UNIVERSITY OF CAPE COAST

EXPLORATION OF TEACHING OF ~~BASIC INORGANIC~~ QUALITATIVE ANALYSIS IN CHEMISTRY IN SENIOR HIGH SCHOOLS

NICHOLAS ARTHUR

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EXPLORATION OF TEACHING OF QUALITATIVE ANALYSIS IN CHEMISTRY IN SENIOR HIGH SCHOOLS

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BY

NICHOLAS ARTHUR

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

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~~FEBRUARY~~ DECEMBER 2021

DECLARATION

Candidate's Declaration

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

Candidate's Signature: …………………………....... Date: …………………...

Name: Nicholas Arthur

Supervisor's Declaration

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

Supervisor's Signature: ………………………… Date: …………………….

Name: Dr. Kenneth Adu-Gyamfi

ABSTRACT

The study explored and co-developed a theory that would assist chemistry teachers in teaching qualitative analysis (QA). To achieve this purpose, the study made use of the grounded theory. Ten teachers selected through convenience and purposive sampling techniques participated in the study. Interviews, observations, and field notes were the main instruments used to collect data from the teachers. The researcher used 11 weeks for concurrent data collection and analysis using Nvivo software. Findings from the study show teachers did not see concepts they teach under QA as difficult. However, lack of resources for lesson delivery and the support staff deficit, such as laboratory technicians and assistance to help to teach QA pose problems for smooth teaching. It is, therefore, suggested based on the findings of the study that the Ghana Education Service should regularly inspect the physical conditions of the school laboratories and provide the needed support in terms of materials and equipment since the selected schools had insufficient material resources for teaching QA to students.

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KEYWORDS

Exploration

Teaching

Qualitative analysis

Chemistry

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To all the wonderful kind, considerate teachers who allowed me to interview and observed their lessons even amid the Covid-19 pandemic, I say a big thank you.

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I wish to express my appreciation to my Religious Brothers and Sisters of Holy Cross for their spiritual, material and emotional support.

DEDICATION

To my parents; Mr. and Mrs. Arthur, and my siblings~~;~~ Linus, Victor (deceased), Harrison, Theresah, Dominic, Samuel, and William.

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CHAPTER ONE

INTRODUCTION

Many mysteries which used to hold persuasive powers no longer do, because we have come to know the sources and causes of some of our daily problems through techniques of chemical analysis. Every single product (consumable or non-consumable) put out for public consumption was presumed to have been analyzed and certified by a chemical analyst. There were growing concerns and questions among many people, especially about the safety and authenticity of most of our local drugs, cosmetics, food, drinks (both alcoholic and non-alcoholic), insecticides, and weedicides. The silent questions were: How did we know that we were getting value for our money? How safe were we? These were the questions that an analytical chemist sought to answer. The chemist's role in identifying both quantitative and qualitative constituents of substances was the lifeline to our survival. It was because of the extreme importance of analytical chemistry to society and life that young and aspiring scientists got introduced to the identification of cations and anions in quantitative/qualitative analyses in our senior high schools.

Background to the Study

Chemistry has been considered the central science among the sciences because of the vital role it has played in both living and non-living things (Brown, LeMay, Bursten, & Bursten, 1994). Its link with other natural and applied sciences created numerous fields of study such as biochemistry, chemical engineering, medicine, geochemistry, agro-chemistry, and environmental chemistry (Salman, Olawoye, & Yahaya 2011). Practically, daily life of humans centres around the chemical choices we make with food, air, clothing, cosmetics, fuel, medicine, home, and family members (Nbina & Viko, 2010).

Analytical chemistry is one of the branches of chemistry that deals with methods of identification, separation, and determination of substance (atoms, ions, and molecules) in a sample. Analytical chemistry could be broken down into two general areas, (qualitative analysis [QA] and quantitative analysis), and each of these two could either be classical or instrumental. Qualitative instrumental analysis employ the use of instruments to separate and distinguish substances (organic or inorganic) in samples. Examples are Gas Chromatography – Mass Spectrometry (GC – MS), High-Performance Liquid Chromatography – Mass Spectrometry (HPLC – MS), Infrared Spectra (IR) and Induced Coupled Plasma – Mass Spectrometry (ICP–MS) or ICP – AES (Atomic Emission Spectrometry) (Svehla, 2008).

The teaching syllabus for senior high school chemistry requires that analytical chemistry is introduced to students through the identification of selected cations and anions (Ministry of Education [MoE], 2010). Students' understanding of most of these selected cations and anions, as required by the syllabus, depends on firm background knowledge of some essential topics. According to Svehla (2008), the following topics should be covered by students before the understanding of quantitative/qualitative analyses (QA).These are: stoichiometry, and chemical reactions especially in the writing of chemical symbols; formulas and equations; chemical bonding with a focus on ionic bonding; metallic and covalent bonding; state of matter focusing on properties of gases; acids, bases and salts constituting the bulk of QA; solubility with a focus on solubility rules and the principles behind; redox reaction in the area of

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balancing of the equation, redox potential, reduction and oxidation; electrolysis which looked at the mechanism of electrolysis and principles behind it; inorganic chemistry in the area of complex ion formation; transition metals in the area of metallic properties, variable oxidation state, colour formation, and complex formation.

Qualitative analysis, which determines the constituents of a compound or mixture of compounds, is the process of determining what metallic radicals (cations) and acidic radical (anions) are present in the sample without regard to quantities (Svehla, 2008). Moeller (2012) summarized the theoretical principles underlying quantitative or qualitative analysis as; in qualitative analysis, the mixture was put into a solvent such as water (or dissolved in acids) where the dietetic constant of the medium overcame the interionic forces of attraction and in this way put the ions somewhat separately. This was now made to react with the ions of various reagents to bring out the various characteristic changes such as colour, appearance, precipitation and complex formation which formed the basis for the identification of various ions present in the solution (Moeller, 2012).

The practical aspect of the West African Examination Council (WAEC) chemistry examinations consists of three sections: volumetric analysis, qualitative analysis, and general knowledge in practical chemistry work. The QA is also divided into three sub-units which students must master under QA. These are: the identification of inorganic cations, inorganic anions, and organic functional groups. The Chemistry syllabus does not have a structure for the practical chemistry work and does not state how teachers should teach it as well as the exact content to cover (MoE, 2010). However, WAEC gives some directives and requires students to know and perform the characteristic tests of cations with dilute NaOH (aq) and NH_3 (aq), and with the following ions (NH_4^+; Ca^{2+}; Pb^{2+}; Cu^{2+}, Fe^{2+}; Fe^{3+}; $A1^{3+}$; and Zn^{2+}). Confirmatory tests for the above cations do not specify the reagents to be used. On anions, characteristic reactions of dilute HCl on solids or aqueous solutions and concentrated H_2SO_4 on solid samples containing $C1^-$; SO_3^{2-}; CO_3^{2-}; NO_3^-; and SO_4^{2-} are required. The confirmatory tests for the above anions (without specifying the reagents to be used) and comparative study of the halogens (displacement reactions) for H_2, NH_3, CO_2, HC1, and SO_2 are required.

> Characteristic test tube reactions of the functional groups in the following simple organic compounds: alkenes; alkanols; alkanoic acids, sugars (using Fehling's and Benedict's solutions only); starch (iodine test only) and proteins (using the Ninhydrin test, Xanthoproteic test, Biuret test and Millon's test only) (WAEC, 2013, pp. 134-135).

Qualitative analysis was considered one of the most challenging areas for students in senior high schools (Treagust, Tan, Goh, & Chia, 2004; Uzezi, Ezekiel, & Auwal, 2017). In their study, Treagust et al. (2004) established the following difficulties in QA from students' perspectives. They asserted that QA involved more process skills and one had to learn many chemistry concepts to understand the lesson. Skoog, West, Holler, and Crouch (2014) agreed with these assertions. According to them, students were unclear about their nature, were tedious and frustrating in testing gases, cations, anions, using other reagents, and found different apparatus as being specified in the syllabus involving lots of memorization, and linking/applying to previous topics.

The study by Uzezi et al. (2017) assessed conceptual difficulties in a chemistry syllabus of the Nigerian science curriculum as perceived by high school students and gives the following highlights supporting the extensive nature of QA, that make QA a difficult topic for students. In the study, Uzezi et al. sampled 12 concepts, representing 63.25%, as difficult, out of 19 concepts in the syllabus used for the study. From the 12 difficult concepts, five concepts formed the basis of QA.

A significant source of difficulty in students' understanding of fundamental inorganic qualitative analysis students' difficulties in "formation of precipitates, complex salts, and addition of acid" (Treagust *et al.*, 2004, p.727). Reasons for students' difficulties, according to the researchers, included a lack of understanding of the procedures and reactions involved in QA. The requirements of QA were not explicit enough for students to understand. Besides, there was content overload in QA, which involved propositional and procedural knowledge, as well as manipulative and inferential skills (Treagust et al., 2004). Other challenges that affected the teaching and learning of qualitative analysis in senior high schools included inadequate time allocated for teaching chemistry, overloaded syllabus with no clear-cut procedure for teaching (especially practical), poor teacher preparation, unqualified chemistry teachers, poor instructional methodology, and reduced use of instructional materials (Muse, Ndirangu, & Imonje, 2019). However, the number one factor that leads to students' academic success is the methodology that teachers use in teaching (Alvarez-Bell, Wirtz, & Bian, 2017). This assertion suggests that despite all the challenges listed above, an excellent teaching technique could significantly enhance students' conceptual understanding.

Research has shown that most chemistry teachers employ the lecture method of teaching (Iqbal, Azam, & Rana, 2009; Kolomuc, Ozmen, Metin, & Acisli, 2012; Uzezi et al., 2017). Hinchman (1992); and Knight (2015) boldly share the view that most teachers use textbooks in the course of teaching and are seen as repositories of knowledge. There is a need for a methodology that is student-centred, activity-based, and technologically enhanced to equip students with 21st-century skills to prepare them to play a significant role in solving the challenges that they will face. As Lerman (2014) puts it, there should be new ways of thinking creatively, using innovative teaching, resulting in pedagogically sound learning.

This current study uses the Constructivist Grounded Theory (CGT) to explore the teaching of QA in SHS qualitatively. Under the CGT approach, the use of methodology and other factors that impede the success of teaching will be explored. The gap that this research sought to fill would be generation of constructivist grounded theory on how chemistry teachers teach a particular topic such as QA.

The Constructivist GT focuses on how participants and the researcher co-construct meaning concerning the issue under study (Charmaz, 2008). It was, therefore, necessary to explore and develop a theory with participants on how to teach QA in secondary school for students to appreciate the vital role QA plays in our society.

Statement of the Problem

The chief examiner's reports (WAEC, 2014; 2015; 2016; 2017; 2018) showed students' poor performance in QA in the final examinations of SHS. For instance, the 2018 report (WAEC, 2018) was laden with comments such as

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candidates: “lack of relevant skills for adequate qualitative analysis”, “inadequate description of precipitates formed”, “Performance for question two (Qualitative Analysis) was not encouraging. E.g. some of the candidates did not adhere to the instructions. In few cases, reagents not stated in the question were used” (p. 301). These comments suggest that the students lacked relevant skill for adequate qualitative analysis and form inadequate descriptions of precipitates formed. The suggested remedies for these poor performances, according to the report were as follows: a) tutors should start the practical work with students right from form one with more practice in the laboratory, b) exercises presented should be marked by the chemistry tutors, c) refresher courses should be organized for all chemistry tutors, and d) teachers should explain the procedures used in practical activities to candidates.

More practical assignments should be given to candidates to practice.

More equipment should be supplied to schools since the class size had increased.

More time should be allocated to practical to enable candidates to practice. The hands-on activities would enable students to match theory with practical and see the relevance of what they do in life.

More practical work is needed to be done in the area of qualitative analysis (WAEC, 2018, p. 301).

From the 2017 WAEC report: "Some candidates did not report on the activity even though they proceeded to work on the filtrate and residue", “…many candidates wrote, "Precipitate dissolves" instead of "precipitate dissolves to form a deep blue solution" (p. 265). Those who reported described the filtrate as 'clear filtrate' instead of the colourless filtrate with wrong use of terms. For example, “precipitate instead of residue." (p. 267).

The suggested remedies for these as proposed by WAEC (2017) were these:

> The solution to the poor standard of students was simply for the teachers and students to work hard in the classrooms and laboratories. Teachers had to use their school laboratories very well. Teachers had to endeavour to expose candidates to a lot of practical exercises, and make time to score the exercises while drawing their attention to essential points. In recording tests, observation and inferences made were pointed out to students (p. 263).

In 2016 the following were observed by the chief examiner (WAEC, 2016):

> Poor knowledge of identification of cations and anions in solution, candidates referred to filtrate … and residue as a precipitate. Most candidates, wrote a white solution for white precipitate and white gelatinous precipitate for silver chloride instead of white precipitate, most candidates did not record their observations and inferences immediately after adding the solutions. Observations and inferences were mixed up (p. 33).

Suggested remedies to these lapses were (WAEC, 2016):

> Candidates needed to have a thorough grasp of the principles behind the answers they were providing in the practical questions. Such understanding helped in a systematic presentation of answers which demonstrated understanding. Candidates were exposed to more practical work to obtain the necessary techniques and knowledge required (p. 31).

In 2015 these were the highlights of poor students' performance (WAEC, 2015).

> Many candidates performed confirmatory tests for cations they had not identified earlier (p.29). They were not able to make correct observations and inferences; the majority of the candidates were not able to perform the correct confirmatory test for the cation identification (p. 31), and some candidates did not follow the procedures outlined in the question thereby messing up with their answers. Most candidates could not give a detailed description of the gas evolved (p. 33). Also, many of the candidates could not write their observations correctly, and even where they were successfully written, they could not make any meaningful inference. In this instance, some of the candidates wrote gelatinous solution instead of the gelatinous precipitate, and other candidates did not give the colour of the resultant solution or precipitate (p. 35).

Suggested remedies recommended by (WAEC, 2015) were that, "candidates should be exposed to much practical work to enable them to acquire the requisite practical skills. Candidates should be taught how to make correct observations and inferences" (p. 29).

Most of these factors point to (how teachers are teaching) teaching methods employed by teachers, as shown in the suggested remedies. Apart from WAEC Chief Examiners' reports, several researchers have also alluded to these same weak teaching methods employed by the teachers in teaching chemistry. (Adesoji & Omilani, 2012; Opara, 2013; Sam, Owusu, & Anthony-Krueger, 2018; Singh, Yager, Yutakom, Yager, & Ali, 2012; Uzezi et al., 2017). Adesoji and Omilani (2012); and Magwilang (2016) shared that the traditional method

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of teaching chemistry affects chemistry education. This traditional method of teaching using the lecturing method was predominantly being used in most of our schools (Sam et al., 2018). . Opara (2013) further expressed that the conventional way of teaching chemistry did not bring out the demand that was expected of a 21st-century student. However, student-centred cooperative interactive learning according to Uzezi et al. (2017) was more effective than the teacher-centred approach. Therefore, the question was which approach or approaches were chemistry teachers using in teaching QA in SHS in Ghana?

The problem was compounded by the fact that while the syllabus demanded that students understand the concepts of QA; no particular teaching technique was stated. Treagust, Tan, Goh, and Chia (2004) advocated a 21st-century teaching methodology that had the pedagogy in teaching QA to boost the confidence, the knowledge, attitudes and skills of students in solving modern-day challenges. This 21st-century methodology should have the ability to concretise abstract concepts and improve the retentive memory of students.

Purpose of the Study

The purpose of this study was to explore and co-develop a theory that would assist chemistry teachers in teaching QA in senior high schools in Ghana. To achieve this, initially, the study explored:

1. teachers' problems of teaching QA in senior high schools.
2. the general pedagogy and content knowledge of chemistry teachers and to find out the context in which they teach QA.
3. how teachers teach QA to students in senior high schools.
4. qualitatively, other factors affecting teachers in teaching QA in senior high schools.

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Research Question

The following research questions were formulated based on the outcomes of the field study of teaching of QA to senior high school students:

1. What problems do teachers have teaching QA to senior high school students?
2. How do teachers use their pedagogy and subject matter knowledge of QA and in what context do they teach QA to senior high school students?
3. How do teachers teach QA to students in senior high schools?
4. What other factors, qualitatively, affect teachers teaching of QA in senior high schools?

Significance of the Study

The findings relating to teachers' problems on teaching QA to SHS students would provide chemistry educators and researchers with rich qualitative data on the nature of the problems. This would help chemistry educators and researchers to formulate and test hypothesis on the effects of those problems on effective teaching of QA to SHS students. The Ministry of Education through the Ghana Education Service would then put measures in place to reduce any impact of teachers' problems on teaching QA to enhance development of conceptual understanding of students on QA.

The findings on the pedagogy, content and the context with which teachers teach QA to students would inform chemistry educators and researchers the pedagogy, content, and context within which teachers use their pedagogies to instruct the content of QA. Chemistry educators and researchers could take advantage of any theory linking pedagogy, content, and context and conduct further research on how context influence teacher pedagogy and content of chemistry.

Findings on how teachers teach QA to students at the high school level could be a revelation as there could be issues on how teachers prepare to teach and how they implement their intentions in the classroom. School managers and administrators could be confronted with reality on how teachers teach QA to students as a practical component of high school chemistry in more than one context. Teacher training institutions could have insight of the strengthens and weaknesses of teachers they have prepared for teaching chemistry, and design and implement curriculum that could help to prepare teachers for effective teaching of QA (and chemistry) to students.

There could be a number of factors militating against effective teaching of QA to high school students and qualitatively, a theory could be established from this research. Chemistry educators and researchers could further test hypothesis on factors that predict most on effective teaching of practical-based concepts in QA. Ministry of Education through the Ghana Education Service could provide the needed support for school managers and administrators to help teachers effectively teach QA to students.

Delimitation

There were many approaches to this study. However, the study was delimited to the use of the grounded theory, which made use of only interviews, observation and field notes as a tool for data gathering. The study was delimited to QA out of many concepts in the teaching of chemistry. The concept of QA could have been focused on either inorganic or organic chemistry, but the current study was delimited to the analysis of cations and anions in inorganic QA.

Limitations

The weakness related to this study was the sole use of the qualitative approach which could not take into account quantitative data to generalize the finding for a larger population. Concerning the sampling technique, the study was limited to a purposeful sampling of chemistry teachers who were willing and could best respond to the research questions; preventing any generalization of the findings of the study to all teachers teaching chemistry in high schools.

Also, the reliance on interviews, focus group discussions, and observations of teachers teaching limits this research since other stakeholders view such as heads of schools were not factored in. At the same time, students' activities were not highlighted except by interviewing a few students about a lesson.

Organisation of the Study

This work has been organised into five chapters. These follow other chapters in addition to Chapter One. Chapter Two presents a review of related theoretical and empirical literature which covered the scope of chemistry, nature, content, context, and pedagogy of teaching QA, teaching and learning resources, supporting agents, and ways of exploring the teaching of qualitative analysis

Chapter Three describes the research methods applied in conducting the research. The areas are research design, population, sampling procedures, research instruments, data collection procedures, and data processing and analysis.

Chapter Four presents and discusses the results from the data collected based on the stated research objectives.

Chapter Five presents the summary of findings, conclusions, and recommendations based on the research objectives leading the emerging research questions.

CHAPTER TWO

LITERATURE REVIEW

The study sought to explore how chemistry teachers teach qualitative analysis in Ghanaian senior high schools. Instead of doing quantitative research to find out, a qualitative approach was chosen for this study to get an in-depth understanding of the phenomenon (Creswell, 2012). The ability of a chemistry teacher to create a lasting impact on students is to connect them to the real-world during lessons through the use of modern methods of teaching which make use of technology such as slides, videos and multimedia artefacts to authenticate examples given during lessons. However, Helliar and Harrison (2010) opine that students' involvement in practical work has been described as the most impactful in their academic work because of the interplay among their cognitive, affective and psychomotor domains. The literature search to support the research is categorised into:

i. the scope of chemistry

ii. nature, content, context, and pedagogy of teaching QA

iii. teaching and learning resources

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The Scope of Chemistry

Chemistry has long been referred to as the central science because of its link to other science such as biology, physics and so on. Its importance cannot be overemphasized (Uzuntiryaki & Boz, 2007). Comprehending the basic concepts of chemistry is important for students in secondary education, as chemistry provides a path for students to excel and create new waves of technology (Gluck, Dillihunt, & Gilmore, 2014). Unfortunately, chemistry is perceived as one of the difficult subjects by students, especially in high school since it includes some abstract concepts (Broman, Ekborg, & Johnels, 2011). A study by Uchegbu, Oguoma, Elenwoke and Ogbuagu (2016) concluded that dysfunctional laboratories, poor teaching methods, ineffective use of instructional materials, and inadequate science materials contribute to chemistry being difficult and frustrating for students, therefore making them shy away from chemistry all the time.

