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Chemistry students' conceptual understanding of organic qualitative analysis

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ABSTRACT

Organic qualitative analysis is one of the challenging chemical concepts in students learning of chemistry. The West African Examinations Council 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 students' conceptual understanding of organic qualitative analysis. Convergent mixed methods procedure was used to collect both quantitative and qualitative data from 263 chemistry students. The 263 students were selected through multistage sampling technique to respond to organic qualitative analysis diagnostic test for students. Quantitative data was analyzed using percentages, means, and standard deviations to determine students' level of conceptual understanding on organic qualitative analysis. The results from the study showed that, students demonstrated no scientific understanding on organic qualitative analysis. The qualitative data was open-coded and constantly compared to establish students' conceptual difficulties on organic qualitative analysis. Students demonstrated conceptual difficulties were in the form of alternative conceptions and factual difficulties. It was, therefore, recommended that chemistry teachers should select and use appropriate conceptual change instruction approaches in their teaching to help students conceptualize organic qualitative analysis contents in organic chemistry.

Keywords: organic qualitative analysis, functional groups, alternative conceptions, factual difficulties, chemistry students

INTRODUCTION

Chemistry is a scientific discipline that requires learners with the ability to deal with its concepts at the macroscopic and submicroscopic 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 et al., 2000; Marais & Jordaan, 2000). According to Ebbing and 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 characterized into various branches namely; organic, inorganic, physical, and analytical. Organic chemistry is that 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 et al., 2004).

Chemistry concepts are difficult for many students to learn, as its very fundamental concepts are insufficiently grasped by students (Coll & Treagust, 2001; Nicoll, 2001). 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. Hanson (2017) opined that adequate understanding of organic chemistry is a pre-requisite for many graduate and professional programs. It is a key to the development of new products in the society and it is the basis for the production of food flavors, plastics, clothing, car tires, fuels, cement, pharmaceuticals and house cleaning agents. Researchers have indicated that students have difficulties in understanding organic chemistry concepts (Childs & Sheehan, 2009; Graulich, 2015; Wasacz, 2010). Students indicated that organic chemistry is an abstract (Anim-Eduful & Adu-Gyamfi, 2022), onerous task and a memorization-oriented subject with many concepts to be learnt (Bhattacharyya & Bodner, 2005).

Stieff (2007) revealed 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 meaningful learning.

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Hence, for good understanding in organic analysis or reactions to be achieved, students have to fully conceptualize reaction 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 analyze 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 et al., 2010). Difficulties arise when students classify these organic compounds regarding their understanding of physical properties, reactions and mechanisms of organic (Hassan et al., 2004). 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 memorization-oriented approach in learning organic chemistry.

The main goal of science education is teaching for conceptual understanding (Konicek-Moran & Keeley, 2015), a phenomenon which is complex (Nieswandt, 2007). Conceptual understanding refers to what learners know and understand about a concept that is 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 memorization approach rather they formulate ideas while learning; ask questions continually based on their state of understanding; and transform and reconstruct their knowledge structures. Science teaching should be focused on conceptual understanding to improve students' ability to reinforce connections and organize knowledge (Mills, 2016). Nieswandt (2007) posits that students with conceptual understanding in science concept are able to apply the learned scientific concepts to scientific phenomena in their everyday life.

Meaningful science learning requires conceptual understanding rather than memorization (Adadan et al., 2010). Meaningful learning requires knowledge to be constructed by the learner, not transmitted from the teacher to the students (Jonassen et al., 1999). Students who are excellent at memorizing 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 (Mills, 2016). 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 memorized 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 memorization (Grove & Bretz, 2012).

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). 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 (1994) revealed that chemistry students have difficulties in understanding chemical concepts and reactions that underpins qualitative analysis. A study done by 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 et al., 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 concept (Moe, 2011).

Chemical tests (qualitative analysis) on functional groups may improve students' understanding of basic concepts about the structure of organic compounds and their reactivity (Adu-Gyamfi & Anim-Eduful, 2022). Chemical analysis is one of the important areas in chemistry learning. Chemical analysis is categorized into two namely: quantitative analysis and qualitative analysis. Quantitative analysis determines the amounts or volume of element or group of elements present in a given sample of solution whereas qualitative analysis determines which elements or ions are present in given sample of solution. Qualitative analysis is further categorized into two namely: organic qualitative analysis and inorganic qualitative analysis. Organic qualitative analysis basically deals with detections of functional group present in a given sample of a solution whiles inorganic qualitative analysis finds inorganic substances (cations, anions), and gases present in a given sample of solution (Ministry of Education, 2010). Identification and characterization 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 group 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, decolorization or disappearance of the reddish-brown color 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).

Functional groups are atoms or group 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). Functional group detections deal with writing appropriate reaction for different functional group, indicating correct method for preparation/synthesis of different organic compounds, and proposing mechanism of reaction for different functional group (Domin et al., 2008). The presence of carbon, hydrogen and oxygen in most of these functional groups makes it difficult for students to differentiate between them, especially the carbonyl group (*-C=0*) comprising of aldehydes and ketones.

