European Journal of Education Studies
ISSN: 2501 - 1111
ISSN-L: 2501 - 1111
Available on-line at: www.oapub.org/edu

DOI: 10.46827/ejes.v9i7.4378

Volume 9 │ Issue 7 │ 2022

FACTORS INFLUENCING HIGH SCHOOL CHEMISTRY TEACHERS' AND STUDENTS' TEACHING AND LEARNING OF ORGANIC QUALITATIVE ANALYSIS: A QUALITATIVE STUDY

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Abstract:
Identification and characterisation of the structures of unknown substances are important parts of learning organic chemistry. This paper reports on a study that investigated factors that influence the teaching and learning of organic qualitative analysis in organic chemistry. In all, three teachers and nine students from three different categories of schools participated in the study. Interview guides and an observation checklist were developed and used to obtain qualitative data. The qualitative data gathered from the interview were transcribed by reducing them to patterns and themes and analysed thematically. The study revealed, among others, that teaching and learning resources, practical-based instruction and the nature of the chemistry curriculum were the factors that impede chemistry teachers' and students' teaching and learning of organic qualitative analysis in organic chemistry.

Keywords: organic qualitative analysis; functional groups; teaching and learning resources; practical-based instruction

1. Introduction

Chemistry is a branch of science that deals with the composition, properties (physical and chemical) and reactions of matter (Ebbing & Gammon, 2005). Sirhan (2007) indicated that chemistry is very vital in studying science since most of the concepts are about the structure of matter which provides a detailed explanation and enables students' understanding of an occurring chemical phenomenon. Analysis of chemical compounds is one of the areas studied in chemistry. Analysis of chemical compounds is classified into two categories; that is quantitative (volumetric) and qualitative analysis. The quantitative

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analysis finds the amount of each element or group of elements present whiles 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) and aromatic (benzene); alkanols, carbonyl compounds made up of alkanals (aldehydes) and alkanones (ketones), amides, alkanoic (carboxylic) acids, alkylalkanoate (esters), carbohydrates (reducing sugars and non-reducing sugars) and proteins (MOE, 2010).

2. Literature Review

The functional groups 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). The functional groups studied in organic chemistry at the senior high school level are: hydrocarbons consisting of aliphatic hydrocarbons (alkanes, alkenes and alkynes) and aromatic (benzene), alcohols ($-OH$); aldehydes ($-CHO$); ketones ($-C=O$); carboxylic acids ($-COOH$); esters ($-COO-$); amides ($-CONH_2$) (MOE, 2010).

Identification and characterisation of the structures of unknown substances are important parts of organic chemistry (Anim-Eduful & Adu-Gyamfi, 2021). 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 an important tool for structure determination of substances in the early days of organic chemistry (Fieser & Williamson, 1992). Unsaturated hydrocarbon (alkene and alkyne) is 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). Hydrocarbons that contain carbon single bond carbon are called saturated hydrocarbons which do not give observable colour changes to the purple colour of cold acidified or alkaline tetraoxomanganate(VII) ($KMnO_4$) solution. Alkanes are also unreactive to bromine water (Br_2/H_2O) 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 and 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) of an 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 the pink/purple colour takes place with the formation of a brown precipitate of MnO_2. This is due to the change of the oxidation state of manganese from +7 to +4. Purple colour of cold acidified tetraoxomanganate (VII) ($KMnO_4$) solution decolourizes, due to the 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 (-OH) functional group and general molecular formula of $C_nH_{2n+1}OH$. There are three types of alkanols namely: primary ($R\text{-}CH_2OH$), secondary ($R_2\text{-}CHOH$), and tertiary (R_3COH). Alkanols react qualitatively with Ceric Nitrate test where the colour changes from yellow to red (Zumdahl & Zumdahl, 2003). During the 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, alkanoic 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 change the orange colour of potassium heptaoxodichromate (VI) ($K_2Cr_2O_7$) to green, which is due to the change of oxidation state of chromium Cr^{6+} to Cr^{3+} (Bettelheim et al., 2004; Vishnoi, 2009).