Chemistry educators and researchers have been looking for ways of making the teaching and learning of chemistry more interesting and less abstract, and increase active participation of students (Broman, Ekborg, & Johnels, 2011; Broman, Bernholt, & Christensson, 2020; Uchegbu, Oguoma, Elenwoke, & Ogbuagu, 2016). The important role of learning qualitative analysis in our schools and colleges cannot be overemphasized. For us to be proficient and well equipped to solving in solving the challenges of hunger, diseases, water and air pollutions, in the 21st Centry, Chemistry in the branch of qualitative analysis, is seen as the backbone of science for these challenges (Lerman, 2014). Lerman (2014, p. 80) expressed that "to have these types of chemists, we must have in the pipeline, students who will become the future chemists to be able to offer solutions to existing and new problems" and this should be seen among the young analytical chemists. According to Matlin and Abegaz (2011), the major contribution of chemistry in modern times is to eliminate diseases and hunger as well as improve the quality of living.

One of the contributing factors associated with students' poor performance, according to Nbina (2012), is how chemistry teachers teach. Ali (2012) held that students with poor schooling, including a lack of individualised attention, prevent solid teaching in later forms. The inability of teachers to make connections with relevant previous knowledge and experiences in a context that students are familiar with also contribute to this poor achievement (Treagust, Tan, Goh, & Chia, 2004).

Exploring teaching methodologies and context of teaching QA

The methodology is a way a teacher thinks about the learning process to adopt, sort, or organise the contents using appropriate instructional skill in a proper context to maximize learning (Wiesen, 2020).

Tan, Goh, Chia, and Treagust (2001) contented that when it comes to teaching QA, the learner needs to know the structure of the content. Teachers must pinpoint the ideas, schemes, facts, process skills and strategies required for teaching QA. According to Tan et al., a basic understanding of the content of QA must not be presumed in students who probably require a rudimentary review of QA. If students are aware that they are to apply the concepts and knowledge learnt in QA to the experiment they perform, with the process skills acquired, the learning of QA becomes meaningful. The basic principles behind qualitative analysis are solubility and the common ion effect (Svehla, 2008). These principles need to be handled well for students to understand. However, Treagust et al. (2004) noted that instead of experienced teachers teaching QA to students with appropriate learning skills and experiences, they shed that responsibility because of lack of time, which does not support concept understanding.

According to Ali (2012), learning is influenced by multiple factors, including teacher preparedness and access to resources. However, others have extended the range of necessary educational factors (Adesoji, & Omilani, 2012; Uzezi, Ezekiel, & Auwal, 2017). Adesoji and Omilani (2012) asserted that something as basic as comprehension of subject matter in the teacher must be factored into the learning process. Uzezi, Ezekiel, and Auwal (2017) traced poor learning to poor performance in qualitative and quantitative analysis. To help bring about conceptual change, teachers, as well as students, must be aware of factors impeding comprehension (Adesoji & Omilani, 2012). Uzezi et al. state that poor work in examinations is lack of general understanding of concepts. To help bring about conceptual change, Adesoji and Omilani (2012, p. 58) opined that "…teachers should ensure that students are aware of their implicit representations as well as of the beliefs and presupposition that can constrain them from adequate conception." This can be achieved through teachers' dexterousness in the classroom.

Teaching is an act that is continuously metamorphosing, making teachers reflect on their ways of promoting knowledge. This depends largely on the pedagogy, content, knowledge and now, more importantly, the technological ways to communicate the aspect of teaching, be it theory, practical or a blend of the two. The traditional understanding of teaching is someone imparting knowledge into another person. This transfer can be understood from many approaches. A look at some learning theories could help shed more light on why a particular choice of learning theory may be more suitable for teaching and learning of QA.

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Instructional Strategies

Many instructional strategies have been employed in teaching chemistry and notable among the lot are concept mapping (Novak, 1990), algorithms strategy in solving chemical arithmetic problems (Barbin, Borowczyk, Chabert, Guillemot, Michel-Pajus, Djebbar, & Martzloff, 2012), team teaching approaches (Amiodoh, 1984), and flipped classroom model (Bergmann & Sams, 2012). According to Magnusson, Krajcik, and Borko (1999), there are two components of instructional strategies: the subject-specific strategies and topic-specific strategies. The teaching of QA at the SHS level requires more competencies in topic-specific strategies than the subject-specific because of the nature of the QA which requires a good understanding of basic concepts before teaching QA as a whole (Chua, & Karpudewan, 2019; Peterson, Rubie-Davies, Elley-Brown, Widdowson, Dixon, & Irving, 2011). When it comes to practical lessons, Kihumbas (2009) asserts that the two instructional approaches that teachers use most to teach practical lessons are experiment and group demonstration. Some teachers do not use these instructional strategies, because of lack of apparatus and chemicals. Another instructional method which Bamidele (2013) found to help students greatly was peer-tutoring during the practical lessons. This is an approach where students take charge of their lesson and help their peers to come to understanding. Not much has been explored in terms of assessing the efficacy of this method. The possibility of exploring peer-tutoring in the chemistry laboratories lies in what Shidiq and Yamtinah (2019) observed as teachers' lack of experience with methods enabling them to assess their students' understanding and performance in the science laboratory. Other instructional strategies used in most schools include hands-on activities, lecture

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method, group work and demonstration (Kumari, & Umashree, 2017; Landry, Zucker, Williams, Merz, Guttentag, & Taylor, 2017).

There are three major divisions of demonstration: visual aids demonstration, analogical demonstration, and real experiments (Taylor, 1988). In visual aid, teachers use objects that can illustrate the intended meaning that teachers want to convey. For example, teachers use pictures of flames for students to see the nature of ions when in flames. Analogical demonstration involves using a phenomenon with characteristics similar to the intended lesson under investigation, for instance, teachers using egg albumen to illustrate gel precipitate and chalk in water to demonstrate chalky precipitate. Real experiment demonstrations are hampered in classrooms lacking apparatus or chemicals, or when the nature of the experiment demands that the teacher or one person experiments for the rest to see (Taylor, 1988). Demonstration as an instructional strategy in teaching chemistry has been explored by many authors (Bare & Andrew 1999; Hofstein & Welch 1984; Thompson, 2002). Basheer, Hugerat, Kortam, and Hofstein, (2016) stated that, when teachers plan well, demonstrations can be used to effectively aid students' understanding of concepts, an idea corroborated by (Chiappetta & Koballa, 2002). This may be the reason why it is used in most Ghanaian schools. In some instances, teachers do combine more than one instructional strategy such as demonstration and group work.

The importance of group work cannot be understated. This is because it helps students to learn from each other. Group work helps students to ask direct questions among members of their group in the course of experimenting. The challenge is the number of students assigned to a set-up, a situation that teachers often complain about. Group work not only increases comprehension but also brings about accuracy in experiments (Korshevniuk, Yaroshenko, Blazhko, & Blazhko, 2020). The reasons for which some teachers do not engage students in group work is that most teachers do not have the competent skills in ordering students into groups to maximize active participation and getting the full benefit of practical work (Matanda, 2016). Hands-on activities are real handling of chemicals and apparatus in the chemistry laboratory where students enhance their manipulative skills. Those activities in cation and anion identification include performing a flame test, pouring of reagents, holding of test tubes, wafting to smell evolution of gas, filtering solutions, all of which demand students' involvement (Olajide, Adebisi, & Tewogbade, 2017). Ajayi, (2017) asserted that hands-on activities enhance students' learning experiences. Abdullah, Mohamed, and Ismail (2007) maintain that when students handle apparatus and chemicals, their understanding is enhanced and performance increased. On the other hand, Kihumbas (2009) reported that lack of apparatus (88%), chemicals (86.1%), and laboratory furniture (79.6%) among others were some of the factors that hinder students from handling/manipulating the apparatus on their own. Many other terms are used to describe hands-on activities in the literature, such as practical activities, manipulative activities, and material focused activities (Ajayi, 2017). The reason for placing so much emphasis on practical activities is that it can retain students' knowledge for a longer time than the other methods of teaching (Kozleski, 2017)

Process Skills

Presently, the direction of science education is to train individuals who can adapt to different conditions, think flexibly, be creative, think critically and multi-directionally, and use the Science Process Skills (SPS) to solve problems (Saputro, Irwanto, Atun, & Wilujeng, 2019). Science Process Skills are the basic skills that facilitate the learning of science, allowing students to be active, developing a sense of responsibility, increasing the permanence of learning, and providing research methods (Derilo, 2019). Scientific knowledge includes theory, principles, and laws, forming content as part of sciences such as QA in chemistry. Ways to knowledge acquisition are ways to get scientific knowledge. Mastering SPS helps to develop the kind of science programme that mirrors real science (Ülger & Çepni, 2020).

Many studies, including the American Association for the Advancement of Science [AAAS] (1993), have classified science process skills. SPS are classified into sixteen. These include observing, measuring, classifying, communicating, predicting, inferring, using the number, using space or time, relationship, questioning, controlling variables, hypothesizing, defining operationally, formulating models, designing an experiment, and interpreting data (AAAS, 1993). Aydın (2013) classify SPS as observation, classification, measurement, communication, inference, prediction and experimenting. Other authors (Batı, Ertürk, & Kaptan, 2010; Johnston, 2005; Peters & Stout, 2006) categorised SPS into two main groups: a) basic skills such as observation, classification, communication, measurement, prediction, inference and b) Integrated skills which involve defining and controlling variables, formulating and testing hypo~~theses~~thesis , defining operationally, experimenting, interpreting data, and formulating models (Batı, Ertürk, & Kaptan, 2010; Saputro et al., 2019).

Qualitative analysis in chemistry involves a lot of process skills by way of observing physical and chemical properties such as colour and solubility of the sample, predicting cations and anions present, identifying cations and anions present, classifying tests as preliminary tests and confirmatory tests, measuring samples to be analyzed, making inferences, and recording them. Therefore, teachers with sufficient SPS can teach QA efficiently and help their students perform effectively (Saribas & Bayram, 2009). Approaches to assessment in a chemistry class can provide an opportunity to inculcate SPS utilised in teaching QA.

In the process of assessment, the knowledge shared with the student during QA lesson is evaluated, and the teacher's lesson can also be evaluated for improvement (Jusuf, Sopandi, Wulan, & Sa'ud, 2019). In the light of exploring effective methods of teaching QA in the 21st century, a teacher's ways of assessing students' understanding cannot be ignored since it plays a key role in helping teachers to measure students' understanding, knowledge acquired, and skills developed during the lesson. Performance attainment informs teachers about their instructional strategies, enabling them to fill the gap in what the students are lacking during QA lessons (Olajide, Adebisi, & Tewogbade, 2017). Such, methods also motivate students to learn and improve when they see their scores after assessment (Ghosh, Bowles, Ranmuthugala, & Brooks, 2017). According to Ogunleye and Bamidele (2013), the performance of students in practical skills has been poor. What matters most is how the assessment of QA is structured. The methods used in assessment should be able to develop students' requisite skills embedded in them, be related to examinations and enable students to assess their work and progress (Kao, 2019).

With a keen interest in a teachers' way of assessing students when teaching QA, methods such as assignment, marking of scripts, quizzes, on the spot evaluation and student self-assessment are used (Awidi & Paynter, 2019). A chemistry teacher's preference for assessment depends on their workload (Childs & Baird, 2020).

Workload means the amount of intensive labour involved in teaching QA (Werang, 2018). Workload entails preparation for and teaching theory, practical details, extra hours due to large class size, and assessment (Sellen, 2016). Even though workload enables teachers to broaden their knowledge base and develop their ability in multi-tasking, its excessive power reduces a teacher's output and students' performance. The nature of QA, if not aided by its ancillary support, will always be an added workload on teachers (O'Meara, Kuvaeva, Nyunt, Waugaman, & Jackson, 2017). Sugden (2010) revealed that teacher workload is intensifying and teachers are increasingly leaving the profession before having taught for 35 years. The swelling nature of workload about QA can be attributed to extra hours a teacher has to teach due to dividing the class because of the large class size, scoring of exercises, and preparing the laboratory for practical work since most schools either do not have a laboratory technician or the technician is not trained. Meanwhile, most teachers teach a minimum of three chemistry groups of students with between 50 to 60 students per group. Most laboratories are not big enough to accommodate all students in each group at a go and so each class is divided (Katcha & Wushishi, 2015). This is the reason why Cheung and Yip (2003) reported that one of the most worries of chemistry teachers is their workload which stresses them. The issue of workload is a dominant problem in our educational system which needs critical attention. Kibret and Adem (2020) reiterated that the focus of practical work has not been given its needed attention. As a result, the teachers cannot give out their best to students and hence, reduces the quality of students' performance.

Some of the apparatus are test tubes, boiling tubes, reagent bottles, and stirring rods. Chemicals such as $NaOH_{(aq)}$ and $HNO_{3(aq)}$ are prepared to be used as reagents for qualitative analysis (Lou, Wu, & Tan, 2020). Apparatus and chemicals play a central and distinctive role in how chemistry teachers teach QA since it is a practical-based concept. The effectiveness of teaching QA as a practical-based concept depends on the availability of apparatus and reagents, as it aids exposure of students to adequate practical works and leads to raising excellent future scientists (Oladeji, Abubakar, Bolarinwa, & Ajayi, 2019). Kihumbas (2009) revealed that lack of apparatus, teaching and learning materials, and reagents have affected students' performance in science subjects, thereby highlighting the importance of a well-equipped laboratory. Also, from Kibret and Adem (2020), most schools in their study had deficits in laboratory equipment and reagents which affected the frequency of practical work. There is a need for science laboratories to be stocked with enough apparatus and reagents to enhance efficient practical-based teaching. However, even with inadequate resources, a teacher can still perform practically (Surapuramath, 2013).

Laboratory materials: According to Abungu, Okere, and Wachanga (2014), frequent and active participation in QA practical works can be achieved through the provision of adequate laboratory facilities and materials for doing experiments. A well-equipped laboratory with enough space to accommodate as many students as possible ensures the practice of hands-on activities leading to smooth practical work all the time. Practical work plays a pivotal role in enabling students to gain a deeper understanding of the concept of QA and the student gains personal experience, if done well (Caroline, & Lusweti, 2018). In fact, in most schools, there is correlation between impacts of the teacher and the work-load on effective teaching (Kihumbas, 2009). This causes poor academic performance since practical work will be deficient (Imbahala, Odebero, & Nganyi, 2019). The students will also not obtain the necessary skills they have to acquire from practical works on QA that they will need for future employment. In some other schools, it was noted that they do not even have laboratory rooms (Daba, Anbassa, Oda, & Degefa, 2016).

Time has always been an issue when it comes to practical work in the laboratory. Unlike teaching the content that can be stopped at any time or broken down into units and picked up later, practical work needs a continual flow of time to get results (Mwangi & Mwangi, 2016). Ejidike and Oyelana (2015) reported that what makes the teaching of practical concepts ineffective is lack of enough practical periods. Uzezi et al. (2017) advocated that more time should be given to practical work for both teachers and students to have ample hands-on experience during practical lessons. Most teachers agree that time for practical work is woefully inadequate, thereby limiting students experiencing time on relevant reactions, thinking, sharing, and communicating their findings (Tan, Goh, & Chia, 2004).

Extra time is the additional time over and beyond the periods allotted for Chemistry on the school's timetable (Abdullah, Mohamed, & Ismail, 2007). It is essential for Chemistry practical, as it avails time for teaching QA, due to its bulky content. Extra time also enables the practice of hands-on activities, in effect producing quality students. The numerous reasons why extra time is needed include division of class due to large class size, to be able to complete the Chemistry syllabus and to revise concepts that students did not understand during the lesson (Charkoudian, Bitners, Bloch, & Nawal, 2015). Even though extra time has a lot of positive impacts, it also has some side effects on both students and teachers (Oladeji, Abubakar, Bolarinwa, & Ajayi, 2019).

Each period on the school's timetable has a duration of 30 to 60 minutes for specific subjects (MoE, 2010). For Chemistry, the period allocation on the timetable (four periods for both theory and practical works) is not enough (Kibret & Adem, 2020), considering the number of concepts that must be covered in the syllabus. Meanwhile, some of the concepts in the syllabus are practical ones, requiring more time for students to be equipped with the necessary skills (Mwangi & Mwangi, 2016). Period allocation, if done properly, establishes a natural routine which is comforting to teachers and students, informing students about the specific time a subject is scheduled, letting them know the duration of each class period and ensuring that no teacher is scheduled for too many classes or two classes at the same time (Mandina, 2012). More importantly, it enables administrators of schools to allocate sufficient resources to the most important curriculum areas (Mwangi & Mwangi, 2016). Without period allocation, students will not be able to prepare properly for class, some teachers might be reluctant to go to class and teach, and management effects can even drop down, creating indefensible student behaviour (Cheruiyot, 2020).

It is very worrying that a specific time on the timetable is not allotted for practical works (Chala, 2019). The importance of finding time on the timetable allotted to doing practical works is a must, as curriculum researchers have opined that there should be an increment in the number of periods to three periods or four per week but in many counties, there is no scheduled time (Chala, 2019). Thus, teachers concentrate on teaching the theory till the last minute when students are going to write practical examination before they teach practical concepts, causing poor performance in practical aspects (Akor, Egwu, & Omeiza, 2020).

Space in the chemistry laboratory of each school and time constraints for teaching practical works exhibit duality, meaning they have an inter-related impact on teaching (Nordström, Qvist, Natri, Närhi, Kähkönen, Palomäki, & Vepsäläinen, 2010). When a school population is small, the Chemistry laboratory can accommodate and enhance hands-on activities, and the teacher can give attention to each student (Casanova, Civelli, Kimbrough, Heath, & Reeves, 2006). No extra time is needed (Tesfamariam, Lykknes, & Kvittingen, 2017). This results in good performance of students since teacher output is high (Folounrunso & Sunday, 2017). The small size of most Chemistry laboratories is not able to accommodate large classes. Then if the class is divided, extra time is needed to teach the other half of the class. While the other class is waiting, the students must be engaged effectively through practical videos or exercises, and if the school has laboratory personnel, then they can supervise them.

Class size is the average number of students per class. Koki (2019) shared that to enhance the quality of teaching and learning of Chemistry, either the number of Chemistry teachers must be increased to reduce the teacher-student ratio with new and equipped infrastructures or the number of learners must be reduced. As part of the determinants of impactful practical lessons on a concept such as QA, class size cannot be overlooked since it controls how a teacher teaches QA (Daba & Anbesaw, 2016). The number of students in a small class increases student participation, individual attention, good moral behaviour of students, better communication between the teacher and students, leading to the good academic performance of students. With large class sizes, students get an isolated learning experience with a lot of students in a class to co-operate with (Hubbard, Tallents, & Learn, 2020). Also, students get the opportunity to enrich their critical thinking skills, knowledge acquisition and learning, way beyond what is the norm found within the walls of the classroom (Koki, 2019). Large class size makes teaching unproductive at times and normally leads to poor academic performance due to poor assessment of students, and teachers are not able to score the assignments of students frequently, and bad behaviour occurs (Adesoji & Olatunbosun, 2008). The enormous challenges faced by teachers is to decoupling of the laboratory from the classroom and in most cases even if the two are together the class size makes it difficult (Kibret, 2020).

Syllabus contains organisational information about a subject or a topic that guides teachers as to what is expected of them to teach (Kaufmann, Johnson, Kardos, Liu, & Peske, 2002). There are two syllabi used in the Ghanaian secondary school: a) the Ghana Education Service (GES) syllabus and b) the West African Examination Council (WAEC) syllabus for all the member states that have come together to take international examinations **(**Bosson-Amedenu, 2018)**.**

In-service training: Professional development: In the light of training students who will fill gaps in society, teachers and laboratory technicians must receive some form of retraining from time to time (Abungu, Okere, & Wachanga, 2014). Retraining will affect instructional strategies for teaching QA positively. This will equip teachers with the necessary expertise they need to raise good students (Helliar & Harrison, 2010). Sometimes, it looks as if some teachers are less concerned about the practical aspect of QA because they lack the technical know-how to treat the concept.

According to Kibret and Adem (2020), students' poor performance can be attributed to teachers' poor performance as a result of lack of in-service training, coupled with untrained laboratory assistance or technicians or lack of it. Mwangi and Mwangi (2016) noted similar outcomes. The undeniable fact that teachers and laboratory technicians need some form of training from time to time will not only affect students but will also impact the society and the nation at large (Okwuduba, Eke, & Offiah, 2016).

Constructivism

Constructivism is a broad term used by many educators and philosophers to describe a learner's contribution to his or her education as well as the benefits society gets from the learning (Bruning, Schraw, & Ronning, 1999). According to Bodner, Klobuchar, and Geelan (2001) knowledge is built within the mind of the learner and not received given. A shift in a teacher's perspective will occur in good teaching so that received knowledge is more of a "negotiation" than a transfer (Bodner, Klobuchar, & Geelan, 2001). There are several learning theories from this constructivist philosophy and prominent among these are sociocultural and inquiry constructivism.