The findings of Adu-Gyamfi et al. (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. (2017) indicated among others that, students had difficulties in identifying functional group and correct position and number of multiple bonds in an organic molecule.

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, 2001, 2003, 2005, 2006, 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. According to Ministry of Education (2010), one of the aims of the chemistry teaching syllabus is to assist students in SHS 2 to identify organic functional group, their reactions used to confirm their presence in compounds or otherwise and also by means of qualitative analysis be able to distinguish between various functional group when provided with suitable reagents. The qualitative organic analysis which is basically functional group detection. The functional group studied in organic chemistry at the senior high school level are hydrocarbons consisting of (alkenes and alkynes), and aromatic hydrocarbons (benzene); alcohols (*-OH*); aldehydes (*-CHO*); ketones (*-C=O*); alkanoic acids (*-COOH*); esters (*-COO-*), and amides ($-CONH_2$) (Ministry of Education, 2010). The specific objectives outlined in the Chemistry teaching syllabus are for students to: distinguish between saturation (alkanes) and unsaturation (alkene and alkyne) using acidified purple $KMnO_4$, andvBr_2/H_2O; tests for carbonyl compounds (alkanals (aldehydes) and alkanones (ketones) using 2, 4-dinitrophenylhydrazine, Fehling's or Benedict's solution and Tollen's reagent (ammoniacal silvernitrate); classify and determine the products formed by the oxidation reactions of primary, secondary and tertiary alkanols using acidified $K_2Cr_2O_7$, acidified $KMnO_4$ and I_2 in $NaOH$ solutions; test for the presence of amides ($-CONH_2$) using ethanamide or urea with $NaOH$ to give ammonia (NH_3) gas and also test for alkanoates (esters), a reaction between alkanol and alkanoic acid in the presence of concentrated tetraoxosulphate(VI) (H_2SO_4) and heat (Ministry of Education, 2010, p. 49-60).

Again, from the Ministry of Education (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 students' conceptual understanding on organic qualitative analysis.

For instance, 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 silvernitrate ($AgNO_3/NH_3$)] and ethanamide (CH_3CONH_2) reacting with diluted sodium hydroxide ($NaOH$). In 2004, students were provided with organic compounds 2-butyne ($CH_3C \equiv CCH_3$), methylethanoate (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; could readily decolorize Br_2/CCl_4, has two functional groups, will give effervescence with $NaHCO_3$, and can be prepared from an alkanol and alkanoic acid. From WAEC (2004), the report indicated that students could not perform well. Most of the students had difficulties in identifying the functional groups.

Similarly, 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/NaOH(aq).

In 2012, chief examiner's 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 colorless instead purple color of $KMnO_4$ will remain unchanged since benzene do not exhibit unsaturation and same to bromine solution.

Again, 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 ($HOOC$)C_6H_5($CH = CH_2$)(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: $CH_3(CH_2)_2CH_2OH$ *and* CH_3CH_2OH; $CH_3CH_2C \equiv CH$ *and* $CH_3C \equiv CCH_3$; $CH_3CH_2CH_2CH_3$ *and* $CH_3CH_2CH = CH_2$. The report pointed out that most of the students who tackled had difficulties giving correct suitable reagents and products.

Also in 2017, students were asked to state the functional group and name the compound $H_3CCOOCH_2CH_3$. In the same year, students were again asked to name the class of organic compounds that could be identified using each of the following reagents: acidified tetraoxomanganate (VII) solution, and sodium trioxocarbonate (IV) solutions. WAEC chemistry chief examiner's report indicated that most of the students could not name and give the correct functional group(s) present in a given organic compounds. Further, in 2018, chief examiner's report revealed that students could not name the class of organic compounds and students also had difficulties giving correct suitable reagents used in detecting these organic compounds: CH_3CH_2COOH and $CH_3CH_2CH_2OH$, and CH_3CH_2OH and $CH_3CH_2CH_2OH$.

These reports suggest that SHS chemistry students in Ghana have challenges with conceptual understanding of organic qualitative analysis. It is important, therefore, to investigate chemistry students' conceptual understanding of organic qualitative analysis.

RESEARCH DESIGN

This current study adopted convergent mixed methods design procedures (Creswell & Plano Clark, 2018) to investigate chemistry students' conceptual understanding of organic qualitative analysis at the SHS level. A cross-sectional survey design was employed to collect both quantitative and qualitative data on students' conceptual understanding on organic qualitative analysis using an achievement test in the form of two-tier diagnostic test. From the diagnostic test, the performance (conceptual understanding) of students on organic qualitative analysis was analyzed using frequencies, percentages, means and standard deviations. This enabled us to determine and further categorized students' level of understanding into full scientific understanding (FSU), partial scientific understanding (PSU), and no scientific understanding (NSU) based on the quantitative data obtained. Thereafter, the qualitative data was analyzed using thematic analysis that helped us to investigate students' conceptual understanding as they demonstrated weak performance (classified as low scientific understanding) on organic qualitative analysis. The outcome from the data that is, quantitative and qualitative aspects were further merged through discussion to help investigate chemistry students' level of conceptual understanding on organic qualitative analysis.