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 ($R_2\text{-}CHOH$). For example, 2-propanol ($(CH_3)_2CHOH$) will oxidize in the presence of an oxidizing agent such as $KMnO_4$ or $K_2Cr_2O_7$ in the 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).

Primary alkanols are oxidized to aldehydes then further oxidation produces alkanoic acid and secondary alkanols are oxidized to ketones all in the presence of acidified potassium dichromate ($K_2Cr_2O_7$) and dilute H_2SO_4. The yellow solution of potassium dichromate turns green, due to changes in the oxidation state of chromium from +6 (yellow) to +3 (green) (Ebbing & Gammon, 2005; Fessenden & Fessenden, 1994; Fieser & Williamson, 1992).

The functional group in an alkanoic (carboxylic) acid is the carboxyl group (RCOOH) with a general molecular formula of $C_nH_{2n+1}COOH$. Many alkanoic 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 by a sweet fruity smell (Fessenden & Fessenden, 1994). Alkanoic 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).

Carbonyl compounds (aldehydes and ketones) readily 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, a little amount of the carbonyl compound is added to the reagent. Aldehydes produce a deep violet-red colour immediately whiles with ketones, the appearance of the violet colour takes time (Vishnoi, 2009). In the Fehling's reagent/Benedict's test, the formation of a brick-red precipitate of copper (I) oxide indicates the presence of an aldehyde. Ketones will not react with this reagent (Ebbing & Gammon, 2005; Vishnoi, 2009).

An ester (alkylalkanoates) is a compound formed from a chemical reaction between a carboxylic acid, RCOOH and an alcohol, R'-OH in the presence of concentrated sulphuric acid and heat. Esters have sweet, fruity smell that is in contrast to the pungent odours of the parent carboxylic acid (Fieser & Williamson, 1992). The amide functional group can be detected qualitatively by reacting the solution containing amide with aqueous sodium hydroxide (NaOH) with heat leading to the evolution of pungent smell gas called ammonia (NH_3) which is basic by nature (Morrison & Boyd, 1992).

Cognitive scientist Carey (2000) stated that concepts are complex representational structures, and that concepts can be constructed directly by generalizing from experience. In some cases, concepts are difficult to demonstrate and also 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. In chemistry, it is related to the ability to explain chemical phenomena through the use of macroscopic, submicroscopic 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, submicroscopic and symbolic levels (Gabel, 1998; Johnstone, 1993).

Although science educators have drawn attention to strengthening conceptual understanding of scientific concepts and processes, lots of teachers still fail to implement instructional strategies (Adu-Gyamfi et al., 2018) that guarantee assistance to learners. Hence, many students leave science classrooms with misconceptions even after instructions (Nicoll, 2001; Taber & Watts, 2000) Instructional strategies that sort to promote conceptual change require 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 concepts (Chin, 2004).

In order to promote students' understanding of functional groups to prevent related misconceptions, Akkuzu and Uyulgan (2016) 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 instructional activities help to facilitate the development of a deeper understanding of accepted scientific concepts in students. When teachers develop and adopt specific activity-oriented teaching strategies, students' alternative conceptions will be addressed (Fatoke & Olaoluwa, 2014; Hanson, 2017)

Appropriate inquiry-based activities when employed by science teachers help to address students' alternative conceptions (Bradley, Ulrich, Maitland, & Jones, 2002; Hanson & Wolfskill, 2000; Kiboss, Ndirungu, & Wekesa, 2004). A study by (Adu-Gyamfi et al., 2015), revealed among others that, a lack of appropriate and effective instructional strategies in teaching science does not only make students lose interest in learning science but highly demotivate opportunities for innovation, creativity and investigative science learning. Appropriate laboratories are indispensable in science learning as well as well-equipped laboratories with needed chemicals make science teaching and learning exciting and efficient for students, especially in chemistry. With the look at how functional groups of organic compounds are detected, it would be very appropriate and necessary for chemistry teachers to teach students OQA through the use of activity-oriented teaching methods to minimize the abstract nature of the concepts.