According to Jonassen, "most cognitive psychologists think of the mind as a reference tool to the real world; constructivists believe that the mind filters input from the world to produce its unique reality" (as cited in Ertmer & Newby, 2013, p. 16). Ertmer and Newby (2013) stated the following specific principles that have direct importance for instructional design:

i. an emphasis on the identification of the context in which the skills are learned and subsequently applied thereby anchoring learning in meaningful contexts.
ii. emphasis on learner control and the capability of the learner to manipulate information actively by using what is learned.
iii. the need for information to be presented in a variety of ways by revisiting content at different times, in rearranged contexts, for different purposes, and from different conceptual perspectives.
iv. supporting the use of problem-solving skills that allow learners to go "beyond the information given." Here, learners develop pattern-recognition skills, presenting alternative ways of representing problems.
v. the assessment focused on the transfer of knowledge and skills by presenting new problems and situations that differ from the conditions of the initial instruction.

The sociocultural theory of learning which was pioneered by Lee Vygotsky proposed that most learning occurs as a result of a guide by a more knowledgeable other (Vygotsky, 1978; Walshaw, 2016). Concept learning describes the mental representation of the categorisation of objects. In this, learners look for attributes that can be used to distinguish examples of various categories. The problem-solving learning theory forwarded by Mayer and Wittrock (Mayer & Wittrock, 1996; see also Herde, Wüstenberg, & Greiff, 2016) asserted that problem-solving involves four parts: problem-solving is cognitive; problem-solving is a process, problem-solving is directed; and problem-solving is personal.

In constructivism, the learning is aimed at students building their knowledge through socialisation and active participation of the learner who is the centre of the learning process (Fernando & Marikar, 2017). The teacher in this learning process is seen as a facilitator who initiates the learning process with some leading questions that guide learning in groups or collaboration with more knowledgeable learners (Mwangi & Mwangi, 2016). This learning aims to create impacted life-long learning. The teacher uses the syllabus through discussion methods with a reflection on the students' insight by sharing (Briggs, 2019).

School culture serves as the central foundation of how schools operate. It might be positive or negative. A positive school culture entails proficient satisfaction of teachers, and morale and efficiency of students' learning whilst a negative school culture has customs that see students as responsible for lack of advancement of the school and discourages teamwork of management and stakeholders who can help to develop the school. According to Zhu, Devos, and Li (2011), heads of schools and supporting agents shape the values, beliefs, and attitudes important to stimulate a positive and nurturing school environment which is geared towards tutors' well-being and students' learning. Generally, per a school culture, a school can be a boarding or day school, or both. It can also be a single-sex school or boarding school or a mixed-sex school. A school culture includes the contribution of everything in the school such as how the academic programs are run, quality of food given to students and staff, extracurricular activities such as sports, club meetings, maintenance, and cleanliness of facilities in the school, security, approachability of the main office staff and so on. School culture can be assessed consistently and modified for the growth and development of the school. Although school culture may vary from school to school, they all have a set standard by the MoE. For instance, the culture of some schools permits them to have practical works on weekends and in the evening during preps due to the insufficient time of Chemistry periods and division of students because of the large class size, but this is not possible in some schools since their day students would not be on campus during preps and weekends. Some schools have special rooms for brilliant students, especially science students such that they always have the free will to study in the laboratory without any permission to do so. Some of these measures enhance students' learning and healthy competition among students.

In some schools, allowances are given as motivation for any extra duty a teacher performs, but in other schools, the management feels the salaries of teachers are enough without any allowance for any extra duty as a teacher. Due to that, most teachers in such schools feel reluctant to do any extra duty to enhance the development of the school. The study by Uzezi, et al. (2017) shows gender and environment have influences on concepts in the Chemistry syllabus, including QA.

Even though the role of **school administration** depends on various factors as to whether the school is private or public, it has enormous responsibilities in ensuring curriculum standards are met, providing professional development for teachers, and monitoring students' success with test results and other data (Victor, 2017). For a school to maintain its standards, the administration needs to always refurbish its science laboratories. Kihumbas

(2009) notes that some schools avoid routine maintenance which includes laboratories and related science facilities because of financial constraints. For Chemistry teachers to effectively teach QA, which is a practical topic, the school administration must buttress their efforts by ensuring that the necessary facilities, chemicals, and equipment must always be provided. In some schools, administration hardly plays any major role in supporting the science department, affecting the ability of some Chemistry teachers to teach QA effectively (Daba & Anbesaw, 2016). If Chemistry teachers will be able to teach QA effectively, then the role of school administration is very vital, as it will enhance their teaching.

Alumni and PTA (Parent-Teacher Associations)

Most alumni and Parent-Teacher-Associations (PTA) serve as a backbone to their former schools and play a key role in supporting the school administration with facilities such as boreholes, libraries, and science laboratories. There are times the alumni renovate the science laboratories and some of the buildings in their former school, showing appreciation to the school for the positive impacts on their lives. Most alumni take delight in seeing their schools acknowledged as one of the best schools. Most grade A and grade B schools have strong alumni.

Over the years, the government has been building schools, including science laboratories, and funding science projects in the educational sector. The efforts of the government have affected science education positively, as it furnishes schools with chemicals and equipment. However, once the science laboratory is built, renovations to maintain the science laboratories are scarcely done. This poses a great challenge in the quality of science education, as it

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prevents the Chemistry teacher from teaching practical topics such as QA effectively. Pareek (2019) proposed that, the government should support science practical activities. This can be done through constantly providing the necessary resources needed to enhance efficient practical especially in Chemistry (Chala, 2019).

The government has also built tertiary educational institutions such as training colleges and universities which offer educational courses to train teachers including science teachers. It is rather unfortunate that some of these tertiary educational institutions do not have some of the facilities to give their students the technical know-how of practical works. Some of their tutors lack the prerequisite skills to teach practical works such as QA effectively. Most teachers after graduating from tertiary institutions will still have to go through some form of training to enable them to teach effectively. As Chala (2019) rightly stated in his research, curriculum development that promotes the practice of laboratory method to make better the quality of science education in institutions should be reviewed and amended from time to time and some form of retraining or seminars should be given to science teachers, especially Chemistry teachers. According to Kibret and Adem (2020), there is a need for attention to be given for science practical work by the government, as it will promote the quality of science practical work.

Laboratory technicians play a dynamic role in providing quality education. Their roles vary from setting up experiments, maintaining laboratory equipment, taking an active part in practical classes, and giving technical help to students. Even though their roles vary from school to school, their pivotal role in ensuring students achieve their full potential through practical work cannot be underestimated. According to Chala (2019), most African schools lack technical assistants. According to Kibret and Adem (2020, p. 49), most schools have no "intentions of recruiting laboratory technician experts".

Grounded Theory

According to Mills, Bonner, and Francis (2006), the pioneering work of grounded theory has its roots from Strauss (1987) and Strauss and Corbin (1998), which is embedded in their relativist philosophical position that the researcher co-constructs meaning from the data with participants in their lived experiences in a constructivist approach. This approach to research on how Chemistry teachers teach QA is preferred because there is now an emphasis on the 'how' of research (qualitative) especially in education (Chong & Yeo, 2015). A broad range of disciplines use this approach to unearth social issues affecting people's lives (Mills et al., 2006). Another reason that makes this approach adaptable to this study is its ability to see multiple issues from the same data gathered and the flexibility of the researcher to make inferences (Jones & Alony, 2011). To use grounded theory effectively, the researcher must adopt a non-traditional state of mind. However, there is a question as to whether this freedom is one of the courses of it not being fully embraced initially by researchers.

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Charmaz (2014, p. 1) described the grounded theory as a "method that consists of systematic, yet flexible guidelines for collecting and analysing qualitative data to construct theories from the data themselves." Grounded theory is inductive with data invoking iterative strategies of going back and forth between data and analysis using comparative methods. The inquirer interacts and involves himself or herself with data merging analysis (Morse, Stern, Corbin, Bowers, Charmaz & Clarke, 2016). Some features make grounded theory adaptable to how teachers teach QA, especially getting first-hand information from teachers, going back and forth with information that is shared, and comparing ideas on how they do it. In many instances, enquiries have been conducted on what is lacking and how it came to that point (Charmaz, 2014).

Students' poor performance in QA analysis had largely been attributed to the poor teaching method (Ali, 2012; Nbina, 2010; WAEC, 2017, 2018). This poor performance had an underlying tone of overshadowing the interest of students in realizing the important role that QA plays in life. In the grounded theory method, the review of related literature is approached differently (Dunne, 2011; Glaser, 1992). Dunne (2011) asserted that one of the most problematic issues with grounded theory relates to how and when existing literature should be used in a study. Glaser (1992, p. 31) wrote:

> In our approach, we collect the data first and then start analyzing it and generating theory. When the theory seems sufficiently grounded and developed, then we review the literature in the field and relate the theory to it through the integration of ideas.

In grounded theory, literature review too should include a brief review of related literature at the start of the study to inspire the research and to justify the need for it. However, there is a need not to review any of the literature in the substantive area under study to avoid any interference with the finding that will emerge (Aryl, Jacobs, Sorensen & Razavieh, 2010). Strauss and Corbin (1998) indicated that involving literature at the beginning adds more clarity when it comes to the building of theory. However, the review of related literature can increase theoretical sensitivity and can stimulate thinking about properties or dimensions to be used in the examination of the collected data. Charmaz (2014) proposed that a literature review can be done before data collection, provided creativity and insight will not be compromised. Therefore, this study seeks to include a brief review of the literature at this point ahead of data collection.

The theory that drives this study is the grounded theory (GT) in the constructivist school of thought. Strauss and Corbin (1994, p. 273) reported that "grounded theory is a general methodology for developing theory that is grounded in data systematically gathered and analyzed. Theory evolves during actual research, and it does this through the continuous interplay between analysis and the data collection." This method of spending time with the material generated and looking out for the other possibility that can emerge from the data is what makes this method a powerful tool since reality is looked at from multiple angles of view (Morse, Stern, Corbin, Bowers, Charmaz, & Clarke, 2016). GT is its engagement of 'why', 'what', and 'how' questions (Charmaz, 2008).

The pioneering work of constructivist grounded theory has its roots from Glaser, Glaser and Strauss, and Strauss and Corbin (as cited in Mills et al., 2006), and it is embedded in their relativist philosophical position that the researcher co-constructs meaning from the data with those who took part in the research. This approach to research on how Chemistry teachers teach QA is preferred because there is now an emphasis on the 'how' of research (qualitative) especially in education, as (Chong & Yeo, 2015) observed. A broad range of disciplines use this approach with the result of unearthing social issues affecting people's lives. Also, this approach is adaptable to this study, as it can see multiple issues from the same data gathered and the flexibility of the researcher to make those inferences (Jones & Alony, 2011).

There are three types of GT design which Creswell (2012) named as the systematic design, emerging design, and constructivist design. Systematic design is associated with a detailed, rigorous process espoused by (Strauss & Corbin, 1998). According to Creswell (2012, p. 424), the systematic design "emphasizes the use of data analysis steps of open, axial, and selective coding, and the development of a logic paradigm or a visual picture of the theory generated." Glaser, not happy with the systematic design developed by Strauss and Corbin, considered their design as rigid and strict and with many rules to follow instead of allowing the theory to emerge. The process that guides the emerging design is its iterative process where there is the constant comparative analysis of data among data to data, data to category and category to category (Charmaz, 2014; Creswell, 2012; Urquhart, 2013).

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Kathy Charmaz developed the constructivist design with a special focus on views, values and feelings of participants and then deducing meaning from these experiences. It tries to focus on the how of the process, away from the systematic approach of describing a process (Charmaz, 2014; Creswell, 2012; Urquhart, 2013). This design is adopted for this study.

The general idea of theory building in GT is the generation of a theory from data gathered to explain a phenomenon and not the other way around (using a theory to gather data to explain a situation) (Creswell, 2012; Morse, Stern, Corbin, Bowers, Charmaz, & Clarke, 2016). Leading up to theory building are some features of constant comparison, theoretical saturation, and theoretical sensitivity coding. Creswell (2012) delineated steps that will help lead to theory generation in grounded theory, which include the following steps:

1. Decide if a grounded theory design best addresses the research problem
2. Identify a process to study
3. Seek approval and access
4. Conduct theoretical sampling
5. Code the data
6. Use selective coding and develop the theory
7. Validate your theory
8. Write a grounded theory research report

Constant comparison

Constant comparison is one of the major features of grounded theory whereby the researcher looks at features that are similar or different from each other. In this process, the researcher draws relationships in events, codes, sub-codes, categories, and sub-categories within the study to get a general sense of direction in the research (Birks & Mills, 2015). The process of constant comparison starts with the first data that is generated to look at emerging features and then comparing that with subsequent data that will be collected (Chun Tie, Birks, & Francis, 2019). One characterisation of this process is the iterative method of constantly going back and forth to the data gathered, codes, categories and even themes to find out more trends and gaps (Charmaz, 2006). The iterative process can be done through inductive, deductive, and adductive reasoning (Chamberlain-Salaun, Mills, & Usher, 2013).

Theoretical Sampling

The idea of theoretical sampling is the continuous process of gathering new information after the initial data collection into codes and categories and analysis to specifically speak to the issues under study (Jones & Alony, 2011). Birks and Mills (2015) reported that theoretical sampling is the process of identifying and perusing clues that arise during analysis in a GT study. The purpose of this is to saturate information gathered around the situation or issue under study to draw more understanding, map up relationships among other events or to fill gaps to bring clarity (Chun Tie, Birks, & Francis, 2019). Theoretical sampling does not start with data collection, but after categories and codes have been formed from the initial data, only then does it start. To stop theoretical sampling, Brown, Stevens, Troiano, and Schneider (2002) proposed a three-step process: a) when there is no new information coming from the data gathered, b) when the information gathered can exhaustively explain the phenomenon, and c) and when the information can explain the relationships that exist within the phenomena. In line with theoretical sampling is theoretical sensitivity where a researcher gets to know which piece of information is appropriate to study. The sources of theoretical sensitivity include a literature review of books and journal articles, personal experiences as well as knowledge gained and the emerging understanding gained from the event under study (Strauss & Corbin, 1990). Birks and Mills (2015) asserted that developing a theoretical sensitivity helps the researcher to be focused more toward the goal of developing the theory.

Coding

Codes can be words, images or symbols that are used to denote or describe a part of the data under investigation. GT is breaking down the complex interviews or data that have been gathered into smaller units that can be analysed to other theories (Charmaz, 2014). Urquhart (2013) reported that coding is an act of attaching a concept to a piece of data, which is the heart of the grounded theory method, and how we analyse the data. The ability to decipher what is hidden in the data is the work that needs to be done with care because whatever is coded is what will inform the sort of theory that one will get. Also, GT tells the researcher what and where to sample next (Creswell, 2012). Charmaz (2012, p.12) stated that "codes rely on the interaction between the researchers and their data. Code consists of short labels that we construct as we interact with the data. Something kinesthetic occurs when we are coding; we are mentally and physically active in the process." Different terms can be used in grounded theory to describe coding, depending on various traditions. Glaser (1992) proposed the following as ways of coding: open coding, theoretical coding and constant comparative coding. The idea of coding can be grouped into three main groups, as observed in Birks and Mills (2015): initial, intermediate and advance coding. The traditional form of coding, as observed by Glaser (1978), has open coding, selective coding, and theoretical coding. Open coding is the first step in a theoretical analysis where researchers develop codes from raw data; theoretical coding involves the conceptual formation or connecting the various codes to form a theme that can express an idea with its related factors and constant comparison is where the researcher goes back and forth with data, categories and codes to further locate more and detailed ideas. A new form of coding is situated in the constructivist grounded theory paradigm (Charmaz, 2006).

Urquhart (2013) proposed another way of coding: bottom-up coding, top-down coding, and middle-range coding and thematic coding. The bottom-up approach involves deducing the codes from data and not from literature which implies coding by the inductive approach proposed by Charmaz (2006). In this approach, the researcher codes the text line-by-line drawing close to what the data is saying more than what has been read. Top-down coding is described as a literature-driven approach where codes are made based on literature and not what the data is suggesting. The middle-range coding is to approach the coding by combining both the bottom-up and top-down coding approaches based on the awareness and intent that the researcher wants to bring (Urquhart, 2015). In this study, the inductive approach will be used as codes will be based on the data but not literature.

Summary of Major Finding of the Literature Reviewed

This chapter looked at the literature that backed the study from the perspective of grounded theory methodology. Specifically, the nature, content, context and pedagogy of teaching QA, the resources needed and supporting agents provided the literature for this study.

1. The more students involve themselves in practical work the more impactful they become in their academic work because of the interplay among their cognitive, affective and psychomotor domains (Hellair & Harrison, 2010)

2. Chemistry has long been referred to as the central science because of its link to other science such as biology, physics and so on. Its importance cannot be overemphasized (Uzuntiryaki & Boz, 2007).
3. Unfortunately, chemistry is perceived as one of the difficult subject by students, especially in high school since it includes some abstract concepts (Broman, Ekborg, & Johnels, 2011).
4. Chemistry educators and researchers have been looking for ways of making the teaching and learning of chemistry more interesting and less abstract, and increase active participation of students (Broman, Ekborg, & Johnels, 2011
5. One of the contributing factors associated with students' poor performance is how chemistry teachers teach (Nbina, 2012).
6. A basic understanding of the content of QA must not be presumed in students who probably require a rudimentary review of QA (Tan, Goh, Chia, & Treagust, 2001)
7. The basic principles behind qualitative analysis are solubility and the common ion effect (Svehla, 2008).
8. There are two components of instructional strategies: the subject-specific strategies and topic-specific strategies (Magnusson, Krajcik, & Borko, 1999).
9. When it comes to practical lessons, the two instructional approaches that teachers use most to teach practical lessons are demonstration and group demonstration (Kihumbas, 2009).

10. The reason for placing so much emphasis on practical activities is that it can help students knowledge for a longer time than the other methods of teaching (Kozleski, 2017).
11. Mastering SPS helps to develop the kind of science programme that mirrors real science (Ülger & Çepni, 2020).
12. Kihumbas (2009) reported that lack of apparatus (88%), chemicals (86.1%), and laboratory furniture (79.6%) among others were some of the factors that hinder students from handling/manipulating the apparatus on their own.
13. The nature of QA, if not aided by its ancillary support, will always be an added workload on teachers (O'Meara, Kuvaeva, Nyunt, Waugaman, & Jackson, 2017).
14. The effectiveness of teaching QA as a practical-based concept depends on the availability of apparatus and reagents, as it aids exposure of students to adequate practical works and leads to raising excellent future scientists (Oladeji, Abubakar, Bolarinwa, & Ajayi, 2019).
15. Even with inadequate resources, a teacher can still perform practically (Surapuramath, 2013).
16. More importantly, it enables administrators of schools to allocate sufficient resources to the most important curriculum areas (Mwangi & Mwangi, 2016).
17. Government should support science practical activities (Pareek, 2019).
18. A frequent and active participation in QA practical works can be achieved through the provision of adequate laboratory facilities and materials for doing experiments (Abungu, Okere, and Wachanga 2014).

19. The inability of teachers to make connections with relevant previous knowledge and experiences in a context that students are familiar with is another contributing factor (Treagust, Tan, Goh, & Chia, 2004).
20. The numerous reasons why extra time is needed include division of class due to large class size, to be able to complete the Chemistry syllabus and to revise concepts that students did not understand during the lesson (Charkoudian, Bitners, Bloch, & Nawal, 2015)
21. As part of the determinants of impactful practical lessons on a concept such as QA, class size cannot be overlooked since it controls how a teacher teaches QA (Daba & Anbesaw, 2016).
22. **Syllabus** contains organisational information about a subject or a topic that guides teachers as to what is expected of them to teach (Kaufmann, Johnson, Kardos, Liu, & Peske, 2002).
23. Heads of schools and supporting agents shape the values, beliefs, and attitudes important to stimulate a positive and nurturing school environment which is geared towards tutors' well-being and students' learning Zhu, Devos, and Li (2011).
24. Even though the role of **school administration** depends on various factors as to whether the school is private or public, it has enormous responsibilities in ensuring curriculum standards are met, providing professional development for teachers, and monitoring students' success with test results and other data (Victor, 2017).

CHAPTER THREE

RESEARCH METHODS

This chapter addresses the questions of the research design used, the study area, and participants of the study to achieve the aim of exploring teachers teaching of QA in SHS. The procedure of selection of participants, data collection instruments, modes of data collection, and data processing and analysis will be addressed in this chapter.

Research Design

The philosophical assumption underpinning the study was the interpretive paradigm and research design used was constructivist grounded theory (Urquhart, 2013), which viewed knowledge as co-constructed by the researcher and participants (Creswell, 2012). The aim was to co-create a theory with chemistry teachers on how they teach QA in SHS. The nature of knowledge, which was the epistemology, looked closely at the interaction between the participants and myself, looking at realities from multiple approaches on the teaching of QA. The axiology dealt with the beliefs and values of both the participants and myself that established the known motivation that drove their teaching.

