How best can you be helped in learning organic QA?

APPENDIX D

TEACHER INTERVIEW GUIDE ON ORGANIC QUALITATIVE ANALYSIS

The purpose of this instrument is to find out from chemistry teachers their experiences during teaching and learning of organic qualitative analysis. This will be in two sections, Sections A, B. Section A will be their teaching experiences before organic qualitative analysis lessons, and Section B will be after organic qualitative analysis lessons.

Section A (Before the lessons on organic QA)

1. Do you teach organic qualitative analysis to students?
2. How do you structure your lessons on organic qualitative analysis?
3. Can you identify some problems associated with your teaching of organic QA?
4. How do you help in solving them?
5. What should I expect from this lesson on organic qualitative analysis today?

Section B (After the lessons on organic QA)

1. Was this lesson successful according to your aims of teaching today?
2. Give any reason for the success or otherwise of the lesson?
3. What will you do differently when given the opportunity once again to teach organic qualitative analysis?

APPENDIX E

OBSERVATION CHECKLIST ON TEACHING ORGANIC QUALITATIVE ANALYSIS (OCTOQA)

The intent of this instrument is to use class observation checklist to find out from chemistry teachers and students whether the intended purposes have been achieved. There will be two sections (A and B). Section A will seek for general information about teacher and students, class size, duration for lesson. Section B will seek for expectations from teachers and students before and after the lesson.

Section A: General information about the teacher and students.

1. Gender of teacher: Male [] Female []
2. Number of years in teaching chemistry.....
3. Number of students.....
4. Duration of lesson

Expectation	Present	Absent
5. Use of lesson plan to guide lesson implementation		
6. Activity-driven pedagogical approach to support students conceptual understanding		
7. Revision of previous concepts before introducing the lesson		
8. Use of organic models to teach organic functional group detections		
9. Link examples of compounds to available substances present in the immediate environments during teaching		
10. Give detailed explanation of the concept		

APPENDIX F

DETERMINATION OF KR 21 COEFFICIENT OF RELIABILITY

Mean and Standard Deviation of students' chemistry Diagnostic test scores

n	π	S	S^2
30	8.89	7.218	52.101

$$KR\ 21 = \left[\frac{n}{n-1} \right] [1 - \pi(n - \pi)/nS^2]$$

Where n is the number of items, which is 30 π is the mean score, which is 8.89

S^2 is the variance, which is 52.101

$$KR\ 21 = \left[\frac{30}{29} \right] [1 - 8.89(30 - 8.89)/30(52.101)]$$

$$KR\ 21 = 1.0344 \{1 - (266.7 + 79.0321/1563)\}$$

$$KR\ 21 = 1.0357 (1 - 0.221198)$$

$$KR\ 21 = 1.0357 (0.7788)$$

$$KR\ 21 = 0.81.$$

APPENDIX G

DETERMINATION OF KR 21 COEFFICIENT OF RELIABILITY

Mean and Standard Deviation of teachers' chemistry Diagnostic test scores

n	π	S	S^2
30	21.60	11.515	132.594

$$KR\ 21 = \left[\frac{n}{n-1} \right] [1 - \pi(n - \pi)/nS^2]$$

Where n is the number of items, which is 30

π is the mean score, which is 21.60

S^2 is the variance, which is 132.594

$$KR\ 21 = \left[\frac{30}{29} \right] [1 - 21.60(30 - 21.60)/30(132.594)]$$

$$KR\ 21 = 1.0344(1 - (648 + 466.56/3977.82))$$

$$KR\ 21 = 1.0344(1 - 1114.56/3977.82)$$

$$KR\ 21 = 1.0344(1 - 0.28019)$$

$$KR\ 21 = 1.0344(0.71981)$$

$$KR\ 21 = 0.74$$