In Ghana there are profile dimensions that describe underlying behaviours for teaching, learning and assessing students studying science at the senior high school level (Ministry of Education [MOE], 2010, p. viii). There are three such profile dimensions that are specified for teaching, learning and testing in chemistry, and these are: Knowledge and Understanding; Application and Knowledge and Practical and experimental skills with their percentage weight being 30%, 40% and 30% respectively (Ministry of Education [MOE], 2010, p. viii). This implies that, practical and experimental skills help students acquire and demonstrate manipulative skills using tools and equipment for practical problem-solving during inquiry processes. Learning outcomes are maximised when content knowledge is promoted together with strategic learning approaches (Conner & Gunstone, 2004).

In addition, 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. From the MOE (2010), students' understanding of the qualitative analysis will help them improve their understanding in chemistry as a whole since they confirm what they have learnt theoretically. However, reports of Chemistry Chief Examiner for SHS available at WAEC for the years have repeatedly lamented the weakness of most students in organic qualitative analysis both in practical and theory examination (WAEC, 2001; 2003; 2004; 2005; 2007; 2012; 2014; 2016; 2017; 2018). 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 a problem with the teaching and learning of qualitative organic analysis. It was, therefore, right to investigate what accounts for chemistry teachers' and students' difficulties in teaching and learning of organic qualitative analysis.

3. Material and Research Methods

In an attempt to obtain an in-depth understanding of what accounts for teachers' and students' problems in teaching and learning of organic qualitative analysis, a qualitative study design was employed. This was because an analysis of statements of explanations from participants were presented. A qualitative design was used because the intention was not to draw generalizations but to help reveal deep understanding issues (Cresswell, 2009) about factors that account for chemistry teachers' and students' problems in teaching and learning of organic qualitative analysis.

3.1 Purpose of the Study

This study was purposely undertaken to investigate the difficulties encountered by senior high school chemistry teachers' and students' during their teaching and learning of organic qualitative analysis. The purpose was to help ascertain the learning difficulties, problems, and students' expectations before and after lessons on organic qualitative analysis. Qualitative data from chemistry teachers and students using interviews were collected. The qualitative data collected from the teachers and students were refined and explained to investigate participants' views in more depth on teaching and learning of organic qualitative analysis. Based on the outcome of teachers' and students' interviews, an observation checklist was designed. The purpose of the observation checklist was to have an instrument for case studies on the teaching and learning of OQA in the selected schools. The purpose was to investigate teachers' intentions and the problems encountered during their teaching of organic qualitative analysis. To achieve this, a research question was raised to guide the study as:

- What accounts for teachers' and students' problems in teaching and learning of organic qualitative analysis?

3.2 Population

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.

3.3 Sample and Sampling Procedure

This current study was taken from Author[1] master's thesis. The sample selection process involved in the main study was a multi-stage sampling technique. Schools were classified into A, B, and C categories basically due to the 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 was 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. A 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 the study.

For the purpose of this current study: three schools out of the six schools that participated in the main study were involved with each school selected from the three classes of schools (class A, B and C). Purposive sampling techniques were applied to select one teacher each from the three schools for the interviews and lesson observations. This is because teachers in the other three 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 organic 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 researchers. Hence one school was selected each from class A, B and C categories of schools. In all, three chemistry teachers from the three schools were involved in the study out of the six schools initially.

3.4 Instrument

Interview guides and observation checklist were the research instruments employed in the data collection. These instruments were the student interview guide on organic qualitative analysis (SIGOQA), teacher interview guide on organic qualitative analysis (TIGOQA) and observation checklist on teaching organic qualitative analysis (OCTOQA). Students and teachers involved in this study were interviewed using SIGOQA and TIGOQA 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 researchers to delve deeper and obtain an in-depth understanding of processes students experience during their learning of organic qualitative analysis. 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.