The study made use of the qualitative approach. I chose this approach because of the in-depth knowledge I sought to explore with chemistry teachers. Under qualitative approaches, the study made use of the grounded theory design to explore the teaching of QA at the SHS level (Morse et al., 2016). The type of grounded theory design employed was the constructivist grounded theory (Charmaz, 2014). This helped me to find out the views, feelings, and assumptions of teachers other than just collecting facts and describing acts

(Creswell, 2012) and highlighted the lived experiences and perceptions of SHS chemistry teachers on how they taught QA.

Also, the purpose of the constructivist exploratory grounded theory design was to develop a theory with teachers that helped in understanding how chemistry teachers teach QA. This design had the social constructivist philosophical paradigm underpinning it. The design involved the careful selection of specific methods and procedures for the collection and analysis of data. The schema chosen evolved through purposive sampling, collection of data, initial coding, focused coding, axial coding and theoretical coding that led to theory generation in an iterative, recursive, and dynamic process (Charmaz, 2006; Chun Tie et al., 2019). The design was developed through a six-course stage:

i. gathering of essential documents
ii. purposive sampling and developing of instruments and protocols
iii. entering the field and data collection
iv. pooling, transcribing, and coding
v. analysing data and shaping theory writing, and
vi. engaging literature review and theory development of the teaching of QA (Eisenhardt, 1989).

Figure 1 presents the fluid that held these stages together as theoretical sensitivity, theoretical sampling, concurrent data collection and analysis, constant comparative analysis of data, and memoing (Charmaz, 2014; Chun Tie et al., 2019; Urquhart, 2013).

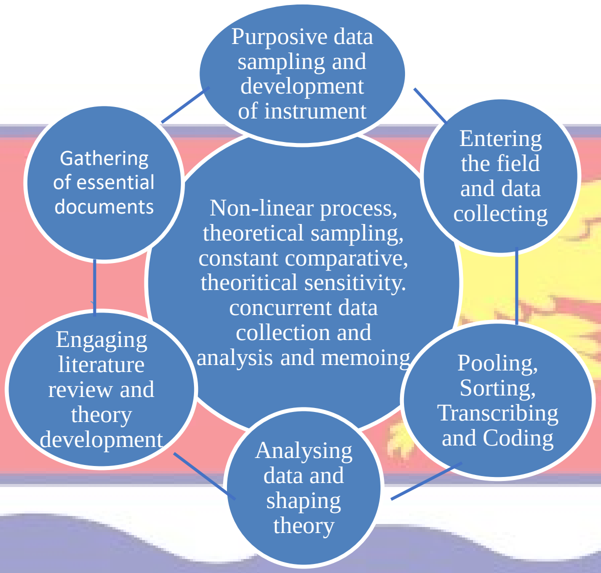

Figure 1~~11~~: A diagram showing the design of the study.

Source: Author's construct (Arthur, 2020).

Stage 1: **Gathering of essential documents for the conduct of the study.** The initial documents gathered to set the tone for the study include ethical clearance from the University IRB, permission letters, consent forms, and introductory letter. Also, the geographical areas for the research were marked and assessed, the number of schools and school-types were gathered, chemistry teachers and experts to be contacted were also found. Timetables, dates, and nature of data to be collected was documented and memos kept.

Stage 2: **Purposive sampling and development of instruments.** This stage helped to advance the research objectives. The purposive sampling of teachers who were willing to share their experiences freely and willingly was conducted, clarity on in-depth interview schedules and observation of a teacher's lesson in the classroom on the teaching of QA was also made. Provision for experts who might contribute to the research was made through direct face-to-face interaction. The two major instruments that were used to collect data were interviews and observations.

Stage 3: **Entering field and data collection involved collecting both primary and secondary data.** Primary data included conducting interviews with chemistry teachers and experts on teaching QA, and observing practical lessons on QA from participants in their schools. The secondary data source was preparing thematic content analysis on how chemistry teachers are expected to teach QA from chemistry syllabus (MoE, 2010), and preparing a thematic review of WEAC chemistry chief examiner's report (WAEC, 2014; 2015; 2016; 2017; 2018) on suggested approaches for teaching QA in SHS. The characteristic feature of GT that accompanied this stage was the memoing, constant comparison and document analysis.

Stage 4: **Pooling, transcribing, coding, and sorting of data** involved the gathering of the collected materials such as audio interviews, memos, filed notes, and pictures. This was followed by transcribing and sifting all the data collected into the Nvivo software. Coding process involved the forming of initial codes, focused coding, axial coding, and theoretical coding. The first three transcripts were coded line-by-line. This process was also characterized by re-categorizations, sub-re-categorizations, validation, and member checking, constant comparison, memoing, theoretical sensitivity and theoretical saturation.

Stage 5: **Analyzing data and shaping theory** was achieved through carefully glancing through the entire documents gathered, which gave a bird's overview of the rich data gathered. The pilot test conducted and refined was used to develop a coding frame. The analysis was done through reading the codes, categories and sub-categories and then used comparative, thematic, and constant comparative analyses in the findings on the teaching of QA into perspective. The writing style used the *in vivo* narration, which blended some of the direct quotes of participants as well as my own experiences from the field notes, memos, and years of teaching chemistry. Again, the use of constant comparison and theoretical sensitivity was employed to guide the study.

Stage 6: **Engaging literature review and theorizing** is where theory developed was related to the literature to find out how reliable and valid the findings on the teaching of QA will be. Major features that characterized the study was non-linear process approach, theoretical sampling, constant comparative, theoretical sensitivity, memoing, coding, and concurrent data collection and analysis (Charmaz, 2014; Chun Tie et al., 2019; Creswell, 2012; Corbin & Strauss, 2008).

Study Area

The area of study for this research was the Central Region of Ghana. The region has the hub of second cycle institutions in the country. This region was chosen because of the rich educational institutions that it was endowed with. It can boast of the two teaching universities, technical university, three colleges of education, and some of the best second cycle schools in Ghana. Though the region had all these best second cycle schools, there were several schools from other parts of the region within the category of less-endowed schools. Therefore, there was a blend of both endowed and less endowed schools for consideration in this study.

Three catchment areas were considered Cape Coast Metropolis, Mfantsiman Municipality, and Abura/Asebu/Kwamankese District. The Cape

Coast Metropolis was chosen because it has five grade A (well-endowed) schools, three grade B (endowed) schools, and two grade C (less-endowed) schools. Mfantsiman Municipality has only one grade A school, one grade B, and three grade C schools. Abura/Asebu/Kwamankese District has no grade A school, but one grade B, and two grade C schools. The reason for choosing these three areas was to reflect the nature of teaching and learning with the infrastructure and opportunities that each area had. It was presumed that a school in a metropolis ought to have all the needed teaching and learning facilities, and infrastructures for teaching and learning.

Population

There are 22 Metropolitan, Municipal, and District Assemblies (MMDAs) in the Central Region of Ghana. The 22 MMDAs are in a ratio 1 Metropolitan, 7 Municipal and 14 District Assemblies. The participants of interest were all chemistry teachers who had once taught QA in senior high schools from these 22 MMDAs in the region. Teachers of schools from three strata (Metropolis, Municipal and District) of the 22 MMDAs participated in the study. The three MMDAs were Cape Coast Metropolis, Mfantsiman Municipality and Abura/Asebu/Kwamankese District. There were 18 SHS in the three selected MMDAs. Of the 18 schools, only one school did not offer a General Science programme to students.

The purpose of selecting chemistry teachers from schools in these three MMDAs was that they had characteristics that could adequately address the research objectives in terms of experiences of teachers teaching in the various schools and the conditions under which teaching and learning take place.

Sampling Procedure

Participants for the study were selected through convenience and purposive sampling techniques. Three MMDAs (Cape Coast Metropolis, Mfantsiman Municipality, and AAK District) in the Central Region were selected purposively. The selection of the three MMDAs was informed by the performance of the schools in chemistry examinations by WAEC, school-type according to Ghana Education Service categorisation, and the location of the MMDA in the region. A grade A school was selected based on the weak performance of students in chemistry from the Cape Coast Metropolis. The only grade A school in the Mfantsiman Municipality was selected by convenience to participate in the study.

From grade B schools, one each was selected from the three MMDAs based on students' performance in chemistry examinations. Since there was only one grade B school in the AAK District, it was selected through convenience sampling technique. Also, one grade C school each was selected from the three MMDAs. Though the grade C schools were less-endowed, the three were selected based on their performance in chemistry examinations conducted by WAEC. In all, eight schools were chosen, consisting of two grade A schools, three grade B schools, and three grade C schools.

Teachers teaching chemistry in the eight schools participated in the study. Hence, all teachers teaching qualitative analysis (chemistry) for at least 2 years were introduced to interact with me through interviews. Thereafter, the participating teachers were stratified into three groups concerning their teaching experiences. The three groups were 1-5 years, 6-10 years, and above 10 years. In each of the eight schools, at least one teacher currently teaching QA and willing to have his or her classroom observed by me was selected to participate in the lesson observations. The teacher's experience was a factor in the selection, as teaching experience is seen as influencing teacher pedagogical content knowledge (Chu, Loyalka, Chu, Qu, Shi,&Li, 2015; Wei & Liu, 2018). Due to the outbreak of Covid-19 pandemic and ensuing restrictions at the time of data collection only 11 teachers of the targeted 24 teachers teaching chemistry participated in the study.

Data Collection Instruments

Modes of data collection were interviews, observations, and field notes.

Interviews

The interview schedule for collecting data on teaching QA was Teacher Interview Schedule on Qualitative Analysis (TISQA). This interview approach was appropriate for collecting data from participants in this study because of the aim of the study being to generate theory on teaching of QA in SHS and as such it allowed respondents to express the rich experiences that they have had in their respective jurisdictions about teaching QA. TISQA helped to explore issues that may have had a direct or indirect impact on teaching QA from teachers. The nature of the interview was face-to-face interaction with teachers using the developed TISQA. TISQA was a self-developed interview schedule and there were five themes developed with several items and prompts on it. The themes reflected a biodata question and three other areas. The areas were labelled as A, B, C, and D on TISQA respectively (see Appendix A). A major item on TISQA referred to specific questions asked under each theme represented as 1, 2, 3, and so on. Prompts were minor items under each major item. The purpose of the minor items was to further guide the direction of the interviews. Theme A on biodata had four major items. Theme B on 'what are teachers' problems in teaching QA' had three major items with 11 prompts. Theme C on 'how teachers assessed their general pedagogy, content knowledge and context in teaching QA' had five major items and 13 prompts. Theme D on in 'what context do teachers teach QA' had two themes and five prompts. Theme E on 'how do teachers explore factors qualitatively affecting the teaching of QA' items had three major items and 12 prompts respectively (see Appendix A).

Concerning the validity and reliability of TISQA, the items on TISQA were constructed based on a review of the literature and my 10 years of teaching experience in the senior high school. To ensure the credibility of TISQA, three of my colleague researchers peer-reviewed the instrument to check whether it could measure what it was supposed to measure. Their suggestions were used to improve the instrument. Thereafter, TISQA was given to my supervisor who critiqued and made suggestions which further improved on the quality of the instrument. The suggestions from my supervisor were used to improve the credibility of TISQA. The revised and improved TISQA was pilot-tested in three schools and transcribed data were sent to participants to member-check their interview schedule to ascertain their credibility. Another step that was taken to ensure the credibility of TISQA was triangulation of the responses from the three pilot tests on each item to find out whether there was no ambiguity in the responses. Steps were also taken to ensure that I became aware of my biases in constructing the interview guide in order not to skew my interview through reflexivity (Cohen et al., 2007). Further corrections, omissions and suggestions made by my supervisor were drafted to constitute the final TISQA used for collecting data. To ensure the dependability of the interview schedule, I kept all originally drafted interview questions with the revised versions, as well as the unedited audio tapes, field notes, and transcripts, intact for future reference.

Observations

I used Teacher Observation Schedule on Teaching of Qualitative Analysis (TOSTQA) to conduct my observations. TOSTQA was used to augment content knowledge and pedagogical skills of participants in the teaching of QA. The nature of this schedule was marked by ongoing note-taking with categorized in situ, observer-as-participant where my presence was known by the participants but less contact during the period of observation (Cohen et al., 2007) on teaching and learning of QA. The construction of TOSTQA had five sections developed with a theme(s) under each section which were the open-ended. A section reflected the six major areas of classroom observation labelled A, B, C, D, E and F. A theme focused on a specific question guide as to what was observed and labelled as 1, 2, 3 and so on. Section A which focused on the introduction of the lesson had one theme. Section B dealt with how the teachers delivered their content and was observed on four themes. Section C looked at skills development and had three themes. Section D looked at assessing learning effects and under it were two themes. Section E focused on the closure of the lesson with one theme. Section F focused on the state of chemistry laboratory with no theme under it (see Appendix B).

With regard to validity and reliability of TOSTQA, to enhance credibility for this instrument, I gave the constructed TOSTQA to three of my colleagues to peer review and their corrections and suggestions were used to draft TOSTQA very well. After that, my supervisor critiqued the constructed instrument and the suggestions thereof were used to improve the quality of the

TOSTQA. It was then pilot-tested in three schools. Another was the prolonged engagement of teachers on the observation made. This brought clarity, as observation is highly subjective in nature. At each stage of data collection, participants were given the opportunity to member-check their transcribed observed lessons or in vivo quotes. My biases were constantly reflected upon through reflexivity because of my background as a chemistry teacher. The dependability of this instrument was its reproducibility, as it was used in different areas of Central Region. Again, all materials and processes used in constructing the instrument were kept in their original forms for audit trial.

Field notes

The field notes gathered primarily contained observation made, reflections and memos on a day-to-day unfolding of events in the classrooms. A detailed well-written note with dates, times and events characterized this field note. It documented sequentially events with participants, insights, interactions with materials, questions and other things that needed documentation. Observation made in one area was triangulated with the rest of the areas in my field notes. The reliability of this instrument was its chronicled documentation and ability to produce all notes reading to the final theory generation.

Data Collection Procedures

In the first week of the study, the needed documentation and formalism were undertaken before the commencement of data sampling. The focused areas of documentation and formalism were ethical clearance from the University Institutional Review Board (IRB), permission letters from my Department of Science Education to the various schools that allowed me to conduct my research, introductory letter spelling out what I intend to do, and teacher consent form which detailed what was required of participating teachers, their rights and benefits. Also, the geographical areas used in the study were marked with reasons why the areas were appropriate for the study; the number of schools and school types visited; chemistry teachers and experts were contacted informally to check their willingness and availability for the interviews and observations of their lessons. Times, dates, and nature of data to be collected were discussed with prospective participants.

During week 2 of the study, I focused on the sampling of participants and the preparation of the various instruments, TISQA, TOSTQA, and Field notebook, for data collection. These instruments were used in pilot-testing in week 3. The pilot test helped to establish the validity and reliability of the instruments. Thereafter, TISQA was used in week 4 of the study to interact with selected chemistry teachers. The purpose was to find out the views of teachers on teaching QA to students. I moved from schools in Cape Coast Metropolis to AAK District through the Mfantsiman Municipality from week 5 to 7 to collect data. For convenience, I used one week in each district, interacting with chemistry teachers from the selected schools. The views of teachers on teaching QA to students were open-coded and constantly compared, memo taken, and observation well document in week 8 of the main data collection. The open coding, triangulation of data and constant comparison helped to identify areas that guided the QA lesson observations in the selected schools in week 9 to week 11.

From week 9 to week 11, I visited the selected teachers in their respective schools to observe lessons on QA using TOSTQA and took field notes as well. I again moved from schools in Cape Coast Metropolis to AAK

District through the Mfantsiman Municipality. There was a follow-up lesson observation for teachers whose lessons were truncated due to impromptu assignments and extra duties. Before and after each lesson on QA, I interacted with chemistry teachers and had more insight into teacher's pre-delivery, delivery, and post-delivery practices which ensured their effective teaching of QA to high school students. Again, memoing and constant comparison was employed to ensure trustworthiness.

Data Processing and Analysis

One of the major characteristics identified early on in this study was the concurrent data collection and analysis. This stage paralleled the preceding stage of the data collection procedure. There were four-step processes to this data analysis. They included cleaning and uploading; reorganizing and exploring; coding and visualizing; and exporting and communicating. After week 11 of the data collection procedure, cleaning and uploading of data were done. This involved formatting all the documents needed for analysis and organizing them into the Nvivo software for analysis. Thereafter, they were reorganized and explored for all other documents to be in sync.

The coding and visualising of data processing and analysis saw the coding, sorting, synthesizing and visualizing of the data using Nvivo software that assisted and managed data analysis. I made meanings of the transcripts and generated themes that followed the constructivist coding frame of initial coding, focused coding, axial coding and theoretical coding (Charmaz, 2014). Initial coding was a gathering of prominent information through the data collected. The approach to this step was the application of the constant comparative method and qualitative content analysis on the field notes, the views and observation data until saturation was reached. Focused coding was followed with the intent of shifting the volume of data to synthesize and proposing an explanation (Charmaz, 2014). The axial coding focused on relating categories to categories and categories to sub-categories because of bringing ideas which were scattered in open coding into perspective (Charmaz, 2014) as themes. Theoretical coding stage looked at the emerging prominent themes in the study and stringing these themes into a coherent theory. This stage involved going back iteratively to relook at the various open coding, focused coding, and axial coding to improve the theory generated (Charmaz, 2014) on how chemistry teachers teach QA to students in SHS.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presents the results of data analysis and discussions of the findings. The results were presented in a narrative form with an in vivo quoting of teachers' views, as well as observations made in line with the worldview of a qualitative researcher. The results generated were data-driven and meanings and interpretation co-constructed between the chemistry teachers and myself. The multifaceted factors that determine how chemistry teachers teach QA, the assessment of teacher's content, pedagogical and context, how they teach QA, and factors affecting the teaching of QA have directly been explored by this research, with results and discussions presented. The interviews highlighted some significant factors which militate teachers' output in practical work. Major stumbling blocks impinging on how teachers teach QA inductively emerged from the data:

1. **Available resources**; are consumable and non-consumable materials in nature. These are chemicals and apparatus used; human resource such as teachers, laboratory technicians and laboratory assistance; time resources such as the extended time, period allocation for teaching practical and time management; and school-type resources such as the type of grade of school and their present infrastructures.
2. **Content, pedagogical and context;** deal with content nature of QA, a look at the syllabus, the pedagogies used in teaching, and class size. These covered the concept of QA; conceptual understanding of QA and difficulties teachers encounter when teaching QA. The pedagogy

talks about the instructional strategies, process skills, workload and assessment found in the syllabus

3. **Support systems;** are about people and systems that play a key role in grounding practical work through their contribution. These systems are school administration, school culture, and laboratory technician role.

Research Question One: What problems do teachers encounter in teaching QA to senior high school students?

Theory of Available Resources in Teaching QA

Research Question One sought to assess the problems teachers' encounter in teaching QA to students in SHS. The main theme here is available resources. That is, resources desirable to influence the teaching of QA to make teachers effective professionally. It is difficult to talk about effective teaching of QA without considering the availability of resources. The interview with the selected teachers and the observations of their respective schools revealed a concern with resource availability:

> *Not well resourced, we have eight students to one set-up. Our challenge is the numbers and the apparatus that are not enough* (John, a Teacher).

Anthony buttressed the point saying:

> *As for the laboratory resources, you can see for yourself. It can take a maximum of 20 students. It is too small for the population of the school. When it comes to materials, we have some that we do make use of, but of course, it is not enough* (, a Teacher).

However, others claimed to have a well-resourced laboratory:

> *We have enough but going forward; we should be looking for more of the chemicals we consume. We have old boys, who from time to time, bring us some apparatus, with the chemicals; some time ago the PTA bought enough chemicals for us. We can say that we have enough, but we still need more because the chemicals are consumable. The apparatus also breaks from time to time. The system of the school says do not bill the students with a broken apparatus* (Mike, a Teacher).

Upon the observation of the schools where John, Justice and Mike were teaching, I realized that the chemistry laboratory was not in good shape and standard. For instance, John had fewer benches on which students could work; Justice's laboratory had an old stock of chemicals piled in the same room where students were working, exposing them to hazard; and Mike had a good laboratory with many of the apparatus and chemical in place but working benches and space for students were not enough.

The available resources are sub-grouped into four: material resources, human resources, time resources, and school-type resources.

The material resources focused on reagents and apparatus as well as other related materials used in the chemistry laboratory. For instance, Max talked about general materials without specifying any but added space as material need:

> *No, the materials are not enough and even the space for the laboratory is not there for all of them to have a simple set up* (a Teacher).

Coffie also talked about lack of chemicals:

> *The chemicals are our major challenge as we do not have a lot of the important ones and even those that we have are insufficient* (a Teacher).

Baba was more specific on apparatus:

> *No, because the apparatus is not enough for everyone besides the place is too small* (a Teacher).

Other teachers, however, expressed that chemicals and apparatus were sufficient for teaching QA. For example, Mike posited that:

> *We have enough chemicals and apparatus but going forward; we should be looking for more of the chemicals we consume. We have old boys, who from time to time, bring us some apparatus, with the chemicals; some time ago the PTA bought enough chemicals for us* (a Teacher).