Purpose of the Study

The intent of this current study was to investigate chemistry students'conceptual understanding of organic qualitative analysis.

Sampling Procedure

This study was carried out in Central Region, which is one of the 16 regions in the Republic of Ghana. Central Region was chosen for the study due to the high number of renowned senior high schools found in the Region: which had all the observable characteristics in the Ghanaian senior high schools, thus attracted students from all other regions of Ghana. Central Region had 68 public senior high schools during the 2019/2020 academic year.

Not all the 68 schools in central region were targeted for this study. This is because 55 out of the 68 offered chemistry as one of their elective subjects for students offering general science. Thus, multi-stage sampling technique was employed for the sampling selection process for this current study. In the first stage of the sampling process, a stratified random sampling technique 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. There were six class A schools, 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 31 class C schools.

These classes of schools were further stratified into single-sex and co-educational schools. There were six class A schools made of three males single-sex and three females single-sex. Stratified sampling followed by simple random sampling were to select two schools from single-sex, and four from co-educational schools. In all, six public schools participated in this study.

The study involved 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 Ministry of Education (2010) chemistry syllabus, and they were in a better position to contribute to the study. 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. Stratified sampling procedure followed by random sampling were used to select 163 students (50.3% males and 49.7% females) from the four selected co-educational 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 3 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.

Data Collection Instrument

The research instrument for collecting both quantitative and qualitative data for this study was an achievement test in the form of diagnostic test named organic qualitative analysis diagnostic test for students (OQADTS). The diagnostic test was used to investigate chemistry students' conceptual understanding of organic qualitative analysis. The diagnostic test was made of nine two-tier four-option multiple choice diagnostic test items. The first-tier of the test sought to measure students' content knowledge in organic qualitative analysis in organic chemistry; and the second-tier also sought to measure students' explanation knowledge (reasons). We used the second-tier to determine students' explanation (reasons) for their selected options from the first-tier. This helped us to answer the research question raised '*what is chemistry students conceptual understanding in organic qualitative analyses?* Students were required to respond to each item by selecting one of the four options deemed correct to them and provide a reason for the option. The reason provided for selecting a particular option helped us to investigate students' conceptual understanding on the test. The other two tests items on the diagnostic test were essay-type but not multiple-choice. The two essay-type test items involved organic functional groups detection and analysis using suitable organic reagents. This essay-type test items enabled us to investigate what students' conceptual understanding and their difficulties is in conceptualizing organic functional group detections. That is, students' ability to:

1. detect and identify some organic functional group such as hydrocarbons (alkenes, alkynes and benzene), alcohols (alkanols), carboxylic acids (alkanoic acids), alkylakanoates (esters), carbonyl compounds (alkanones and alkanals) and amides; and
2. write with justification, the observation seen when certain organic compounds react with known and suitable oxidizing and reducing agents.

The diagnostic test items on the OQADTS were constructed by the researchers. To ensure content validity of OQADTS, the items were compared to standardized 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 during the process of designing the test items. The instrument was shown to two experienced and assistant examiners who were colleague chemistry teachers of the first author and a colleague science educator of the second author for expert critique and advice on the content in order to ensure face validity of the instrument. The quality of the OQADTS test items were improved as a result of the inputs made by these experts. Thereafter, the improved test items were pilot-tested with 30 students in a senior high school in the Sekondi-Takoradi Metropolis of Western Region of Ghana. Determination of the difficulty and discrimination indices of the test items were achieved through the pilot-testing of the OQADTS test items which consequentially, helped improve 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. Thereafter, we calculated the Kuder-Richardson (KR) 21 coefficient to determine the reliability of the instrument and was found to be 0.81. The (KR) 21 value indicated that the diagnostic test item was reliable.

Data Collection Procedure

Administering of the research instrument (OQADTS) was done by the researchers. For the purpose of the study to be achieved, the researchers had a brief discussion with teachers and their students before the administration of OQADTS. This helped the researchers a lot as students appreciated the need to participate in the research. Again, during the data collection session, the final year students were preparing for their West African secondary school certificate examinations organized by WAEC. After the briefing session, researchers found out if chemistry teachers have covered enough on organic chemistry with their students in each of the participating schools. The selected schools and students who had not covered enough were exempted from the research. Other schools were made to replace those selected but exempted schools. In all, it took the researchers 3 weeks to administer the OQADTS to the 263 chemistry students within all the six selected senior high schools.

Data Processing and Analysis

The items on OQADTS for 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 had a total score of 44 marks. Structure of level of understanding were adopted from previous studies in the area of chemistry teachers' difficulties in organic functional group detections (Anim-Eduful & Adu-Gyamfi, 2021). Students' 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 mark. Students' conceptual understanding of organic qualitative analysis were categorized into three levels. The first level that was based on correct content and reason responses; being 2 scores was FSU, the next level being the second, went with correct responses for either content or reason but not both; being 1 score was PSU; and the third level, which happened to be the last, went with incorrect content and reason responses for both content and reason; being 0 scores was NSU.