TIGOQA was also a semi-structured interview guide type developed by the researchers 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 to 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 analysis lesson. The purpose was to help the researcher to obtain an in-depth understanding of teachers' experiences and best practices in the 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 were 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 teachers who are examiners 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 we moved from one teacher to another and the same was done to the students. During the interviews, we made sure our personal views and experiences did not influence the views of teachers and students as they were recorded. We further avoided asking too many questions at a go and made it more interactive. Themes were then generated from the views of teachers and students on teaching and learning of organic qualitative analysis. The themes were given to some selected experienced teachers to critique and later for a peer review. In an attempt of reporting the views of teachers and students, sufficient data were provided under each theme for readers to make their own inferences.

An observation checklist (OCTOQA) was designed by the researchers after interactions with chemistry teachers and students to investigate how their teaching and learning of organic qualitative analysis instructional lessons are carried out. The intent of the 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 their students' conceptual understanding. The 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 of the lesson. The 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 otherwise of what teachers professed to teach. To check for the validity and reliability 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 researchers 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.

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.

3.5 Data Analysis

The qualitative data gathered from the interviews were transcribed by reducing them to patterns and themes. Thematic analysis was then used to answer the research question raised.

4. Results and Discussion

The research question for this current study sought to determine what accounts for SHS teachers' and students' problems in teaching and learning of OQA. To achieve this, lesson observations by three chemistry teachers were made 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 were:

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 a 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.

4.1 Teaching and Learning Resources

Inadequate teaching and learning resources were one of the major factors that came up during the interviews and lesson observation that accounted for teachers' and students' problems with teaching and learning of OQA. Examples of those resources are boiling and test tubes, bromine in tetrachloromethane solution (Br_2/CCl_4) solution, ammoniacal silvernitrate ($NH_3/AgNO_3$) (Tollen's) solution, potassiumheptaoxodichromate (VI) ($K_2Cr_2O_7$) solution, Benedict's solution and Fehling's solution. When asked whether teachers have introduced organic chemistry and OQA to their students, all three teachers responded affirmatively 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 major reactions of them. We are almost finishing them in class, and I will try and do the practical works too…. (Pseudonyms: Adama, a Teacher from School A).

…. yes ooo sir but the theory aspect, I mean without practical works" (Akuako, 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 B).

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

Thereafter, students were asked before the lesson observation if they have been introduced to organic chemistry and OQA. Excerpts of our 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 when learning"* (School B, Student 1).
Student: *No, eeeh 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 work. 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 teaching them in the class) we will do these test practically in the laboratory for them to observe and experience these organic reagents and their respective reactions with these functional groups" (Akuako, 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).

The teacher's problem with teaching OQA to the understanding of students, in part is lack of laboratory space. Some schools did not have space solely as a chemistry laboratory.

Excerpts to support this statement are:

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

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

"the chemicals and the reagents are not usually available and I am left with only teaching these concepts to students through the use of 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 many years and rest of the chemicals there are all inorganic salts and solutions" (Agyabeng, 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, alkanoic acids, aldehydes and ketones we do not have reagents such as* $K_2Cr_2O_7$*, Fehling's and Benedict's solution, and this one…. Tollen's reagent to test for those functional groups"* (Akuako, 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 organizing and performing practical lessons are very difficult task for me especially been the only chemistry teacher for the three streams" (Agyabeng, a Teacher from School C).

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 (meaning my friends), to be frank with you, …you know those chemicals (referring to OQA solutions) 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 the effective teaching and learning of OQA. An excerpt is:

"seniors for me, I think if these organic reagents and compounds are made available, they 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 viewpoint of their teachers that their schools were not having adequate chemicals and reagents for teaching and learning of OQA. Excerpts to amplify this point is:

"sir, we are always given examples of these 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 group detections very confusing" (School B, Student 4).