In other instance, teachers explained that, though they have chemicals and apparatus in their schools, there is the need to add more. This is because the chemicals are consumables and some glass-wares are fragile.

> *We can say that we have enough, but we still need more because the chemicals are consumable. The apparatus also breaks from time to time. The system of the school says do not bill the students with a broken apparatus* (Mike, a teacher).

Justice was more specific not just about the materials but also the nature of it as he says:

> *We have a serious deficit and most of the chemicals here have all expired* (a Teacher).

From my observations of the chemistry laboratory of the selected schools, the chemicals and apparatus were unavailable and where they were, there seemed to be some, which were not in good state. The observation made in Coffie's laboratory showed no sign of restocking of the laboratory and there was a lot of broken apparatus and used chemicals stacked inside the preparation room. Mike had a refurbished good-looking laboratory with new equipment and chemicals neatly shelved but some crucial chemicals such as Silver nitrate, Lead ethanoate solution or paper, Lead compounds and apparatus, such as fume chamber and gas cylinder were not available.

Material resources

The **availability of material resources** was viewed to be the teachers' problem in teaching and selection of the most appropriate instructional strategy for teaching QA in the selected schools. For example, Coffie mentioned that:

> *… so looking at the available chemicals, you cannot distribute them to the students such that each of them will get a set-up to themselves and so you are forced to put them into groups because of the limited chemicals that we have but in terms of the apparatus we have some* (a Teacher).

Max's exposition highlights the real challenge that teachers go through in selecting the appropriate instructional strategies, taking into consideration some basic factors:

> *Yes, it has to do with, apart from the chemicals and space, water taps mostly are not running or distilled water or getting water to perform practical work has been a problem. There is no safety equipment, no fume chamber and we sometimes work under stressful conditions. I do teach using what is available. Yes, sometimes you have to endure to teach in these deplorable conditions* (a Teacher).

Human resource

The **human resources** such as the teacher, laboratory technicians, and laboratory assistance in terms of in-service training and these were seen as another teacher problem. The teachers' interviews maintained the need for some in-service training to be organised for them, especially for those who are novice. The teacher is the foremost resource needed in the teaching of QA. By his or her training, they have to pedagogically break down the complex nature of QA into small units for students to understand. Any defect in the teacher's training will adversely affect the delivery of the teacher in the classroom. For example, Coffie explained that:

> *That is the problem; they are not enough at all. Can you imagine even the old University where I was trained to become a Chemistry teacher, I was taught qualitative analysis on paper, and the reason was simple. The resources were not enough for us to do the practical work, and so even in the University where attention should be given to practical work, I was taught on paper, so the resources are not sufficient* (a Teacher).

John also contributed as:

> *Teachers everywhere need help in teaching qualitative analysis because the younger teachers themselves were not appropriately taught* (a Teacher).

All Chemistry teachers, especially those involved in this study, have had a minimum of 3 years of preparation from Ghanaian universities. The qualifications of the selected teachers as presented in Table 1.

Table ~~11~~1: Qualification of Teachers

Name	Sex	Grade of school	Status of school	Qualification	Number of years of teaching QA
Mike	Male	Grade A boys school	Single	BEd. Science	17
Ben	Male	Grade A girls school	Single	Master of Science	20
Baba	Male	Grade A boys school	Single	BEd. Science	12
John	Male	Grade B school	Mixed	MPhil. Science Education	26
Anthony	Male	Grade B school	Mixed	BEd. Science	3
Justice	Male	Grade B school	Mixed	MPhil. Science Education	16
Max	Male	Grade B school	Mixed	BEd. Science	6
Sam	Male	Grade C school	Mixed	BEd. Science	6
Lizzy	Female	Grade C school	Mixed	BEd. Science	2
Coffie	Male	Grade C school	Mixed	BEd. Science	5

Source: Field data (Arthur, 2020)

During the interviews, teachers identified some lapses in their university preparation. It is more evident when it comes to teaching practical-related concepts such as QA. John explained:

> *They come in from the university having that deficiency. Their inability to handle practical works very well and they keep carrying it along* (a Teacher).

As identified by the selected teachers, the lapses in teacher preparation have resulted in them not well-equipped to handle the practical aspect (teaching QA) even though there are numerous calls for help. Teachers believe that mentorship and in-service training could help equip teachers to teach QA to their students effectively. John opined on in-service training:

> *Teachers everywhere need help in teaching qualitative analysis because teachers themselves were not appropriately taught… for students to learn effectively, we need help in teaching qualitative analysis* (a Teacher).

Ben shared on mentorship and its effects on teaching as:

> *You know, here, at times, we do team teaching. So, when new teachers come, they are helped. I hope that is mentorship … there are specific topics that we meet and discuss to help everybody* (a Teacher).

Some of the selected schools offer some in-service training for new teachers who join their staff, but it is not clear how detailed and intense these programs are. The in-service support is mostly the peer or colleague experienced teachers who help less experienced ones. Sam mentioned that:

> *Yes, the new chemistry teacher needs orientation and needs to understudy the more experienced teacher because certain things are not taught at the university but need to know it to function well* (a Teacher).

Mike also shared that:

> *All of us need help. In my department, if I do not understand anything, I ask a colleague. Sometimes I practice a lot. We share ideas, especially when the students get to the third year; we collaborate a lot and share ideas to prepare them* (a Teacher).

The less experienced teachers expressed some form of worry about how they could finish the content, thereby making all efforts to teach everything. On the other hand, experienced teachers expressed QA's absolute easy nature when one is steeped in its content and skills. Anthony, with three years of teaching experience, expressed that:

> *If you are a new teacher, QA will be one of the challenging aspects for you to teach as you have to cover all the aspects of it before students write their exams* (a Teacher).

On the other hand, John, with 26 years of experience, shared that:

> *The teaching of QA is elementary as it only involves concepts and principles. Part of it is also with the teacher because we assume that students should observe, but if the student does not know how to observe, they report it as they want it. This way you need to understand the concept and also have experience in it* (a Teacher).

Novice teachers usually have problems grasping the concept of QA from the curriculum, and their teaching experiences make the problem more compounded. Justice shared that;

> *The syllabus will be challenging for a novice teacher because he has to learn bit by bit. The QA concept is scattered in the syllabus, and you have to lay your hands on one of the system's textbooks. However, as you get teaching experience, you realize that it becomes less and less complicated* (a Teacher).

Justice added that:

> *It will be difficult for a novice teacher from the curriculum because he has to learn bit by bit. The topic QA is scattered in the syllabus, and you*

have to read the good textbooks in the system. But as you get the teaching experience, you realize that it becomes less and less complicated (Justice, a Teacher).

The wisdom of providing laboratory technicians and assistance to schools is still valid and, more importantly, ever needed now. It is because of the increment in enrolment in schools across the country due to the free SHS policy. However, Mike lamented that:

We do not have more than one laboratory assistant, and surprisingly, he is the only one for the three labs. He runs through all three laboratories to support us (a Teacher).

I observed a dwindling number of laboratory technicians and assistants, some reported not having a replacement after the retirements of those in the system, and there have not been recruits of essential personnel in the school environment. Teachers from schools that have personnel also complained of more work on them since the number of students keeps increasing, so the work still becomes the teacher's duty to step in and do the laboratory work and the classroom work. Comments from the interviews highlighted those who have laboratory technicians or assistance and their experiences with no laboratory technician or assistance. Baba and Ben provide deeper insights into what is happes in a grade A school:

We have one laboratory technician who is serving the whole school … so it makes his work difficult to combine the demands of all those teachers who want to do practical work (Baba, a Teacher).

We have a laboratory technician. This place used to be a science resource centre so we have a laboratory technician although it is not

> *enough to assist in teaching QA and other practical concepts* (Ben, a Teacher).

The need for more laboratory technicians and assistants cannot be over-emphasized. Though some schools have none of that personnel, others have only one.

> *We have people in the laboratories but they are not trained, laboratory technicians. We work aside the classroom period to prepare the reagents because nobody will help you* (Mike, a Teacher).

The schools with laboratory technicians and assistants have them due to their status as science resource centers. The number of laboratory technicians and assistants in the selected schools are presented in Table 2.

Table 222: Number of Laboratory Technicians and Assistants

Grade of school	Status of school	No. of lab technician	No. of lab assistanc
Grade A boys school	Single	1	0
Grade A girls school	Single	1	1
Grade A boys school	Single	1	1
Grade B school	Mixed	1	0
Grade B school	Mixed	1	0
Grade B school	Mixed	0	0
Grade B school	Mixed	0	0
Grade C school	Mixed	0	0
Grade C school	Mixed	0	0
Grade C school	Mixed	0	0

Source: Field data (Arthur, 2020)

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My attention was drawn to the fact that a laboratory technician is different from laboratory assistance as remarked by Mike and Justice in these expressions:

> *... it is only when I finish the practical works that I call him to clean the laboratory. Sometimes, you want him to go round and check the set-ups, but he is a non-chemistry person therefore, he does not know whether the set-up is right or wrong. So we handle the laboratory ourselves* (Mike, a Teacher).
>
> *We have a laboratory assistant and not a technician. From my understanding of the technician, he should know laboratory work, someone that I can task him to set up for solubility class, and he can do so. We have people who assist us in the washing of apparatus and others. So if these are not there, it becomes a difficult task; therefore, sometimes you end up not doing it* (Justice, a Teacher).

Those who have neither laboratory technician nor assistance expressed how they managed to teach QA to the best of the professionalism. For instance:

> *We do not have. We use to have but since he went on retirement, no one has been employed. So it is up to the teacher to do all these things as qualitative analysis is unavoidable in secondary school* (Max, a Teacher).
>
> *The school does not have a laboratory assistant and we do not also have a laboratory technician. The technician can handle the chemistry but the assistant only supports in cleaning. However, the two are essential to help teach practical very well* (Mike, a Teacher).

However, a teacher who seemed not worried about this lack of laboratory assistance or technician was Lizzy. With a small class size, the chemistry teacher is effective in teaching QA. Lizzy expressed that:

> *We do not have any laboratory technician at the moment, since our science class size is small, it makes operations in the laboratory easy for me* (a Teacher).

The selected teachers mentioned that it would suffice if laboratory assistance could be recruited and trained to man these all-important facilities to teach practical chemistry concepts. It will go a long way to help teachers to have more interest and control in teaching practical works. For example, John asserted that:

> *Yes. We do have one. The teacher alone cannot do all the work judging by their number and classwork load* (a Teacher).

In the same vein, Ben posit that:

> *Yes we have a laboratory technician. This place used to be a science resource center so we have a lab technician, although it is not enough* (a Teacher)

It is the responsibility of the Government to provide laboratory technicians and assistance to schools. However, Government has failed to do so hence there is the need for other stakeholders to support the teaching and to learn through supporting infrastructure and other areas that the school may need. The selected teachers identified some major stakeholders besides the government such as Parent Teachers Association (PTA) and Alumni (past students from the various schools). However, other schools do not enjoy these benefactors' privileges either due to the grade of the school or the tradition that exists. The contributions of alumni have been phenomenal especially when it comes to helping with science infrastructure in schools especially the grade A schools and the least supported are the grade C schools.

Time resources

Time resources look at the extended time needed, period allocation and time management that teachers need to teach QA comprehensively as another teacher problem. Teachers expressed how they were managing their time coupled with the scarcity of the material resources to meet the demands of the curriculum. Notable innovations among the various means employed by teachers to meet their set target in completing the chemistry curriculum include organizing weekend classes where they can have more time to teach, dividing the class so that each student could have a feel of hands-on practical, teaching practical lessons at a later time such as evening classes or using the prep time, and sacrificing their leisure time to engage students on practical work. Lack of time affects the effective teaching of QA. For example:

> *Time has never been sufficient in anything, especially teaching qualitative analysis where much time is required* (Justice, a Teacher).
>
> *Looking at the time, it is not sufficient to teach qualitative analysis using the regular periods* (Ben, a Teacher).
>
> *Extra time is needed in doing practical work with students to help them understand qualitative analysis* (Lizzy, a Teacher).

Teachers who intend to support their students to learn QA needed to schedule extra teaching hours. For example;

> *Sometimes I use Saturdays to teach practical work because I get enough time to prepare the laboratory and also the students have enough time to practice on Saturdays. If you want to help the students (in practical*

works), you need to engage them outside the class hours (Justice, a Teacher).

Sometimes we use our leisure time, at other times we use Saturdays, so the time is not enough and teaching qualitative analysis to their understanding needs time (Ben, a Teacher).

Most at times, I use one extra hour after school, because the periods for teaching is not enough (Lizzy, a Teacher):

The extra time needed for teaching practical works (qualitative analysis) is evident in the selected schools. It is because my observations confirmed teachers were arranging to have extra teaching hours with students on learning chemistry. For instance, I had to observe one lesson from Justice's class on 13th June, 2020, Saturday, from 9:30 am to 12:15 pm and a makeshift practical class after school from Mike's class on 13th June, 2020 from 7:00 pm to 9:00 pm. The extra time needed by teachers in teaching QA and practical lessons is attributed, in part, to the new reform in the educational system where the number of periods for every elective has been set to 4 hours per week. For example:

You see, per the WAEC timetable, we have 4 hours of the meeting (for teaching) and you have one-hour practical work so definitely the time is not adequate at all (Anthony, a Teacher).

Chemistry has four periods in a week and it is the teacher who has to decide as to how to use these periods (Max, a Teacher).

The call for and the use of extra time is as a result of no specific period allotted to teaching practical work from the timetable and that teachers cannot engage students for effective learning of QA during the theory lessons. Excerpts from teachers suggest deep-seated reasons such as giving more priority periods to theory, practical period not specified on the school timetable, and teachers deciding as and when to teach practical works. For instance:

> *You need to teach most of the theory topics before the practical work can be done effectively, so from the beginning, you use the whole period for theory until you have treated enough topics. Sometimes, I use all the four hours to teach theory and sometimes I use the four hours for practical so there is a balance in teaching the theory and practical* (Mike, a Teacher).

> *You know that practical takes a long time but we only have four periods so it becomes difficult. If there can be a situation where the timetable can be structured in a way that practical period can be added to the timetable so that teachers can see it and teach when it is time, it will help a lot* (Baba, a Teacher).

> *The teacher has to find time on the timetable to do practical work ... I do not have anyone particular period for practical works, out of the four allotted periods I can choose anyone to do practical work* (Justice, a Teacher).

The absence of scheduled time for teaching chemistry practical-related concepts influences when teachers provide opportunities for students to relate theory to reality in practical work. Sam mentioned that:

> *… it depends. It can be zero, and it depends on the exigency, especially when they are in the final year you can help but to organise practical lessons for students ... this will help them link the theory …* (a Teacher).

Coffie expressed that:

> *It is good to organise intensive practical lessons in the final … the students are well-positioned and need extra time to be ready for the final exams and can transfer knowledge very well*.

The last dimension under time resource that came up was space-time duality dimension. The inquiry specifically looked at how the teacher talked about the space available in the laboratory and the time to cover what teachers are supposed to. Some of the selected schools have time scheduled within the day to organise practical lessons for students, but the laboratory spaces cannot contain all the students at that material time. It usually calls for the need to divide the class into groups of students, creating a huge time constraint on the part of teachers. With little or no expansion in the schools reflecting in laboratory space to accommodate the triple or quadruple number of students, teaching QA and other practical chemistry concepts to students' understanding has been affected. The problem has compelled some teachers to employ other means of teaching practical work, which does not help with the intended aim of developing the process skills of students. Some comments made by Mike, Justice, and Ben respectively are as:

> *There are times we do the hands-on activities, but the class size (to hold the number of students in the laboratory) is always the hindrance. We have about 58 to 60 students per class and with our laboratory capacity, one-on-one laboratory set-up is for 25 students* (Mike, a Teacher).
>
> *As for the laboratory, you can see (pointing to the space available); it can take a maximum of 20 students at a time … if you want to do individual work, it is too small for the population of the school.*

Notwithstanding having some materials available in the school (Justice, a Teacher).

We have the equipment but the laboratory is too small to accommodate a large number of students. This laboratory can take a maximum of 30 students but we have about 60 students in a class and this affects my teaching approach (Ben, a Teacher).

My observations indicate that even the well-endowed schools have a serious issue with laboratory space as a result of an increase in enrollment. This was observed in almost all the schools except Lizzy's class which is one that had the smallest number of SHS3 students reading science and come next year that space will be occupied by the next class which has twice the current number of 20 students (Observation made on 11th June 2020).

School-type resource

Another teacher problem that confronted was the role of the **school-type** and the perceived resources available. The apportioning of schools into grades was based on the type and kind of infrastructure a school had. It is assumed that all grade A schools were well-endowed in resources; grades B and C schools were endowed and less-endowed respectively. In all, grade A schools visited had well-demarcated laboratories for Biology, Chemistry, and Physics, with some having two laboratories (one for the junior class and another for senior class) as observed in Mike's school. Again, in a grade A school, there were a lot of fresh stocked and shelved chemicals and apparatus. Other materials such as sinks, benches, running tap water, functioning fume chamber, and storage room were well in place. Grade B and C schools had the same separate laboratories for Biology, Chemistry, and Physics but with old and dilapidated laboratories, broken benches, taps, sinks, and fume chambers. An exception to this was Lizzy's school, one of the newly furbished schools under the government programme of retooling schools to have a well-resourced and functional laboratory (Observation from field notes from the grade of schools from 18th June to 29th July 2020).

However, the interviews and observations depicted a completely different scenario when it came to well-resourced schools and those that ware less-resourced and their sources of resources. Although the Government of the Republic of Ghana provided the needed resources, other benefactors contributing immensely to laboratory resources are Parents Teacher Association (PTA) and the Old Student groups (alumni) from the various schools. For example, one politician built a whole new and well-stocked laboratory for his alma mater in a grade A school. Another school was Lizzy's school which had a link with Ghana National Petroleum Cooperation (GNPC) adopting her school and so provided a new science block. Schools classified into grades based on the resources and schools' performance was a criterion not followed strictly as I observed several schools with grade A status but with insufficient resources and those of grade C with moderate resources. However, other intervening variables such as the support of alumni to their alma mater made a lot of distinctions between grade A schools, grade B schools, and grade C schools. Excerpts from the interviews and observations further explain this:

> *The laboratory is well resourced. The old girls always do well, and they refurbish it. So, we are well resourced. The only thing is because of the number; we cannot do what we want to do. All the same, we manage.*

We do not have any problem with equipment and reagent (Ben, a Teacher from a Grade A school).

We have enough chemicals and apparatus but going forward; we should be looking for more of the chemicals we consume. We have old boys, who from time to time, bring us some apparatus, with the chemicals; some time ago the PTA bought enough chemicals for us (Mike, a teacher from a Grade A school).

Teachers from Grades B and C schools had slightly different views to share on the material availability. That is, material resources were not adequate for large class size:

As for the laboratory resources, you can see for yourself. It can take a maximum of 20 students ... we have some of the materials that we do use, but of course, it is not enough (Justice, a Teacher from Grade B school).

I think we have some of the essential equipment but the chemicals are the problem, sometimes we do not have enough chemicals and we have to see the appropriate authority in the school for purchases. For the basic equipment, I will not say that we have all. We have most of the essential or basic ones. So, on a scale of 1 to 10, I will rate it at 7 (Coffie, a Teacher from a Grade C school).

The results have shown that resources have a way of influencing how teachers teach QA. Its broad nature encompasses material resources, human resources, time resources, and school-type resources. A teacher's ability to impart productive knowledge on QA to students can be traced down to whether there are enough resources to the schools (Oladeji et al., 2019). It is because resource availability serves as a tool for enhancing how teachers teach QA (O'Meara et al., 2017) to their students to improve academic performance in chemistry (Kihumbas, 2009). As testified by most chemistry teachers, the inadequate resources could be due to no allocation of funds to it. If teachers are not provided with the needed resources, they may not be better positioned to use the most appropriate instructional strategies to teach QA to students effectively. The resources that are sparingly available in the schools include material resources. The materials resources such as reagents, apparatus, running water taps, and fume chambers needed to teach QA are absent in the schools and where available, they are outdated or not sufficient as compared to the class size in most of the schools. This means that there is the need to supply the schools with sufficient material resources. A need to achieving effective teaching and learning of QA in high schools. However, chemistry teachers should as much as they could avoid hiding behind the availability or insufficiency of resources to teaching of QA to students without practical-based approaches (Surapuramath, 2013).

In schools, when students cause damage to any facility or equipment, you cannot bill them as per the culture of the school and the government's directive of not billing students for any damage caused. Through the administrators of the schools, the government should allocate funds to support the implementation of the chemistry curriculum (Mwangi & Mwangi, 2016) to the benefit of students. This is because if breakages are not replaced on time, it leaves the laboratories gradually in a dysfunctional state. The quality of facility and equipment also contributes to how often damage happens in the chemistry laboratory. The government and other non-governmental organisations interested in chemistry education at the high school level should support the schools with the needed material resources to enhance practical activities (Chala, 2019; Pareek, 2019). Human resources are available to the schools when it comes to the teachers with the requisite qualification.