The data obtained were analyzed using percentages, means, and standard deviations. Mean ranges from 00.0 to 0.49 was considered NSU, 0.50 to 1.49 as PSU, and 1.50 to 2.0 as FSU. Explanations provided by the participating students to their content were used for the qualitative aspect of the study. Students' content responses were then open-coded and compared constantly. Thereafter, we made meaning of students' explanations and themes were generated out of them. Sample statements and explanations from students were used to support presentations of any conceptual difficulties of students. For the purposes of this study, students' conceptual difficulties on organic functional group detection were categorized into two namely: factual difficulties and alternative conceptions.

RESULTS

The research question sought to investigate chemistry students' conceptual understanding of organic qualitative analysis basically on functional group detections. To achieve this, students' levels of conceptual understanding on organic functional groups detection were first investigated. This became important as we needed to appreciate the kind of scientific understanding demonstrated by students on functional groups detection either full, partial or low. Again, to be able to investigate students' conceptual difficulties in the form of factual difficulties and alternative conceptions. The results are presented in **Table 1**. Generally, students' scientific understanding on organic qualitative analysis was low, that is they demonstrated low scientific understanding. This is because students average mean scientific understanding on all the diagnostic test items was 0.30 (SD=0.651).

To ascertain that propane readily dissolves in tetrachloromethane, item 6 was used. From **Table 1**, 67 (25.5%) of the students at a mean of 0.92 (SD=0.606) demonstrated PSU that propane readily dissolves in tetrachloromethane. This indicates that 68.1% students had NSU and only 6.5% fully understood the concept. Hence, students have PSU that propane readily dissolves in tetrachloromethane. To ascertain that alkenes and alkynes were organic compounds that usually undergo addition reactions, item 5 was used. From **Table 1**, 104 (39.5%) of the students at a mean of 0.88 (SD=0.775) demonstrated PSU that alkenes and alkynes are organic compounds that usually undergo addition reactions. This indicates that 34.2% students had NSU and 26.2% fully understood the concept. Hence, students have PSU that alkenes and alkynes are organic compounds that usually undergo addition reactions. On item 10, the results from **Table 1** show that 103 (39.2%) of the students at a mean of 0.59 (SD=0.664) demonstrated PSU that ethene is an organic compound which decolorizes both Br_2/CCl_4 and acidified $KMnO_4$. This indicates that only 9.9% had FSU and 51.0% had no understanding. Hence, students have PSU that ethene is an organic compound that decolorizes both Br_2/CCl_4 and acidified $KMnO_4$. On item 12, the results show that 156(59.3%) of the students at a mean of 0.47 (SD=0.610) demonstrated NSU that propene gives brown color solution with alkaline potassium tetraoxomanganate (VII). This indicates that 34.6% students partially understood whiles only 6.1% fully understood the concept. Hence, students have NSU that propene gives brown color solution with alkaline potassium tetraoxomanganate (VII). On item α14B, the results show that, 208(79.1%) of the students at a mean of 0.42 (SD=0.815) demonstrated NSU 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 FSU. Hence, students, have NSU that when propanol is dehydrated in the presence of concentrated tetraoxosulphate (VI) acid and heat propene which is a saturated hydrocarbon with carbon double bond carbon is produced. Again, to ascertain that the functional group present in propene is an alkene, item β14B was employed and the results from **Table 1** show that, 213 (81.0%) of the students at a mean of 0.38 (SD=0.786) demonstrated NSU and only 19.0% students fully understood that an alkene functional group is present in propene. Hence, students have NSU that the functional group present in propene is an alkene which contains a carbon double bond carbon. Again, to ascertain that, the type of chemical reaction involved in converting propanol to propene is called dehydration, item 15β was used. The results show that, as

Table 1. Levels of students' conceptual understanding in organic qualitative analysis (n=263)

Item	Understanding level						M	SD
	NSU		PSU		FSU			
	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
α14B	208	79.1	0	0	55	20.9	0.42	0.815
β14B	213	81.0	0	0	50	19.0	0.38	0.786
15β	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
α14D	223	84.8	0	0	40	15.2	0.30	0.720
β14D	217	82.5	0	0	46	17.5	0.35	0.761
15α	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
α14A	210	79.8	0	0	53	20.2	0.40	0.799
α14E	226	85.9	0	0	37	14.1	0.28	0.697
β14A	210	79.8	0	0	53	20.2	0.40	0.804
β14E	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
α14C	222	84.4	0	0	41	15.6	0.31	0.727
β14C	210	79.8	0	0	53	20.2	0.40	0.804
15γ	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

high as 231(87.8%) of the students at a mean of 0.24 (SD=0.655) demonstrated NSU 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. Hence, students have NSU that the chemical process of converting propanol to propene is dehydration reaction.