"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 8).

Our interactions with one of the students are:

Researcher: How do you understand OQA?
Student: *sir, OQA is very abstract.*
Researcher: what do you mean by OQA is very 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 even 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 purple $KMnO_4$ solution but those of Benedict's and Fehling's we have not, these things make learning of qualitative analysis very difficult* (School B, Student 5).

4.2 Practical-based Instruction

The approach to teaching and learning (that is the instruction strategies) of OQA was seen as a key factor contributing to students' difficulties in learning OQA. All the three teachers involved in the lesson observations and interviews were worried about the instructional approaches they are made to use 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 more easier"* (Akuako, a Teacher).

> *"For me continuous practical lessons should be able to help them understand"* (Akuako, a Teacher from School B).

> *"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"* (Agyapong, a Teacher).

The inadequacy of teaching and learning resources has brought up the use of variety of weak 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 conventional approach (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" (Akuako, 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 teach for them to understand but frankly speaking it has not been easy for me" (Agyabeng, a Teacher).

Students from Schools A, B, and C 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 using theory theory theory …. without practical lessons makes it very difficult for us to learn and understand" (School A, Student 3).

"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 will help me understand it better" (School A, Student 3).

Students explained that their difficulty is that, they force it (resort into memorizing) when learning OQA as teachers barely use activity-oriented and practical-based approaches 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 and difficult" (School B, Student 4).

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?
Student: *"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 A, 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 we made in other schools which could account for students' conceptual difficulties on OQA. For instance, 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, we 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 contained 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 you have done differently another time?*
Adama: *"I will do more explanations and give more examples of compounds containing ethanol, esters and alkanoic 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 (the teacher) 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 1).

With respect to Akuako from School B, he reviewed students' previous knowledge and experiences by actively involving students during the teaching and explained OQA concepts in detail 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?

Akuako: *It was very very successful.*

Researcher: Please, can you explain further?

Akuako: "*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.

Akuako: *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 shells. 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 you have done differently another time?

Akuako: *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 looking at the nature of the detections*" (School B, Students 6).

With respect to Agyabeng, 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?

Agyabeng: *I think so, as you saw it yourself.*

Researcher: What would you have done differently another time?

Agyabeng: *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?

Agyabeng: *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 9).

"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 7)

With respect to Agyabeng, a teacher from School C, he taught OQA by reviewing students' previous knowledge and experiences, involved students and also gave a 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: *hmmmm, I forgot them, I really forgot … but I will do my best to use them in our next meeting.*

From School B, students called for teachers to use animals and models to teach OQA if there are inadequate materials needed for learning of such concept. This approach, students opined 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 B, Student 6).

"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 (he meant ball-and–stick models) that can also help us understand. I have seen one on a television before" (School B, Student 4).

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

4.3 Organic Chemistry Curriculum Content

Another factor that was both mentioned by teachers and students that accounted for their problems in conceptualising OQA in relation to teaching and learning was the nature of the 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 it 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"* (Akuako, a Teacher).

Though the content is voluminous, teachers preferred to teach it at the tail of the 3year senior high school 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 their 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 the 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, 8).

"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 C, Student 7).

"… 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 9).

"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 at school? She laughs…" (School C, Student 5).

5. Discussion

Findings from the interviews showed that teachers admitted that, adequate teaching and learning resources help students comprehend OQA concept but insufficient of these teaching and learning resources (Ngwenya, 2015) interrupt teachers' teaching and subsequently hinder students' learning of OQA. In some of the schools, teaching and learning resources were available but teachers hardly used them in their teaching of OQA. This, then becomes a 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 lessons. 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 it. This attitude of teachers practicing something different from what they profess to do could be that teachers just have theoretical knowledge (Anim-Eduful & Adu-Gyamfi, 2021) about teaching and learning resources and their importance and how best to use them in instruction but are unable to practice it effectively. On the other hand, it could partly be due to teachers lack of content knowledge (Anim-Eduful & Adu-Gyamfi, 2021) in the OQA concepts.