In Ghana, teaching science-related subjects in high schools requires either BEd. Science and BSc. Science backgrounds. These qualifications the teachers involved in the study have and hence, can be in the position to give out their best professionally. Curriculum are reformed and reviewed after some years of implementation but the teachers hardly receive any professional development to help them upgrade and update their pedagogy and content knowledge to meet the demands of reforms and revisions. Though experienced teachers do support the novice teachers, there is the need to take in-service teachers through formal professional development programmes to attain the expertise (Helliar & Harrison, 2010) for teaching QA to students' scientific understanding. Additionally, the assistance and support needed from laboratory technicians and assistants are not available in the science. This is because most of the schools have only one or no laboratory technician or assistant to support the teachers to effectively teach QA to students. Even where there are laboratory assistances and technicians there is the need to give further professional development to bring them to level (Abungu et al., 2014) of modern laboratory and curriculum demands

School-type is an issue in relation to resource availability in the schools. The grade of school is a factor that affect the resource availability in the schools. Even though some schools have enough chemicals, apparatus and other equipment, the number of students in the science class outweighs the number of set-ups for practical works that can be held at a time. As intriguing as it may be, few teachers emphasized that the adequate material resources that they can boast of are as a result of the support from stakeholders such as PTA, alumni, Government and administration as seen in their views. There is strong support from stakeholders in line with grade A, B or C schools. That is, the contribution of stakeholders towards grade B and C schools is not much as compared to the immense support the grade A schools get.

There are other teachers' problem which are not unavailability of chemicals and apparatus but no running tap and distilled water in the laboratory, no fume chamber, no gloves, and no laboratory coat. This implies that the teachers' and students' safety is at risk during practical lessons on QA. Also, using borehole water in place of ionized water for practical works might not give accurate results during practical works and hence the quality of knowledge required by students is not guaranteed under such conditions. The toxicity of some of the chemicals in the chemistry laboratory such as releasing fumes when preparing them for practical works without a fume chamber puts the health of the chemistry teacher and students, laboratory technician and assistant in danger as they inhale these fumes. With no equipment and reagents and reagent bottles present in the laboratories the likelihood of contaminating reagents and chemicals used during practical lessons on QA is high. The few spaces in the laboratory called for more workload on the teacher and their technicians and assistants.

The syllabus a teacher has to cover is time-bound, as students have a duration of three years in school. In an attempt for the teacher to deliver effectively, time factor in terms of time management, period allocation and extended period cannot be overlooked. Though teachers claim they only have four periods allocation for teaching chemistry each week and this is inadequate for theory and practical. This claim is contrary to the recommendations made by the planners of the chemistry curriculum. That is, every chemistry teacher has six periods to teach both the theory and practical aspects of the curriculum, including QA.

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The period allocation for theory lessons is four periods of 160 minutes and practical lessons is two periods of 80 minutes (MoE, 2010). This implies that the schools are not implementing the required period allocation for teaching chemistry to students. Therefore, teachers are doing great in using extra working hours to catch up on the practical works needed to enhance the teaching and learning of QA. Teachers should be motivated to go extra mile to achieve the chemistry syllabus's aims for high schools. Moreover, any revision and reforms should take a second look at the time allotted for teaching practical-related subjects like chemistry.

Research Question Two: How do teachers use their pedagogy and subject matter knowledge of QA and in what context do they teach QA to senior high school students?

Theory of Pedagogy, Content, and Context of Teaching QA

The first thing to consider when teaching QA is for teachers to take a critical look at their content, and context. In this rule, teachers teaching QA are mandated to stop and assess their content knowledge, and the context in which they teach. Therefore, this presentation will highlight both the emerging issues from the research question and the distinctive issues that each question addressed respectively. The emerged issues were the content and concept of

QA, and time allocation. The Chemistry curriculum has two main parts which focus on the nature and structure of the syllabus and the difficulties encountered using the curriculum.

Content and nature of concepts of QA

The content and concept difficulty shared amongst most teachers indicated that the content QA, and the concepts which are knowledge of QA are not difficult for teachers to teach nor too high for students to grasp. Those who shared that the concepts and content are neither too difficult nor too much, expressed themselves as:

> *For me, QA is not all that difficult to teach … It is quite broad and you have to get into the syllabus to pick out what is required* (Sam, a Teacher).
>
> *… it is not that difficult to teacher qualitative analysis but you will need to go through the syllabus very well* (Lizzy, a Teacher).

Teachers explained that, teaching QA to students only become difficult when students do not have knowledge of the basics of QA. Excerpts to support this assertion are:

> *… Only if the students know the basics. Year after year I look to equipping my students with knowledge in the basics* (Baba, a Teacher).
>
> *I first try to teach students the fundamentals of qualitative analysis and makes teaching it less difficult …* (Sam, a Teacher).

Teachers that shared the difficulties of the concept associated it with other factors and not so much about concepts found in the curriculum.

For example, Lizzy mentioned that:

> *Experienced teachers perceive the content of QA not to be difficult while less experienced teachers looked at it differently* (a Teacher).

Justice, an experienced teacher, expressed that;

> *They are not too difficult to teach; most of these become difficult when the teacher does not approach it well* (a Teacher).

Since the approach to teaching QA is not clearly spelt out, it is more prudent to complete the theoretical aspects, which is the basics before the introduction of the practical-based lessons. This minimizes the difficulty with which QA is taught to students. Excerpts to support this assertion are;

> *If you learn the theory aspects, you need to practice those aspects of the practical work in the theory before getting to the qualitative analysis, so that when you get there, it makes the teaching of qualitative analysis easier but some teachers treat qualitative analysis as one topic* (Ben, a Teacher).

> *Just using the syllabus to teach qualitative analysis straight away is not the best, there should be a pre-lesson before teaching qualitative analysis* (Mike, a Teacher).

Lizzy, a less experienced teacher, shared that;

> *They are not difficult unless the teacher did not explain them or demonstrate well to them how these concepts are formed. Since they have done some solubility, it will help them to understand QA* (a Teacher).

The question of the clarity of QA in the curriculum came up as a strong view point. The content to be taught in the curriculum is clear; but not detailed in its present state. For example;

> *It is clear but as to how you have to teach it. It will tell you what the students should learn at the end of the lesson. How you will make sure those objectives in the syllabus are achieved is up to you the teacher* (Sam, a Teacher).
>
> *The syllabus is not detailed enough for a novice teacher and also not clear how to present and record your test, observation and inferences are not in it. It should be clear so that any teacher can pick the syllabus and know what to teach* (Baba, a Teacher).

Other curriculum materials should be read by teachers to appreciate the clarity of the content of QA in order to effectively teach it to students. Sam further explained that;

> *... it is clear as to what students should know. I also think it is best to use the WAEC recommended syllabus in addition to the GES syllabus* (a Teacher).

Notwithstanding teachers claim that QA is not difficult, there are aspects which are difficult for students to learn. The teachers posited that:

> *...One thing about the qualitative analysis is that we need to know the difficult aspects such as the testing of the anions, making students understand precipitation reactions, acids and bases reactions* (Mike, a Teacher).

> ... *The concept of precipitate should be taught under acids, bases and salt and solubility; if not, it becomes one of the difficult topics* (Justice, a Teacher)

The difficulties of students in learning QA are associated with formation of complexions, distinguishing between gelatinous and chalky precipitate, and addition of acids. For example, Anthony pointed out that;

> *The formation of complex compounds is highly difficult for students to understand. Sometimes you teach it over and over and you realize that most of them have not gotten it so you leave it and move on* (a Teacher).
>
> *In terms of a precipitate, my students do not have a problem with understanding what a precipitate is or detecting a precipitate, but for the complex salts and addition of acids, it is a problem for them* (Coffie, a Teacher).

Baba explained that;

> *Formation of complexes is also another difficult concept for students to understand ... because the students do not have enough background knowledge as to why some precipitates are formed and why some dissolve and others do not* (a teacher).

Language is a major tool that students are lacking, causing the difficulties students have on differentiating between gelatinous and chalky precipitate. Sam mentioned that;

> *Sometimes distinguishing between gelatinous and chalky precipitate is difficult. The language used in teaching can also make it difficult for the students to understand* (a Teacher).

> *I see it as a language problem. The ability to differentiate between the chalky and the gelatinous precipitate, although you tell them they mess it up at times by shaking the test tube as they add the chemicals in drops* (John, a Teacher).

Though some concepts are difficult to students but teaching experience is the solution to teaching those concepts to them. This is because with sufficient teaching experience teachers will be able to adopt the most appropriate instructional strategies to support students learn QA. For example, Baba mentioned that;

> *I do not have any difficulty in explaining these concepts to my students the topics they see difficult … just because I have taught it for a very long time and can select the best approach to help my students learn in the laboratory and be practicing* (a Teacher).

Content and context of the syllabus (Chemistry curriculum)

The nature of the curriculum as identified poses a problem to teaching and learning of QA. The exploration of the concept of QA in the curriculum used in teaching revealed seemingly no united front on the use of the curriculum as a guide. From my observation and analysis done on the curriculum, it was a fact that QA was not specified under any particular topic or as a substantive topic to be taught at any stage. The chemistry curriculum had bits and pieces of the concept on QA spread in it. For instance, precipitation is taught under Periodic Chemistry and continued from Solubility. It is also a fact that the curriculum did not contain a separate section on any practical but all build within the theory and teachers have to decipher. As noted earlier, the curriculum does not give a context to teaching QA. Excerpts to demystify this assertion of the selected teachers are:

> *No, it just tells you, these are the ions, you have to detect, so I can say that the syllabus does not give direction as to how to teach these concepts* (John, a Teacher).
>
> *The syllabus only listed some process skills that the students will develop as they (students) go through the topic in the syllabus but does not give direction as to how they should be taught* (Justice, a Teacher).
>
> *The syllabus gives just the general guidelines but not specific* (Mike, a Teacher).

Since there are no clear-cut instructional strategies in the curriculum for teaching QA to students, teachers have to rely on their ingenuity and resourcefulness to teach. Excerpts to support this assertion are:

> *So it comes back to the ingenuity of the teacher. The teacher owns the ability to make alive the subject matter. The teacher needs to try to do so many things and see the one that will be okay for the students* (Justice, a Teacher).
>
> *You need to be resourceful to deduce the specifics out of it and teacher it in the most appropriate ways* (Mike, a Teacher).
>
> *… you have to go the extra mile as a teacher to teach QA. The approach is limited, but it gives some suggestions as in letting the students do this experiment and let them add this reagent to the other, that is not enough and so the procedure there is not any proper structured procedure* (Coffie, a Teacher).

The concept of QA is not treated as a major topic in the curriculum. However, it is treated as sub-concepts under major ones such as acids, bases and salts, and solubility. These sentiments expressed by the teachers are true as I verified from the chemistry syllabus. Coffie mentioned that;

> *There is no major topic in the syllabus on qualitative analysis … it can only be seen under some major topic. If am teaching acids and bases, I know I have to do experiment (that is, practical) on it. The ions to be detected will be listed* (Coffie, a Teacher).

To appreciate the context of teaching QA effectively to students, the teacher has to consult other curriculum materials with elaborate procedures and approaches to teaching the concept:

> *… you the teacher will have to consult some other materials or textbooks to get some of these procedures for teaching his students* (Coffie, a Teacher).

The curriculum material that has been helpful to chemistry teachers is the WAEC syllabus which gives an elaborate procedure. Max explained that;

> *… but the direction is not that clear, and so you the teacher, you have to find some other means of adding up to what is in the syllabus in other to teach your student. The WAEC syllabus has been helpful to us (teachers) so that they can learn and understand the concept. I hope you know WAEC is the exams body* (a Teacher).

Though using the curriculum together with other curriculum materials is crucial, teachers should structure the concept of QA for effective teaching and learning.

For example, Anthony mentioned that;

> *You cannot teach them all together, you need to structure it. You need to teach those distinctions that will give you the colour changes and the ones that will dissolve so it is structured to help students to assimilate* (a Teacher).
>
> *... under various topics that make up qualitative analysis. You have to sort out the various aspects and bring them together, strategize so that you can teach the concept very well to students' understanding* (Lizzy, a Teacher)

In an attempt to structure the content of QA, teachers need to be cautious in grouping sub-contents of QA. If the sub-contents of QA are well-grouped, students easily assimilate. Anthony expressed that;

> *... you need to know how to group them and attend to them so that students will assimilate them easily. If care is not taken you will finish teaching and the students would not get what you taught them* (a Teacher).

Also, there are few authentic textbooks in the system where teachers can make inferences and that depends on the ability of the teacher to gather what is required from the curriculum to make a meaningful presentation. For instance, Lizzy opined this about the curriculum;

> *... the syllabus did not give a full exposition on the content of qualitative analysis. You have to do more research on the topic from good books before you will be able to teach it right* (a Teacher).

My observation of the chemistry curriculum (teaching syllabus) revealed that the context of the curriculum was explicit. That is, the planners of the curriculum recommended that students should be well-prepared prior to practical works and that practical works should begin in the second year of the 3-year programme. From MoE (2010, p. iii);

> *Teachers should ensure that students are adequately prepared before each practical class.*
>
> *Teachers should also ensure that practical classes are started in the second year alongside the theory classes.*

There were suggested activities to guide the teacher's instructional strategies and when to teach QA to students. This is not necessary at the end of the 3-year programme. For instance, in SHS 2 under Unit 1 of Section 2 (Inorganic Chemistry) the planners of the syllabus suggested that;

> *Students should perform simple experiments to compare the thermal stabilities of Na_2CO_3 and Li_2CO_3 or $CuCO_3$;*
>
> *Test for any gas that evolves by passing it through lime water* (MoE, 2010, p. 24).

Also, in SHS 2 under Unit 6 of Section 4 (Acids and bases) the planners suggested that;

> *Perform preliminary and confirmatory tests to qualitatively identify the ions Pb^{2+}, Ca^{2+}, Zn^{2+}, Al^{3+}, Cu^{2+}, Fe^{2+}, Fe^{3+} and (Cl^-, Br^-, I^-, SO_4^{2-}, S^{2-}, CO_3^{2-}) in solution using appropriate reagents (HCl, NaOH, NH_3, $BaCl_2$, $AgNO_3$).*

The content of QA is not difficult to teachers but students' lack of background knowledge and language are contributing factors to their difficulties on QA. However, teachers can use the most appropriate instruction approaches to help students overcome their learning difficulties on QA. The less experienced teachers may not have the needed PCK to transform the content of QA to students as compared to the experienced ones. That is to say that teaching experience (Treagust et al., 2004) is a key to effective teaching of QA to students. Commenting on the role of context, Harris and Hofer (2009) shared that it is important, as it affects the sensitivity of the whole system of teaching, in which the teaching of QA needs to be considered. Teachers see the content relating to QA as less difficult to teach but difficult to students to learn although Treagust et al. (2004) see the content as abstract and difficult. The context of teaching and content areas are clearly spelt out in the curriculum (teaching syllabus) and that, teachers claim of otherwise has no basis. Is either teachers hardly consult the curriculum or do not know how to implement the recommendations and suggestions of the curriculum. The curriculum recommends that teaching QA to students should start in the second year alongside the theory to give students sound knowledge prior to practical works. This confirms the findings of Svehla (1996) where pre-requisite concepts are to be taught to students to facilitate their understanding of QA. The curriculum is also clear in the number of periods for teaching theory and practical works of which QA is inclusive. There are six periods of 40 minutes but not four periods. Teachers together with their respective schools may not be implementing the chemistry curriculum as planned with respect to the required time for effective teaching of chemistry in the senior high school.

Research Question three: How do teachers teach QA to students in senior high schools?

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Theory of How Teachers teach QA

Research Question Three sought to explore how teachers teach QA to students at the SHS level. The main theme here is the instructional strategies teachers employ. It is vital to talk about teachers' approach to teaching and perceived students' difficulties, process skills, and workload in the teaching of QA. Based on the interviews with the teachers on how they teach QA, various approaches used were identified by the teachers. Views of teachers were revealing and that John an experienced teacher and Lizzy a novice teacher capture how most other teachers teach QA. The views of John and Lizzy are reported in this section.

John's approach to teaching QA is as follows:

First of all, you have to tell the students, what you are coming to do. Then you tell them the application of what you are coming to teach in the industry so that you do not lose the attention of the students, the moment you lose the attention of the students at the beginning, that is the end. You have to capture their attention that is, what I am coming to teach is applicable in the industry such as the Ghana Standards Authority, where they analyze the content of drugs; the mining industry where they analyze metals; the water research industry where they analyze the pollution level of water; the environmental studies where they analyze the pollution level of particles in the air.

Then you move on to tell them that qualitative analysis, is in two parts; … preliminary analysis and the confirmatory tests.

The preliminary analysis is also in two parts; ... physical observation of the salt, you show them the colours of copper, the colours of iron and those that are not coloured like lead, aluminum. And the second part you tell them that qualitative analysis is done in solution. You are testing for ions. The substances that you have are solids but it is the ions that we are testing for so there is the need to dissolve it in water so that we can test for it. The volume of water that you will add to the sample must not be too much. Averagely, we will say 10cm^3 of distilled water.

You need to dissolve it in distilled water so that you do not introduce extra ions. If you use tap water and maybe you are finding calcium, the tap water already has calcium ions in it so that we can strengthen our bones. You might be finding the wrong ion ... the solution must not be too dilute, that is why, and it is advisable to use about 10cm^3 of water to get the specified results.

There is a technique in adding the solutions, you must not add it anyhow because you want the best results. You have to take just about 2cm^3 but there is no point using the measuring cylinder to do that. Using our normal test tube of this size, you just fetch a little, if you want to be so sure of what 2cm^3 is, then you can use the measuring cylinder to fetch it inside and get to know what volume exactly to use. ...if you take too much sample, the results may be so confusing, you may not be able to tell exactly the nature of the precipitate that was formed. You have to use just about 2cm^3 and start to add dilute $NaOH_{(aq)}$, which is the chemical for the preliminary analysis.

… $NaOH_{(aq)}$ is added because of solubility rules, the hydroxides of most cations are insoluble. The idea is for us to form precipitates and based on their nature and colour, we will be able to start some deductions. When you add dilute $NaOH_{(aq)}$, you will form a precipitate. When you see a white precipitate, all the ions that are coloured are not there. All the ions that are coloured are Fe^{2+}, Fe^{3+}, Cu^{2+}, straight away, you eliminate them. You have Pb^{2+}, Ca^{2+}, Al^{3+} and Zn^{2+}.

You need to go further by differentiating between them, so then, you introduce adjectives. It is white, fine, what other adjectives will separate them, such as chalky precipitate or gelatinous precipitate. The moment you introduce an adjective, you eliminate two of the ions straight away. When we say white chalky precipitate, then we are going in for Ca^{2+} and Pb^{2+}. That is what teachers have not been able to emphasis.

I normally prefer to add their charges because we have other charges. Both Pb^{2+} and Ca^{2+} cannot be there. You have to write it as Pb^{2+}/Ca^{2+} or you use the word "or" between the two cations. If you rather write Pb^{2+}, Ca^{2+}, you will be marked down because you are saying that both of them are present but both of them can never be present. They will interfere with each other. Since we are saying that it is only one cation that is there, we need to go further and differentiate them again, because we are narrowing it down small, small. Also, we use the fact that some cations are amphoteric, others are not. Pb^{2+} will dissolve in excess dilute $NaOH_{(aq)}$ but Ca^{2+} will not, that is the purpose of adding in drops and excess. After you have gotten your observation for adding in drops and you do the inference for in drops, you do same for in excess too. If *you add in excess, you shake, it is important because it increases the reaction rate by collision, so when you shake and the precipitate dissolves then you are going in for* Pb^{2+} *because you know* Pb^{2+} *is soluble, if it does not dissolve then you go in for* Ca^{2+}*. You have sorted* Ca^{2+} *and* Pb^{2+} *out.*

Then you go to the next cation which is aluminum. Originally, it is white, assuming you added and had white gelatinous precipitate. If you add dilute $NaOH_{(aq)}$ *in drops, you may not be able to tell whether it is chalky or gelatinous. Hold the test tube as if you want to pour the solution out and return. If it is chalky, it will start draining from the side down and if you give it two minutes, it will settle from the top and the top will become clear, that is the nature of chalky precipitate. In exams, you do not have the laxity to do that, but if you want to be double sure. Do one test and leave it, leave the inference for the meantime. The chalky precipitate will settle. For gelatinous precipitate, it sticks to the side of the test tube as if you are dealing with starch. Depending upon the concentration, sometimes, it is very thick.*

The right concentrations of the ions are important. If the ion is too concentrated and you add the excess, it will still not dissolve. That is why preparing the right concentrations is important. With experience, you do not need to prepare the right concentrations. Add a little to water, dissolve it. Ideally, under standard conditions, you need to prepare the right concentrations. It varies but it is often around $0.1 mol/dm^3$*.*

Zn^{2+} and Al^{3+} are all amphoteric. Their hydroxides are amphoteric. So you cannot use dilute $NaOH_{(aq)}$ to dissolve them. In drops, both Zn^{2+} and Al^{3+} gives you a white gelatinous precipitate and in excess, both of them dissolves, you will not know the difference. That is where dilute aqueous NH_3 comes in. Dilute aqueous NH_3 does not produce enough hydroxides because it is a weak base. So, the ksp of the hydroxides of the metal will be different for dilute $NaOH_{(aq)}$. When you use aqueous ammonia, you get small hydroxide ions. Aqueous ammonia and water also produce hydroxide ions because it becomes ammonium hydroxide. The $Zn(OH)_2$ will dissolve in excess but aluminium hydroxide will not dissolve in excess. The ksp will not be exceeded for $Al(OH)_3$. What differentiates the white or colourless in solution but in solids they are white, in solution they are colourless. For the ones that have colour, they are so clear. Some solids have confusing information, at times you see blue, and you might think it is Copper (II). There is a technique that is used depending on whether it is crystalline or not but Copper (II) Carbonate is powdered, it is light blue, the Copper (II) Sulphate is a little crystalline, Iron (II) is also crystalline and it is pale, with you can sort them out before you start giving their inference. For the irons, the ones which are coloured, when you add dilute $NaOH_{(aq)}$ the colours become so clear if it is copper it is deep blue and no other solution hydroxide is coloured so that the moment you get it, you know you are targeting Cu^{2+}, if you get green gelatinous precipitate you know you are targeting Fe^{2+}, reddish-brown precipitate, you know you are targeting Fe^{3+}.