To determine that but-2-yne is unsaturated hydrocarbon and will decolorize brown (Br_2) bromine solution, item 18 was used. The results show that, 211 (80.2%) of the students at a mean of 0.25 (SD=0.535) demonstrated NSU that 2-butyne is unsaturation and that it decolorizes bromine solution. This indicates that 14.9% students partially understood and only 4.9% students fully understood the concept. Again, students demonstrated NSU that, but-2-yne is an unsaturation, and that it decolorizes bromine solution. On item 8, the results indicate that 90 (34.2%) of the students at a mean of 0.59 (SD = 0.703) demonstrated PSU that benzene completely hydrogenates to produce cyclohexane. This indicates that 53.2% students had NSU and only 12.5% fully understood the concept. Hence, students demonstrated PSU that, complete hydrogenation of benzene produces cyclohexane. On item 21, the results show that, as high as 230(87.5%) of the students at a mean of 0.17 (SD=0.494) demonstrated NSU that either bromine solution or acidified $KMnO_4$ is used to distinguish between benzene and ethene. This indicates that only 7.6% students had PSU and only 4.9% fully understood the concept. Hence, students have NSU that, benzene (aromatic compound) and ethene (alkene) is distinguished using brown bromine solution or acidified purple $KMnO_4$. With both solution changing from their initial colors to colorless.

Regarding alkanol functional group detection, the results on item 9 show that, 168(63.9%) of the students at a mean of 0.43 (SD=0.626) demonstrated NSU that secondary alkanol undergoes complete oxidation reaction to produce an alkanone. This indicates that only 7.2% students had FSU and 28.9% had PSU of the concept. Hence, students have NSU that, secondary alkanol undergoes complete oxidation reaction to produce an alkanone. To ascertain that, ethanol and propanoic acid are produced when ethyl propanoate undergoes acid hydrolysis, item α14D was used. The results show that, 223 (84.8%) of the students at a mean of 0.30 (SD=0.720) demonstrated NSU. This indicates that, 15.2% teachers fully understood the concept that ethanol and propanoic acid can be prepared when ethyl propanoate undergoes acid hydrolysis. Hence, students have NSU that, ethyl propanoate undergoes acid hydrolysis to produce ethanol and propanoic acid. On Item β14D, results from show that, 217(82.5%) of the students at a mean of 0.35 (SD=0.761) demonstrated NSU. This indicates that only 17.5% students fully understood that alkanol and alkanoic acid functional groups that are present when ethyl propanoate undergoes acid hydrolysis. Hence, students have NSU that, ethanol (alkanol) and propanoic acid (alkanoic acid) functional groups are present when ethyl propanoate acid hydrolysed. Item 15α was used to determine that, the type of chemical reaction involved during the conversion of propanol to propanoic acid is oxidation. The results show that 213 (81.0%) of the students at a mean of 0.38 (SD=0.786) demonstrated NSU. 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. Hence, students have NSU that, converting of propanol to propanoic acid is an oxidation reaction. On item 16, the results show that, 207 (78.7%) of the students at a mean of 0.23 (SD=0.455) demonstrated NSU that, an oxidizing agents yellow-colored potassium heptaoxodichromate (VI) solution changes to green when it reacts with an alkanol. This indicates that 19.8% students demonstrated PSU and 1.5% students fully understood the concept. Hence, students have NSU that, an alkanol reacts with and changes yellow-colored potassium heptaoxodichromate (VI) solution to green. To ascertain whether conceptualize that, a yellow precipitate is formed when an alkanol is treated with hot solution of iodine in sodium hydroxide, item 20 was used. The results show that, as high as 255 (97.0%) of the students at a mean of 0.06 (SD=0.328) demonstrated NSU 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. Hence, students have NSU that, an alkanol yields a yellow precipitate (triiodomethane) when treated with hot solution of iodine in sodium hydroxide in a reaction called iodoform test.