The findings from the lesson observation brought to bear that, even though teaching and learning of OQA concept should be practical oriented, teaching and learning transpired without practical work. This is partly due to either unavailability of learning resources or learning resources or available but teachers' refusal to use them. The finding of this study reaffirms (Ajayi & Ogbeba, 2017) that teaching and learning resources effectively enhance students' understanding of the scientific concept. Teachers' lack of specific content knowledge (Anim-Eduful & Adu-Gyamfi, 2021) and weak teaching instructional strategies (Adu-Gyamfi et al., 2018; Uyulgan & Akkuzu, 2016) are problems that result in students' difficulties in conceptualizing OQA. In addition, teachers' weak teaching instructional strategies also resulted in students' inability to develop scientifically inaccurate conceptions about functional group detections (Adu-Gyamfi & Ampiah, 2019; Adu-Gyamfi et al., 2015; 2017).

The problems of teaching and learning of organic qualitative analysis were associated with lack of 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 with organic qualitative analysis. And that, where there is a unavailable chemicals and reagents for teaching and learning organic qualitative analysis through practical-based instruction which was absent in the selected schools, the use of models could be the solution.

6. Conclusion

This study has contributed to the literature that organic chemistry which is difficult for students to learn and conceptualise (Adu-Gyamfi, & Anim-Eduful, 2022) is equally difficult for teachers to comprehend and teach as well (Anim-Eduful & Adu-Gyamfi, 2021) as teachers demonstrated conceptual difficulties in a concept they teach to students. This phenomenon could partly be due to lack of teaching and learning resources and the kind of instructional strategies employed during their teaching and learning processes. The conceptual difficulties teachers' and students' face towards this phenomenon could partly be due to the abstract and difficult nature of organic qualitative analysis in organic chemistry. This study has also revealed that, difficult and abstract nature of concepts affect how that concept is been taught by teachers and learned by students. This is due to that fact that, organic qualitative analysis has been found difficult to teachers (Anim-Eduful & Adu-Gyamfi, 2021) and also to students (Adu-Gyamfi, & Anim-Eduful, 2022). Furthermore, this study has revealed that teaching and learning chemistry concepts such as organic qualitative analysis should be practical oriented. Even though teaching and learning of OQA concept should be practical oriented, teaching and learning transpired without practical work. This is partly due to either unavailability of learning resources or learning resources available but teachers' refusal to use them.

Additionally, the study has further added to the literature that, chemistry teachers normally proclaim best teaching practices in theory but practice different things during teaching, and this attitude of teachers makes students have difficulties in learning OQA.

This attitude of teachers practicing something different from what they profess to do could be that just have theoretical knowledge about teaching and learning resources and their importance and how best to use them in instruction but are unable to teach it effectively due to their lack of content knowledge in OQA. Since teachers do not have positive attitudes toward their practice (as they practice something contrary to what they teach their students), it is, therefore, recommended that Ministry of Education through Heads of senior high schools should organize in-service training in chemistry content knowledge for teachers to update their content knowledge and also monitor chemistry teachers to ensure that they effectively teach the concept to students by using the limited available teaching and learning resources.

The Ministry of Education should provide SHS schools with well-equipped laboratories containing organic reagents needed for effective teaching and learning to reduce the abstract nature of chemistry concepts such as OQA to students.

6.1 Suggestions for Future Research

This study essentially explored factors that contribute to teachers' and students' problems in teaching and learning of 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.

Disclaimer

This manuscript was taken from Benjamin Anim-Eduful master's thesis which has been archived in the University of Cape Coast, Ghana, institutional repository with the url: https://ir.ucc.edu.gh/xmlui/handle/123456789/6814

Conflict of Interest Statement

We declare no conflicts of interest.

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