To carry the test to the next level, you need to do a confirmatory test to be so sure that the ion that you are seeing is probably present, that is why from the beginning in the preliminary test we do not say confirmed, we simply say present or may be present but when we carry out the confirmatory test, we are specifically targeting a particular ion based on its behaviour. Each of them specifically has a confirmatory test reagent. For instance, if you add an acidified solution of sodium oxalate, then you are targeting Calcium, when the question says use Ammonium sulphate solution, then you know that you are targeting Calcium, so if you add a few drops of that to the test solution you will have a white precipitate. So, we say Calcium is confirmed because no other ion behaves that way. Previously, you started suspecting Calcium. This test you just did is confirming that it is Calcium that is present. You cannot say at the beginning of a test that Calcium is present and then do a confirmatory test for Zinc. It cannot happen that way. During the preliminary analysis, you cannot say that Ca^{2+}, Pb^{2+} may be present, then you do the confirmatory test then you say that Zn^{2+} is present. At times I tell my student they do not have to memorize the confirmatory test reagents except you are writing NOV/DEC or theory exams where you might be asked which of the following ions can be confirmed by so and so. In an exam condition, if you see a confirmatory test reagent you will know because they are not the normal dilute aqueous sodium hydroxide or aqueous ammonia and dilute $HCl_{(aq)}$ that we have, even if you have forgotten you can take the confirmatory test reagent bottle, add a little, whatever you observe, record it and by adding confirmed.

When you do that 99% you are correct. You do not have to memorize a whole lot of the confirmatory test. It is good you know it especially for quizzes and other purposes. In reality, the average student does not have to commit all the QA test into memory. You have to just read through and understand them. In case you see a strange reagent just add it and record your inference. There is a technique for performing test especially during examination period where you are stressed. Again, confirmatory test is done for you to be sure that the ion you have or suspected earlier on is the same ion which is present. That is why we do the confirmatory test. What I have said so far closes the chapter on cation analysis.

For amphoteric oxides, there are some cations you cannot differentiate them using dilute sodium Hydroxide like Zn^{2+} *and* Al^{3+}*. They are hydroxides, they will react with dilute* $NaOH_{(aq)}$ *and dissolve, so you will not know which is which. Luckily for us, the addition of dilute aqueous ammonia produces few ions of the hydroxides, therefore you can use it to differentiate between amphoteric oxides because one will dissolve but the other will not dissolve in it.*

I also use an acronym to know which one dissolves and in excess and which one does not. I call it LAZ CuZ CuFeCa LAFe where they stand for the following respectively, L - Lead ion, A - Aluminium ion, Z - Zinc ion, Copper ion, Iron 2+ ion, Calcium ion, Lead ion, Aluminium ion and Iron 3+ ion.

LAZ are ions which are soluble in excess dilute sodium hydroxide, CuZ refers to ions which are soluble in excess dilute ammonia, CuFeCa *illustrates ions which are insoluble in excess dilute sodium hydroxide and LAFe exemplifies ions which are insoluble in excess dilute ammonia.*

LAZ CuZ CuFeCa LAFe further elucidates the colour and nature of each precipitate formed during the test for cations. It has expatiated as follows: Pb^{2+} white chalky ppt, Al^{3+} white gelatinous ppt, Ca^{2+} white chalky ppt, Cu^{2+} light blue gelatinous ppt, Fe^{2+} green gelatinous ppt, Fe^{3+} rusty brown gelatinous ppt, Zn^{2+} white gelatinous ppt.

The aqueous dilute ammonia is needed to differentiate between the Cations you cannot differentiate using dilute Sodium hydroxide. The reason is that ammonia does not generate enough Sodium hydroxide ions. Also, Aluminum hydroxide and Zinc hydroxide, they have their ksp being different. A precipitate will only form when the ksp of the ionic compound is exceeded. Ammonia is not producing a lot of hydroxide ions, therefore the ksp for Aluminium hydroxide will not be exceeded. The anions are more specific and the dilute sodium hydroxide will give you options; the anions are specific. We have different solutions you can use for them but dilute sodium hydroxide and aqueous ammonia for all the cations. With a little recap, hydroxides of sodium and ammonium ion are soluble. If you add dilute sodium hydroxide and you did not see any precipitate, what then do you do? You can go in for sodium and ammonium possibly present. Add excess dilute sodium hydroxide, then you go and heat. All this idea is for the preparation of ammonia gas. Ammonium ions, when they come into contact with excess hydroxide ions and you heat them, ammonium ions decompose. Based on the smell *and all that you can know that ammonium ion is present but Sodium ion is absent. If no precipitate is formed, just write, no ppt formed, then go in for Sodium and ammonium and then differentiate them by excess dilute sodium hydroxide.*

The anions have been categorized into two. Three anions will always give you a gas during your test, they are CO_3^{2-}, SO_3^{2-} *and* S^{2-}*. In the old system, it will be called Carbonates, Sulphates and Sulphides. They come from weak acids so when you add strong acids their gases are eliminated. That is our preliminary line of test for anions, even if you are not asked, that is the first thing you must do to know which anion is present. You have to add dilute mineral acid. HCl,* H_2SO_4, HNO_3, *and then as you add it, observe the reactions well. The purpose for you adding the acid is, you are suspecting that gas might evolve. The moment you add, you look out for gas and when gas is evolved, you have four levels of identifying them. The way the gas comes out, the colour and smell of the gas and the test of the gas and further chemical test like lime water for testing for Carbon dioxide or acidified potassium dichromate used to test for* H_2S*. When you add the acid, try and smell. The gas may not come out quite a lot so you have to bring it closer to your nose that is where the danger is, especially when a pungent smell comes out. Whenever aqueous ammonia is added, you will get a precipitate.*

When the gas comes out, then you can identify the ion. Example: if you add the acid and you see a colourless, odourless gas evolving, at times it changes wet blue litmus paper to red, at other times it does not change *too much because CO_2 is a weak acid. Some authorities say that it changes to claret that is light red. You can also pass it through lime water but if you do not do it well, you might not see the milky precipitate, especially when you overpass it through the lime water, it will change to colourless. At times, I grind $CaCO_3$ and give it to them so that they will get enough CO_2 as inference. At other times during the test, you might not get enough CO_2 but if you do not write the answer you will lose marks, so I tell them to write the answer once they have observed gas.*

Since the CO_2 comes from Carbonates, you have to write the presence of CO_3^{2-} then you have scored five marks then you move on. For observation correctly alone, you score three marks. Identifying the gas correctly, you score one mark and the ion correctly, you score another one mark.

The other gases have certain smells like H_2S has a rotten egg smell, SO_2 has a pungent irritating smell etc. So, during the test for anions, the smell first followed by the precipitate. In exams, you just have to use the technique and write the answer but you have to look around and see if the other reagents that were supposed to be used are there before writing your inference. In exams, you adopt a strategy using the knowledge that you have gained in class to get your answers. That ends the test for anions.

At times, you will be given the solid in a bottle and instructions, say add $10cm^3$ of water. Students must learn to record the test because it carries marks. It must be recorded as say Sample F + $10cm^3$ of distilled water.

The reason for doing that is to find out whether the solid dissolves in water or not. Under observation in your table, you have to write, solid dissolved or solid partially dissolved.

If you were given a mixture, then you might be asked to filter. When you filter, you will be asked about the colour of the filtrate and the colour of the residue. With the filtration, you can sit by it for ten minutes that is if you do not fold your filter paper well. My advice to students always is that when they get a little filtrate, they should start working on it whilst the rest is filtering, they should not just fold their arms and watch for the filtration to be complete before they continue. This one is just practical knowledge; you have to apply because exams paper will not tell you. After the filtration, you have to give the colour of the filtrate and the colour of the residue. If the filtrate is colourless then you have to suspect the presence of the cations that are not coloured.

At times in exams, students might be asked to heat the sample so you have to teach the students effect of heat on compounds. Some compounds, when heated, they sublime so you have to start suspecting ammonium ion. Some of the compounds, when you heat you will observe a colour change and when you leave them to cool down, another colour shows up. Students have to know all these before they enter into the examination hall. That is all the lesson on the identification of cations and anions.

We also have the GRID method, used for cation and anion analysis. With that one you will be told, the sample contains A, B, C, D etc. in that order, you are not allowed to use dilute sodium hydroxide to try *and test whether the sample contains gelatinous precipitate or not. After the test you can take the sample and add the appropriate reagents, just to be sure that your inference is correct. For instance, if sample A is $CuSO_4$, you can go behind and quietly add the reagent to see if you will get light blue gelatinous precipitate or a different answer so that if you made a mistake, you can quickly go through and correct your mistake. For the GRID method, we use solubility rules. If I mix my solution A and solution B and they all react, is one soluble and the other insoluble. If all my products are soluble, then I will not see anything. That is where the inference, no visible reaction observed started from since in this method you do not know what you are expecting, that is why, the inference, no visible reaction observed was permitted. There might be a reaction but you are not seeing it. For the other method, once you add your reagents, you might observe a precipitate, so there is no reason for you to inference: no visible reaction observed. For the GRID method, you are going to do permutations, so it is advisable to use one as a sample and the other as the test solution. Assuming you were giving $CuSO_4$ as one of your samples, you have to put $CuSO_4$ as the heading as the test solution then you add the other substance to it. Let's assume, one of the substances is dilute $NaOH_{(aq)}$ you add it to aqueous $CuSO_4$. Your resulting solutions will be $Cu(OH)_2$ and Na_2SO_4. Then you use the solubility rule, which is Na_2SO_4 soluble, yes, it is soluble because all Sulphates are insoluble unless they combine with group one metals. $CuSO_4$ is not soluble, against that equation we are going to write blue because the copper sulphate solution is blue. Therefore, you write that* *against all the solutions what you observed such as, was it blue gelatinous precipitate? did it dissolve in excess or not? The table must be filled vertically and your identification must also be vertical and so if you take copper sulphate. Look at all the columns that you have under which column do I have, that information I have against copper sulphate. So, the ones that I have against them is it sample B, C or D. Then sample A is copper sulphate. If you do not write the equations, you will get confused about what to write. At times, some of the equations will give us gas. Given the table, there is no way to identify gas and you do not have the practical knowledge of what would have happened or what took place, that is why we call it the grid method.*

We need to include a flame test for the cations. Some cations, have colour when you put them in a flame. The flame test is also important; they do not ask of it often but they can ask a question on it in the theory aspect or objectives. So that is what qualitative analysis of cations and anions is all about.

Talking of the reverse, if you take, for instance, silver nitrate to test for the halides. You have to acidify it first to get rid of the interfering ions or SO_3^{2-}*,* S^{2-} *but if you add the silver nitrate straight away and there is a white precipitate, it could be for chloride ions, Carbonates and so on. When the question is turned around the student must know that Carbonates, Sulphates and Sulphides are also there* (John, a Teacher with 26 years of teaching experience from Grade B school).

Lizzy, a novice teacher, shared how she teaches QA as follows:

In order for the students to get the concept well whenever I am teaching qualitative analysis, I involve the students since this is a practical topic. I do some demonstrations and then let them practice by themselves as I guide them in groups. I do so because we do not have enough apparatus to get a set-up for each student.

I revise small aspects of some topics that are relevant to QA such as acids, bases and salts, solubility, and periodic chemistry. I also explain the words gelatinous ppt and chalky ppt. This serves as the foundation for the main topic QA; which is about the identification of cations and anions form a compound.

Making them understand that QA can be categorized into two is very important, which are: Inorganic qualitative analysis and organic qualitative analysis.

With the inorganic part cations and anions have to be identified. The cations can be elaborated as: Pb^{2+}, Al^{3+}, Ca^{2+}, Cu^{2+}, Fe^{2+}, Fe^{3+}, Zn^{2+}. *Whereas the anions to be identified include* CO_3^{2-}, S^{2-}, NO_3^-, SO_3^{2-}, Cl^-, Br^-, I^-. *Small exposition on the stages in QA has to be given to students such as:*

***Preliminary test**, test for cations, anions and **confirmatory test**, also **flame test** and effect of heat on substances has to be looked at critically. Normally, a small amount of the sample is dissolved in 2cm*^{3} *of distilled water to check for its solubility.*

The preliminary test is all about the observation of the sample especially their colour.

With a test for cations, the reagents that will be used are dilute sodium hydroxide, dilute ammonia, whilst hydrochloric acid and sulphuric acid and others are used for a confirmatory test. The flame test also involves dipping a platinum wire into a little concentrated HCl and then holding it at the base of the Bunsen burner flame and then observation is made. Effect of heat on substances involves heating some of the dry chemicals such as $CaCO_3$, a carbon dioxide gas will be evolved due to decomposition of the substance to CaO and CO_2. Effect of heat causes substances which are not stable to decompose, liberating a gas as well. Throughout the tuition of QA any test, observation, and inference made should be recorded in a table with three columns such as test, observation and inference which is the actual cation or anion detected. The gases are also smelled by wafting it towards the nose, of which the gas should be 20cm away from the nose.

To detect cations; Pb^{2+}, Al^{3+} and $Zn^{2+}$are soluble in excess dilute sodium hydroxide, Cu^{2+} and Zn^{2+} are soluble in excess dilute ammonia. Ca^{2+}, Cu^{2+}, Fe^{2+} are insoluble in excess dilute sodium hydroxide whilst Pb^{2+}, Al^{3+} and Fe^{3+} are insoluble in excess dilute ammonia.

As you make the students observe, let them note the various colours that depict the presence of each cation and its precipitate; such as Pb^{2+}white chalky ppt, Al^{3+} white gelatinous ppt, Ca^{2+} white chalky ppt, Cu^{2+} light blue gelatinous ppt, Fe^{2+} green gelatinous ppt, Fe^{3+} rusty brown gelatinous ppt, Zn^{2+} white gelatinous ppt.

Teaching QA to students only become difficult as the instructional approach to teaching it is not clearly spelt out in the chemistry syllabus. Excerpts from the interviews are:

> *The subject matter is clear except that we do not seem to have a particular procedure to teach it. This is because the syllabus does not spell out a particular procedure as to how to teach it but you understand what is there except that you need to devise your methods of teaching* (Sam, a Teacher).

Teachers' choices of instructional approach in teaching QA are very important to effective teaching of the concept. Per the nature of the QA, it presupposes that participatory teaching and learning approach (MoE, 2010) is effective for teaching it to students. For some of the teachers, it is because of the scarcity of the equipment and reagents that necessitate the use of demonstration in teaching. Excerpts to justify this assertion are:

> *I do demonstration most of the time for those compounds that are not available for students to have their hands-on practical work* (Anthony, a teacher).

> *I do a demonstration when I have limited equipment and chemicals* (Baba, a teacher).

The demonstration approach is further used in teaching QA when teachers have the feeling that the chemicals involved could pose danger to the students, something which is doubtful as the content of the curriculum is carefully selected. An excerpt is:

> *I use demonstration whenever the chemical to be used are very dangerous to my students* (Baba, a Teacher).

Teachers use the demonstration approach in teaching QA whenever the concept is first being introduced to students. Excerpts are:

> *I use the demonstration method if I am introducing the topic so that students know what is expected of them for the first time* (John, a Teacher).
>
> *I use demonstration especially when the experiment is new and when the students have not done it before. I sometimes demonstrate it before I allow them to do* (Justice, a Teacher).

The true nature of practical work is when the teacher adopts an instructional strategy that is individual-based, allowing for a direct hands-on activity. This enhances students' development of practical skills. Excerpts are:

> *The best is the individual hands-on practical work where students develop the needed skills of manipulating the equipment and reagents* (John, a Teacher).
>
> *Students are always happy when they are involved in one-on-one practical work where they show their results and take pride in them* (Sam, a Teacher).

The individual-based activity approach is an important feature of practical work but is missing in the schools. The reason for this was shared by Mike:

> *There are times, we do the hands-on activities, but the class size is always a hindrance* … (a Teacher).

There is the need to explain that, apart from the individual-based hands-on activities, there are also group-based hands-on activities. From my observations, the capacity of most school's laboratories cannot accommodate all the students at a sitting during practical work. In most of the schools, teachers used group activities which were hands-on. After an observed lesson, Justice explained that:

> ... *I used more group activities because the laboratory cannot contain all the students and we do not even have most of the materials and equipment for individualised learning* (a Teacher).

The group hands-on work during practical works is preferred to individual hands-on work. This is because students are actively involved in group hands-on practical lessons. An excerpt is:

> *This is where I have a problem! When we get to the laboratory, I am very strict. But you will still get several students who would not take part in the practical* (Anthony, a Teacher).

Sometimes not all laboratory activities and the practical lessons offer students opportunity to have hands-on experience. This is because the laboratory may not have been well-structured to offer students that opportunity. An excerpt is:

> *Sometimes, I take them to the laboratory and they practice by themselves but this does not help to improve the situation. It depends on how you the teacher you will organise the practical work* (Coffie, a Teacher).

The most dominantly used instructional strategy by teachers is a cooperative learning approach where the teacher groups students depending on the grade of the school and the materials available for students' use. The main reasons assigned for cooperative lessons though not sound but grants students opportunity to benefit from cooperative learning approaches. The excerpts to justify this assertion are:

> *Yes, I do a lot of group activities because of the lack of chemicals and space for students to work. The scarcity of resources in our laboratories mostly makes us teach it in small groups whenever they come to the laboratory for practical work* (Max, a Teacher).
>
> *Sometimes you need to manage the chemicals, glassware, and apparatus used. So, if you are to go by the individual, it is either the apparatus will not be enough or chemicals so we go by grouping in 2 or 3 so that it will be easier to teach in groups* (Sam, a Teacher).

The cooperative learning approaches are used in practical lessons on QA to provide students opportunities to interact sharing ideas among themselves. The excerpts are:

> *Sometimes they do it in small groups of three or if the class size is large, then they work in groups of five. This offers students opportunity to learn from the class mates though I wish they learn individually* (Anthony, a Teacher).
>
> *Yes, I sometimes use group activities because it helps the students to also help each other* (Coffie, a Teacher).

Using cooperative learning approaches is a way of dealing with the issue of large class size. A notable aspect of teaching practical work was a division of the class due to large class sizes and large groups. The division of class into small groups enhances hands-on activities during QA lessons.

> *When it comes to the students doing the practical work, I divide my class into two. One group will be doing the activities whilst the other group will be observing and after that, they change roles* (Mike, a Teacher).

> *I divide them into groups, one group comes for their practical lesson and I arrange a scheduled class to take the other half of the class through the practical work. The other group I give them the assignment to engage them while I take the first group through the practical work. This gives small numbers in groups to exchange roles* (Sam, a Teacher).

A challenge with the cooperative learning is that some students do not actively participate in the practical work. For instance, Mike shared that:

> *Everybody does the practical works. However, if you put them into groups, only a few students will do the activity, the rest will be hiding and pretending to be working when they see you coming. Due to that, I do not like group work. I prefer individual work but the large class size is forcing me to go through the group work method which does not bring out the best in students* (A Teacher).

The cooperative learning approaches and the large class size need time to achieve maximum interactions and learning. Teachers do their best to manage the situation to the interest of students. An excerpt is:

> *You have to manage so that they can perform the activities within the time in their groups. At least there should be two students to a setup. The next group in the class should be given the assignment to engage them* (Ben, a Teacher).

My observations show that indeed teachers use the cooperative approaches more often than the other approaches. This was as a result of the large class size in the school in relation to the size of the laboratories and materials and equipment available. Students exchanged roles and shared ideas as they performed the practical works on QA. There were instances where students moved from their groups to make inquiry from another group. Teachers seemed relaxed and once a while moved from group to group to monitor activities in the groups. There was no group where an individualised hands-on activity was the approach to teaching QA to students.