Regarding detection of carboxylic (alkanoic) acid functional group detection, item 11 was employed to investigate that alkanoic acid reacts with sodium metal to liberate hydrogen gas, the results from **Table 1** show that, 120 (45.6%) students at a mean of 0.78 (SD=0.704) demonstrated PSU that hydrogen gas is liberated when alkanoic acid reacts with sodium metal. This indicates that 38.4% students demonstrated NSU and 16.0% fully understood the concept. Hence, students demonstrated PSU that, hydrogen gas is liberated when alkanoic acid reacts with sodium metal. To ascertain that, complete oxidation of propanol in the presence of oxidising agent, such as potassium heptaoxodichromate (IV) and heat produces propanoic acid. Item 13 was used. The results from **Table 1** show that, 156(59.3%) of the students at a mean of 0.45 (SD=0.576) demonstrated NSU that, complete oxidation of propanol in the presence of oxidizing agent, such as potassium heptaoxodichromate(IV) and heat produces propanoic acid. This indicates that 36.5% students demonstrated PSU and only 4.2% students fully understood the concept. Hence, students demonstrated NSU that, complete oxidation of propanol in the presence of oxidizing agent, such as potassium heptaoxodichromate (IV) and heat produces propanoic acid. On item α14A, results from **Table 1** show that, as high as 210(79.8%) of the students at a mean of 0.40 (SD=0.799) demonstrated NSU 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 potassiumdichromate (VI). Hence, students demonstrated NSU that, propanoic acid is produced when propanol undergoes oxidation reaction in the presence of acidified potassiumdichromate (VI). To ascertain whether students comprehend that when ethyl propanoate is acid hydrolysed ethanol and propanoic acid are produced, item α14E was used. Results from **Table 1** show that, 226 (85.9%) of the students at a mean of 0.28 (SD=0.697) demonstrated NSU and 14.1% teachers fully understood that, both ethanol and propanoic acid are produced when ethyl propanoate undergoes acid hydrolysis. This indicates that none of the students demonstrated any PSU on the concept. Hence, students demonstrated NSU that, ethyl propanoate is acid hydrolyzed to produce ethanol and propanoic acid. On item β14A, the results show that, as high as 210 (79.8%) of the students at a mean of 0.40 (SD=0.804) demonstrated NSU on the concept. This indicates that, 20.2% students fully understood the concept, and none of the students demonstrated PSU. Hence, students demonstrated NSU that, an alkanoic acid functional group is present when propanol undergoes oxidation reaction in the presence of acidified potassiumdichromate (VI). To ascertain whether students conceptualize that, both alkanol and alkanoic acid functional groups are present when ethyl propanoate undergoes acid hydrolysis, item β14E was used. the results from **Table 1** show that, 225 (85.6%) of the students at a mean of 0.29 (SD=0.705) demonstrated NSU and 14.4% students fully understood that, both alkanol and alkanoic acid functional groups are present when ethyl propanoate undergoes acid hydrolysis. This indicates that none of the students demonstrated PSU on the concept. Hence, students demonstrated NSU that, the functional groups present when ethyl propanoate undergoes acid hydrolysis are alkanols and alkanoic acids. The results on item 19 show that, as high as 242 (92.0%) of the students at a mean of 0.16 (SD=0.534) demonstrated NSU and only 8.0% students fully understood the concept that carbon (IV) dioxide is evolved when propanoic acid reacts with sodium hydrogentrioxocarbonate(IV). This indicates that none of the students demonstrated PSU on the concept. Hence, students demonstrated NSU that, propanoic acid reacts with sodium hydrogentrioxocarbonate (IV) to evolve carbon (IV) dioxide gas.

With regards to alkylalkanoates (esters) functional group detection, item 7 was used to investigate whether students scientifically conceptualize that, ethyl methanoate is an ester hence is sweet scented. The results show that, 99 (37.6%) of the students at a mean of 0.96 (SD=0.790) demonstrated PSU on the concept. This indicate that 33.1% students demonstrated NSU and 29.3% fully understood that, ethyl methanoate is an ester hence is sweet scented. Hence, students demonstrated PSU that, ethyl methanoate is an ester hence is sweet scented. On item α14C, results show that, 222 (84.4%) of the students at a mean of 0.31 (SD=0.727) demonstrated NSU and 15.4% students fully understood that ethyl propanoate is produced when propanoic acid reacts with ethanol. This indicates that, none of the students demonstrated PSU on the concept. Hence, students demonstrated NSU that, ethyl propanoate is produced when propanoic acid reacts with ethanol. To ascertain whether students understand that, alkyl alkanoate functional group is present in a product formed from chemical reaction between propanoic acid and ethanol, item β14C was used. From **Table 1**, the results show that 210 (79.8%) of the students at a mean of 0.40 (SD=0.804) demonstrated NSU and only 20.2% students fully understood the concept. This indicates that, none of the students demonstrated PSU on the concept. Hence, students demonstrated NSU that, alkyl alkanoate functional group is present in a product formed from chemical reaction between propanoic acid and ethanol. On item 15γ, the results 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 PSU on the concept. Hence, students demonstrated NSU that, process of converting propanol to ethylpropanoate is esterification.

Item 17 was used regarding detection of amide functional group. The results from **Table 1** show that, 223 (84.8%) of the students at a mean of 0.19 (SD=0.491) demonstrated NSU that ammonia gas is evolved when amide is warmed with dilute sodium hydroxide solution. This indicates that only 4.2% teachers had FSU and 11.0% teachers partially understood the concept. Hence, students demonstrated NSU that, amides when warmed with dilute sodium hydroxide solution evolves ammonia gas.

Regarding detection of carbonyl (aldehydes and ketones) functional group, item 22 was used. The results from **Table 1** show that, 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% students had PSU and as low as 0.3% students fully understood the concept. This indicates that, none of the students demonstrated partial understanding on the concept. Hence, students demonstrated NSU that, ammoniacal silvernitrate or Fehling's solution is used to distinguish between alkanals (aldehyde) and alkanones (ketones).

To further explore the general level of conceptual understanding of students on OQA, means were calculated out of the scores awarded for demonstration of FSU, PSU, and NSU. The average 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 44 marks. This means implied that, two-thirds majority of students demonstrated their conceptual understanding by scoring marks ranging between 1.67 and 16.18 out of a total score of 44 marks.

Generally, the items on the diagnostic tests were very difficult to students with an overall index of 0.35 with associated alternative conceptions and factual difficulties in most instances. Students' conceptual difficulties were categorized into alternative conceptions and factual difficulties on the organic functional group detection. To further explore students' conceptual difficulties, explanations from students who demonstrated low scientific understanding were examined. This was relevant as it helped us to identify any alternative conceptions and factual difficulties students had on organic functional groups detection.

For instance, 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 relating to the fact that propane readily dissolves in tetrachloromethane. The evidence of alternative conceptions and factual difficulties is

Alternative conceptions: propane is unsaturated organic compound and contains only one carbon-carbon bonds. An excerpt is:

> ''Propane is unsaturated compound because it contains c-c bonds that decolorizes 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 excerpt is:

> "Propane is a polar molecule hence will readily dissolve in a polar organic solvent such as tetrachloromethane solution" (Student, 119).

One of the items that was difficult to students was item 8 with an index of 0.43. Of the 263 students, an equal proportion of (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: benzene is hydrogenated to produce hexane. An excerpt is:

> "hexane is produced when benzene is hydrogenated" (Student, 61).

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).

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) color to orange" (Student, 65).

(ii) saturated hydrocarbons decolorize acidified potassium tetraoxomanganate (VII) ($KMnO_4$) solutions. An excerpt is:

> "saturated organic compound changes color of bromine in tetrachloromethane (Br_2/CCl_4) and acidified potassium tetraoxomanganate (VII) ($KMnO_4$) solutions to pale green …" (Student, 125).

''ethane decolorizes both Br_2/CCl_4 and acidified $KMnO_4$. An excerpt is:

> "ethane changes the colors of Br_2/CCl_4 and acidified $KMnO_4$ colorless" (Student, 59).

Factual difficulties: (i) 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. An excerpt is*:*

> "colors of Br_2/CCl_4 and acidified $KMnO_4$ changes to colorless by ethene" (Student, 72).

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 color solution with alkaline potassium tetraoxomanganate (VII). The evidence of alternative conceptions is:

Alternative conceptions: (i) 2-propanone gives brown color solution with alkaline potassium tetraoxomanganate (VII). An excerpt is:

> "color of alkaline potassium tetraoxomanganate(VII) solution changes to brown upon reaction with 2propanone" (Student, 14).

(ii) propanal produces brown color solution with alkaline potassium tetraoxomanganate (VII). An excerpt is:

> "color of alkaline potassium tetraoxomanganate(VII) solution changes to brown upon reaction with propanal" (Student, 48).

Item 18 was extremely difficult to students with an index of 0.19. Of the 263 students, an equal proportion (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 decolorizes 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 color of bromine solution to colorless" (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, decolorizes bromine solution" (Student, 153).

Item 21 was also 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 $C_6H_3NO_2$ 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 color when react with acidified $KMnO_4$ as compared to colorless color of ethene" (Student, 211).

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 not alone to form alkanone. An excerpt is:

> "alkanones are formed when tertiary alkanols when they oxidize" (Student, 172).

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 color to yellow. An excerpt is:

> "alkanols react with acidified $K_2Cr_2O_7$ to give an observable yellow precipitate colour" (Student, 30).

Also, 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 propyl propanoate. An excerpt is:

"propyl propanoate 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 propyl propanoate this because there is propanol in the propyl propanoate which occurred during the oxidation reaction" (Student, 72).

Item 11 was moderately difficult to students with an index of 0.62. Of the 263 students, an equal proportion (45.63%) students' explanations were in the category of alternative conceptions without factual difficulties relating to the fact that, hydrogen gas is liberated when alkanoic 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 alkanoic acids liberate hydrogen gas in the presence of sodium metal. An excerpt is:

> "… an alkanoic acid because, the alkanoic contains carbon double bond oxygen and carbon double bond –OH, the hydrogen in OH breaks and form the hydrogen gas" (student, 172).

Item 7 was moderately difficult to students with an index of 0.65. Of the 263 students, an equal proportion (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).

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).

Item 22 was also 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 silvernitrate (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 decolorizes 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 color to pale green but alkanones do not" (Student, 70).

DISCUSSION

Students' demonstration of low level of conceptual understanding on functional groups detection is not only limited to hydrocarbons (alkanes, alkenes, alkynes, and benzenes) but derivative of hydrocarbons such as (alkanols (alcohols), alkanoic acids (carboxylic acids), alkylakanoates (esters), alkanals (aldehydes), and alkanones (ketones) and amides as well. Students' demonstration of low level of conceptual understanding on functional groups detections on saturation and unsaturation carbon compounds means that students are not fully conceptualizing the concepts of organic functional group detections. Chemistry educators are therefore encouraged to take a critical look at the nature and possible reasons for students' difficulties identified as revealed by this very study in order to adopt a suitable and appropriate conceptual change instructional strategies to help students overcome their difficulties in detecting organic functional groups using suitable reagents.

Students' difficulties in detecting functional groups through the use of suitable organic reagents could be partly due to their insufficient knowledge on organic chemistry (Anim-Eduful & Adu-Gyamfi, 2022; Coll & Treagust, 2001; Nicoll, 2001), their inability to identity 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 could not identify most organic chemical reactions, the very few who were able failed to state and explain clearly functional groups present in those compounds (Anim-Eduful, 2020). Hence, students could not give correct chemical structures of organic compounds undergoing chemical reactions.

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. The results show that, students have little or no knowledge about organic reagents needed to test for functional groups, and also indicate the expected outcome of their reactions with respect to the exact color changes that occurs during these functional group detections. This was evident, when students failed to provide names and explain reagents needed to detect for these functional group in organic compounds. For instance, students have factual difficulties distinguishing between saturation and unsaturation, primary, secondary and tertiary alkanols, alkylalkanoates, amides, alkanals and alkanones with the use of suitable reagents (Adu-Gyamfi & Anim-Eduful, 2022). Not only do students have alternative conceptions and factual difficulties in detecting organic functional group with the use of suitable reagents, but they also demonstrate similar alternative conceptions and factual difficulties in identifying names of particular chemical reactions such as oxidation, reduction, dehydration and esterification undergone by these compounds. This implies that not only do students have conceptual difficulties in providing and predicting final product in organic reactions with reasons (Tang et al., 2010) but could not also provide the exact name of the reaction that occurred.

The study has showed that, students' demonstration of wide range of factual difficulties and alternative conceptions in organic qualitative analysis is partly due to their teachers (Anim-Eduful & Adu-Gyamfi, 2021) teaching them. This is because, teachers' content knowledge influence what and how they teach the concept to their students. Students' demonstration of wide range of alternative conceptions and factual difficulties could be partly due to difficult nature of organic qualitative analysis (Stieff, 2007). Nature of the content influences the way the subject is taught and learnt (Anim-Eduful & Adu-Gyamfi, 2022; Tatli & Ayas, 2013). This implies that students' difficulties in conceptualizing difficult science content are potentially transferable from their teachers (Anim-Eduful & Adu-Gyamfi, 2021), which mostly results in learners' alternative conceptions about these scientific concepts (Chavan, 2017).

Students' alternative conceptions and factual difficulties could be partly due to how strong or weak of their chemistry teachers' content knowledge. This is due to the fact that, teachers with deep and strong content knowledge better deliver concepts to their students which positively influence students' learning (Adu-Gyamfi et al., 2018; Anim-Eduful & Adu-Gyamfi, 2021). Teachers' understanding of science content influence the way they teach, and consequently the way their learners learn the content (Anim-Eduful & Adu-Gyamfi, 2021; Tatli & Ayas, 2013).

This study 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 partly due to the presence of alternative conceptions and factual difficulties chemistry teachers (Anim-Eduful & Adu-Gyamfi, 2021) have on OQA. These learning difficulties of students in OQA could be attributed to their teachers' low (partial) level of conceptual understanding (Anim-Eduful & Adu-Gyamfi, 2021) on OQA. The results from this study does not only reaffirms works of (Adu-Gyamfi et al., 2017) that students have difficulties in the form of alternative conceptions and factual difficulties identifying chemical structures of organic compounds and functional groups but students also have difficulties identifying organic functional groups in compounds using suitable reagents. Students' difficulties run through all the functional groups stipulated in the senior high school chemistry curriculum (Ministry of Education, 2010).

Conclusively, senior high schools chemistry students' low level of conceptual understanding on organic qualitative analysis is a confirmation of students' weaknesses in functional group detection in organic chemistry as reported in the senior high schools by the WAEC chief examiner on chemistry on this concept (WAEC, 2012, 2014, 2015, 2016, 2017, 2018).

CONCLUSION

The study provides more insights into chemistry students at the senior high school level meaningful understanding into organic functional group detections under organic qualitative analysis concept in organic chemistry. The study has therefore shown that, students have difficulties comprehending the concept organic qualitative analysis as they demonstrated low level of conceptual understanding with factual difficulties and alternative conceptions. The students' conceptual difficulties were qualitatively envisaged as factual difficulties and alternative conceptions. Those alternative conceptions and factual difficulties were seen under all the functional groups as hydrocarbons (such as alkenes, alkynes and benzenes) and derivatives of hydrocarbons such as (alkanols (alcohols), alkanoic (carboxylic) acids, alkylalkanoates (esters), alkanones (ketones) alkanals (aldehydes), and amides. The study has added to the literature that alternative conceptions exist in the area of functional group detections under organic qualitative analysis as there are in other areas of chemistry.

As students' factual difficulties and alternative conceptions existed in the area of OQA, chemistry teachers should select and use conceptual change approaches in their teaching chemistry concepts. 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 organic qualitative analysis as stipulated in (Ministry of Education, 2010) teaching syllabus.

The Ministry of Education should provide SHS schools with well-equipped laboratories containing organic reagents needed for effective teaching and learning of detections of functional group to students. And as students exhibited factual difficulties and alternative conceptions in the area of functional groups detections, chemistry educators and curriculum planners should design and develop instructional strategies that challenges alternative conceptions among students.

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