There is a strong relationship between concepts taught in QA and time as a resource. Teachers used extra time on Saturday and Sunday to help cover the concept of QA. This was because schools did not have time allocations for practical works and the worst case is having four periods instead of six (MoE, 2010). The use extra time to teacher QA to students is attributed to large class size in the selected schools. Magnusson et al.'s (1999) idea of subject-specific and topic-specific instruction approaches seems to be understood by teachers as most are focusing on the topic-specific. However, per the nature of the practical work, it is always topic-specific as demonstrated by the instructional strategies that most teachers employed in teaching QA such as demonstration, hands-on activities, and cooperative learning. Teachers preference for cooperative approaches is a result of large class size and inadequacy of materials and equipment. However, this approach offers students opportunity to interact among themselves. The only shortfall is that it demands extra working hours and class management from teachers. Though teachers use some instructional approaches participatory teaching and learning approaches are recommended for teaching chemistry concepts including QA (Adu-Gyamfi, Ampiah, & Agyei, 2020; MoE, 2010) and this is contrary to the findings of Treagust et al. (2004) where no particular instructional approaches have been selected for teaching QA. Even in this current study teachers are not aware that participatory learning approaches are recommended by the planners of the curriculum. In the MoE

(2010), the teacher and learner activities suggest the instructional approaches to teachers and that teachers are unable to implement or ignorant of them. The curriculum contains sufficient information to aid effective teaching of QA to students (Kaufmann et al., 2002).

In blending research question two and three, the results have shown how teachers do use their general pedagogy coupled with their subject matter knowledge of QA and context to enhance their teaching. This presupposes that, the teacher possesses the knowledge as a result of his training as a chemistry teacher. Shulman (1986; 1987) developed three main features of Pedagogical Content Knowledge (PCK); a component of content, pedagogy, and context, which are the knowledge the teacher possesses in teaching a topic, the instructional methods of teaching and how students learn the topic. This means that, for teachers to teach QA effectively, they must have a sound understanding of the content, pedagogy, and context. The content areas are acids, bases, and salts; solubility; complex ion formation; and precipitation, amphoteric and addition of acids. Teacher's ability to organise those content areas using the appropriate instructional strategies will help students to maximize learning (Wiesen, 2020) though in a short space of time.

Research Question Four: What other factors, qualitatively, affect teachers teaching of QA in senior high schools?

Theory of Supporting Systems

Research Question Four sought to explore the factors affecting the teaching of QA at the SHS level qualitatively. These factors are the extraneous (that is., factors not chemical or apparatus in nature that are not used directly in teaching practical QA but have a great influence on the outcome) and confounding (that is, factors that will interfere in the smooth running of the practical work if they are present and if not checked). They are referred to as supporting systems and are grouped as follows:

i. Management and financial support and

ii. School culture (dealt with existing traditions and key actors that give another dimension to what makes a school great).

Management and financial support

Financial support through school administration is a major player when it comes to practical works in senior high schools in Ghana. The old system of administration in terms of practical works was for the student to pay a certain amount of money each term as science resource fee. The heads of schools used to make provision for chemical, reagents, and equipment when needed and not for major repairs and maintenance. In the current system, with its inception of free SHS policy, the Government of the Republic of Ghana has absorbed all fees. Some schools cannot run their laboratory because the subvention given to the school is not enough to buy chemicals, reagents, and equipment for science practical works. Such schools, therefore, rely on the PTA and the alumni. Aside the financial-related issues, there are others such as the distance from the various classrooms to the laboratories, the correct placement of periods on the timetable and extra co-curricular activities. For instance, Mike talked about the distance between the laboratory and the classroom:

> *… the distance between the laboratory and the classroom is also disturbing, sometimes they come about 10 minutes late for chemistry practical lesson* (Mike, a Teacher).

School management has to look at timetabling as the arrangement tend to affect laboratory work including teaching of QA. This is because students returning from lessons on some subjects will need a break to refresh for the next subject. An excerpt is:

> *Sometimes, they put Physical Education before Chemistry practical lessons on the timetable and you know sometimes students play a lot before coming to the laboratory and they will be sweating. It takes a lot of time before they settle down for the lesson to begin. So the timetable is not helping* (Max, a Teacher).

My observations in the schools showed that some laboratories were located a distant away from the main classroom blocks and that students had to move from one point after lessons to the chemistry laboratory for any practical lessons. During this walk, there was some time loss and that affected time for practical works. Aside the distance issues, there were indeed some co-curricular activities that affected timetable arrangement.

School management should streamline co-curricular activities for both students and teachersas they interfere with the teaching and learning processes in the schools, including practical lessons on QA. The excerpts are:

> *Extra curricula activities often disrupt the scheme of work and give you a backlog of work to be done. These are factors that affect our time … When it is time for reporting, our students take a longer time to report to school which affect the overall scheme of work ... These things greatly affect our teaching of qualitative analysis* (Justice, a Teacher).

> *We have a lot of extra-curricular activities. The challenge is that if the student is average or below-average, then learning qualitative analysis*

becomes a problem due to these activities … there will be less time to cover a lot of the practical works (John, a Teacher).

There are issues of breakages of laboratory materials and equipment and how to replace them. The Government of the Republic of Ghana has instructed that, there should not be any extra billing of students and this has left the laboratories with full of broken and spoilt materials and equipment. Teachers find this problematic as the chemistry laboratory is full of glass wares and these breakages bring teacher problems in carrying on with their laboratory work. A mention to that effect was made by John:

We have a book that when you break an apparatus, we enter your name so that you buy to replace. Some will buy, some will not buy and now, you cannot even ask them to pay because of Government free SHS policy does not permit that (John, a Teacher).

School management, then, has a responsibility to provide the needed budget to support laboratory work including the teaching and learning of QA. However, some of the selected schools had no problem with getting their budget. For instance,

It's a matter of budgeting. We budget and send to the administration if they cannot afford, they tell us and we manage but they will not. That is the problem we have in practical lessons (Mike, a Teacher).

… the school administration is supporting the practical work. Any time we make a requisition and they give it to us. The only challenge here is it may take a long time and that affect practical lessons (Ben, a Teacher).

School management usually come to the aid of practical lessons when final examinations are drawing near and that schools needed to make ready. Teachers take advantage and stock their laboratories and the reason why schools teach QA to students in their third year of the 3-year SHS education. Excerpts to justify this assertion are:

> *When it is time for mock or final examinations, the administration provides that support. As you know, the subject teacher sends the items that they need to the administration and they will supply them. When WAEC instructions for WASSCE comes too, they provide. So after these two periods and you have leftovers, you keep them well for the usage of the other year groups* (Anthony, a Teacher).
>
> *When we send our budget to the administration, they give us the money to do our practical works. In the advent of free education, their hands are tight and can only support when WASSCE is approaching* (Sam, a Teacher).

During the period of the final examinations (that is, WASSCE), schools procure laboratory materials and equipment in excess of demand. The surplus is used in assisting other year groups. Excerpts are:

> *What I have done for the past 5 years during WASSCE when I am to buy chemicals is: I try to buy it in excess because in the middle of the year if you do not have litmus papers it is difficult asking money for it. It is difficult getting money for practical work also* (Justice, a Teacher).
>
> *We know that there is a financial constraint but when we write to them for help in terms of requisition for reagents and others, they do their*

best and get them for us and even in excess. They are helping (Coffie, a Teacher).

School management sometimes delayed in procuring materials and equipment to satisfy procurement requirements. There is the tendency of teachers presenting fictitious requisition and management will have to sort it out. An excerpt is:

Yes, the school administration is making that effort. The problem is all about dishonesty by some teachers who may inflate the prices of some of the apparatus or chemicals which make the administration doubt their budget therefore not getting what they required. Currently, there is procurement issues everywhere (Baba, a Teacher).

School culture

Every school has a culture which determines the disposition of the school. A good school culture affects the school in a positive way which seeks to the growth of the school, through its acquired traditions of doing things. Some of these cultures may be the nature of the school which can be considered a science biased school or technically inclined or grade A, B or C school. Grade A schools practice a system where chemistry teachers are to organise lessons in the evening hours for their students. For example,

*In my school at times, teachers do come to teach in the evening or during prep hours. An arrangement put in place by school administration. We have the regular prep in the evening but a teacher can choose to use the prep time to teach or do practical work and I use these times to teaching qualitative analysis (*Mike, a Teacher from a grade A school).

Yes, we have a culture and affects the teaching of practical works in a way in terms of conducting classes even on Saturdays and Sundays, a situation which is not possible for the day system but in our school it is the practice (Ben, a Teacher from grade A school).

However, the endowed and less-endowed schools have a problem of using the prep or the evening hours to supplement the work done within the day. This is because they have both day and boarding systems with students outside the school compound. Teachers are, therefore unable to teach QA to students as it is the tradition in the well-endowed schools. The excerpts to justify this assertion are:

… our school is mixed type which is a day and boarding. When we have to work on Saturdays, the day students do not come. Not only that, when you want to work on Saturdays you have to confront the house masters who work with students on weekends to allow them to come to the laboratory. So it becomes difficult getting the students to teach them even on Saturdays (Justice, a Teacher from grade B school).

My school admits both boarding and day students, some of the students in my class may be day students so if I want my students to stay for some extra hours after school to take them to the laboratory for us to go through some of the experiment, you remember that the day students have to go home and so it becomes difficult to do that after class hour (Coffie, a Teacher from grade C school).

I observed that the well-endowed schools, unlike the endowed and less-endowed schools, were mostly boarding with all students enclosed. Teachers truly organised extra teaching for their students. This, management was aware and encouraged teachers to use the evening hours to support the regular timetable. Students were observed to be willing and ready to have extra hours in the evening to be engaged in the laboratory for practical works including leaning QA.

Parents Teachers Association (PTA) supports the development of schools in Ghana. The strength of the association depends on its links, tradition and the nature of the grade of school. Some schools have strong PTA while others seem not to be well-organized. Some of the support of PTA have been the provision of materials and equipment for the school, refurbishment of the laboratories, and at times completely building of laboratories for the schools. An excerpt of the interviews is:

> *… some time ago the PTA bought enough chemicals for us. We can say that we have enough, but we still need more because the chemicals are consumable. The apparatus also breaks from time to time … but they always support us to have the best teaching experience* (Mike, a Teacher).

The association, however, seems to have some problems now. Their finances will reduce if not dried up completely. This is because of the new policy directive from the Government of the Republic of Ghana. The excerpts are:

> *… I think the PTA was supportive to the school but cannot now. Because the government is ready to take over the cost of everything and students are not to pay for anything* (Lizzy, a Teacher).

The biggest support when it comes to non-government agents' contribution to schools' development comes from the alumni. This is particularly evident in the provision of laboratory infrastructure, equipment, and chemicals. However, the support hinges on the strength, the tradition and the vibrancy of the group. There is a sense of grade A schools' alumni having a very strong association with their schools than grades B and C schools although they are still contributing to their schools. The grade A schools receive a lot of support in procuring chemicals and equipment for chemistry practical lessons. Ben mentioned that;

> *The old girls are doing so well for the school. They refurbished the laboratories in the school and stocked the laboratories for us, due to that we now have a lot of chemicals and reagents qualitative analysis and other practical works. The old girls are particularly interested in the experiment we do here* (a Teacher from a grade A girls' school).

Baba shared on the support of the alumni of their school that;

> *Oh yes and they are interested in performance in science … here a lot of old boys are doing well. Especially in the infrastructure but for some time now, the chemical is a bit difficult to come by and they have promised on the last visit of their executives* (a Teacher from grade A boys' school).

Not only are the alumni of the grade A schools helping in the laboratory teaching of science, the alumni of the grade C schools do help. However, their capacity to support financially is unlike that of the grade A schools. Coffie mentioned that;

> *They are helping but we still ask for more because we have not gotten to the standard ... They have been helping in terms of the infrastructure of the school, some of the buildings they come and renovate, giving it a new look, fix broken chairs and tables, also, sometimes replacing the broken glassware in our laboratories. Yes, they are helping, we*

> *appreciate their efforts but we still ask for more* (a Teacher from a grade C school).

Notwithstanding the enormous support from alumni in some of the selected schools, others hardly enjoy such privileges from their alumni. Excerpts to justify this assertion are:

> *Some old students are trying to do their best. We hear some of them are helping. They are trying to do their best but nothing has been done concerning the laboratory and the teaching of qualitative analysis* (Sam, a Teacher from grade C school).

> *Some 2 years ago some old students started helping the school but it cannot be compared to first-class schools. Although I have not seen anything yet to development of science laboratory directly, I am hearing that they are helping but not teaching qualitative analysis* (Max, a Teacher in a grade B school).

The provision of laboratory infrastructure and stocking have been the sole responsibility of the Government of the Republic of Ghana through the Ministry of Education. The regularity and checking of stocked laboratories by Government have been the problem. Many schools visited showed a poor state of the laboratory. This was especially the case of the grades B and C schools which have weak PTAs and alumni associations. Excerpts are:

> *No, I have not seen the Government undertaking any new development project about science project to the best of my knowledge* (Lizzy, a Teacher in a grade C school).

> *So far, no for the past 6, 7, or so years. It is the school administration that procure some of the chemicals, reagents, and apparatus for us.*

Practical works in the laboratory usually suffers (Justice, a Teacher from school B).

The role of the supporting systems in teaching QA can be likened to catalysts, which alter the rate of a chemical reaction. That is, the school management and the school culture offer some support to the teaching of QA to students. The role of the school management is pivotal, as it gives direction and manages the school laboratories (Victor, 2017). The management of the schools involved in this study have supported the teaching of QA to students by providing the needed materials and equipment in due season. This is disconfirming the finding that school management hardly support science departments affecting the teaching of QA (Daba & Anbesaw, 2016). School management is now finding it very difficult maintaining the laboratories as a result of Government policies which have resulted in different ways of funding and administering of same. That notwithstanding, school management finds ways of supporting teaching of QA when final examinations (WASSCE) draw near where procurement is made of materials and equipment needed. This, teachers take advantage of to have excess of chemicals and reagents for regular teaching of QA to another year group. Management also provide an environment (Uzezi, et al., 2017; Zhu et al., 2011), especially in the well-endowed schools where teachers can have extra hours for teaching of QA to students in the evening hours aside the regular timetable. However, school management should look at timetabling to ease the pressure of co-curriculum activities and distance between classroom blocks and that of science laboratories. These affect time allotted for practical lessons as students need to use some time to refresh and organise themselves for the practical lessons.

The support of alumni and PTA to teaching QA to students cannot be over-emphasized. Though not all schools have vibrant alumni groups and PTA but they support the schools with materials and equipment for effective teaching of QA. The PTA levy may not be currently paid in the schools due to the policy governing the implementation of free SHS policy but the support they have provided for schools, in relation to laboratories and teaching of QA, are visible. There is strong correlation among the role of administration, resources available, content taught and teachers' timely planning in teaching QA which directly affects -students' performance. The clue lies the fact that there is a financial constraint but "when we write to them for help in terms of requisition for reagents and others, the school management and alumni do their best and get them for schools in the earliest possible time." (Coffie, a Teacher).

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Theorizing

Key: Content-Pedagogical- Context = CPC

Available Resources = AR

Supporting System = SS

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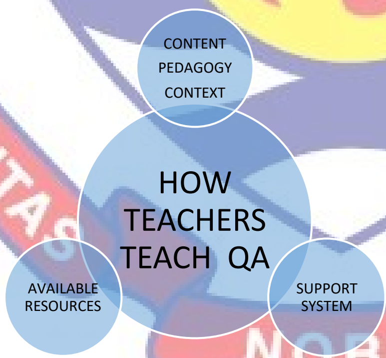

Figure 22~~2~~: A diagram showing the relationship among the three themes.

Source: Author's construct (Arthur, 2020).

The three core themes generated from the research are teachers' understanding of CPC (ACT), teachers accessing resources available (TOOL) and teachers supporting system available (SUPPORT). Each theme in seclusion of the others does not make good teaching of QA. Depending on the school type, one or a combination of the themes can be found. A teacher who is high in the ACT is one who knows the content of QA in terms of concepts, its difficulties and understanding; uses appropriate pedagogy, and uses the context aptly. A teacher who is low in the ACT is a teacher who has a poor understanding of concepts and context, and uses inappropriate pedagogies.

HIGH TOOL refer to a school where the teacher has time, material, and infrastructural resources available to him. A LOW TOOL represents schools where teachers lack the necessary basic resources in teaching QA. HIGH SUPPORT refers to a school where there is support from ~~administration~~ ~~,~~administration, good school culture and available laboratory technicians and assistance. A LOW SUPPORT refers to the lack of support from administration, poor school culture, and absence of laboratory technicians and assistants.

In a school where the teacher is high in the ACT and has HIGH TOOL but LOW SUPPORT, the teacher will be able to teach practical work effectively by developing both cognitive and motor skills of students. The pitfall will be that he/she will not be engaging students in full-scale practical work because of lack of support. The teacher does so well with teaching QA but begins to lose steam when the administration and school culture engages that teacher in extra and co-curricular activities increasing his or her workload. Teachers tend to complain about the lack of motivation and some easily give up because of lack of support. On the part of students, they become happy in practical work and develop a positive attitude towards practical work and their performance becomes high.

In a school where there is a HIGH ACT teacher and HIGH SUPPORT but LOW IN TOOL, the teacher teaches practical work theoretically and focuses more on a few demonstrations. This is because the tools to work with are not available. The teacher develops the cognitive skills of students but less in motor skills. Teachers' potential skills in practical work reduce and gradually they become accustomed to their didactic teaching that even when materials are there, they still prefer to teach didactically. Students lose interest in practical work, thereby not developing their motor skills.

In a school where there are HIGH TOOL and HIGH SUPPORT but the teacher is LOW in the ACT, the teacher will be seen taking students for practical work all the time, but performing low level of application of the concept to practical. This is because the teacher lacks basic CPC to handle and manage classwork. In most cases, it is the laboratory assistance or technicians who support while the teacher will be present with students. This may affect the performance of students in their final examinations. In a school where there is a HIGH ACT teacher and HIGH TOOL and HIGH SUPPORT from the school, the teacher not only teaches well for students to understand but transforms and prepares students with the requisite knowledge and skills for life. Students' performance in their final examinations is encouraging. The effects of these on teachers include teachers not complaining, giving off their best and enjoying what they know how to best. On the part of students, they become well equipped for future carriers.

In an event where pedagogical-content-context and resources are available but supporting staff is absent, we produce students who are good in both cognitive and motor skills. These students become balanced in their studies. This will only be sustained if Government keeps the needed resources replenished because there will not be any means to fall on when the need arises. One effect that they may encounter will be teachers not paying particular attention to individual needs as a result of high-class size because of lack of supporting staff. This means teachers will have to do all the work by themselves. Teachers become burnt-out and may not give off their best.

In a situation where there are resources available and supporting staff are there but teachers lack the needed CPC, the school will produce abysmal performance. This may not be a scenario in most schools. However, it can be seen from a novice or teachers who may not have had a grasp on their teaching of QA. On the part of the students, they become happy doing laboratory work which will result in a waste of time and material resources because teachers may shed their responsibility to laboratory technicians who may not be trained to teach using the appropriate pedagogy. On the part of teachers, some become practical teachers and others theory teachers.

How the teacher teaches QA is by way of teachers getting grounded in sound pedagogical skills, firmly rooted in their content and the context. There is also the need for a constant supply of resources and the full support of ancillary members for teachers to teach QA effectively to students in senior high schools.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter of the thesies presents the summary of the research processes, the significant key findings from the study, recommendations made based on the findings of the study and the study's conclusion.

Summary

The study sought to explore and co-develop a theory on the teaching of qualitative analysis in senior high schools in the Cape Coast Metropolis, Ghana. For better understanding of the current phenomena on students' weak performance on qualitative analysis the study explored the problems teachers do encounter in teaching QA, pedagogy, and subject matter knowledge of chemistry teachers and the context in which they teach QA, how teachers teach QA and other factors, qualitatively affecting the teaching of QA. To be able to achieve these objectives, the study adopted qualitative design using the constructivist grounded theory approach. Through purposive and convenience sampling 10 chemistry teachers with a minimum of 2 years teaching experience participated in the study. Data was collected from the 10 teachers and their respective schools using interviews (TISQA), observations (TOSTQA), and field notes. In all, 11 weeks were used to collect data from teachers. The data collected was analysed via coding, sorting, synthesizing and visualising with the Nvivo software. Themes were then used to present the results.

Key findings

1. The findings from exploration of teachers' problems of teaching QA came up with:
   i. Material resources in the form of reagents and other equipment were insufficient in the schools. This affected teaching of QA as those present were expired. The material resources affect the selection of most appropriate instructional approach.
   ii. Human resources in the form of in-serving training given to teachers, laboratory technicians and laboratory assistants affected the effective teaching of QA. Chemistry teachers has at least 3 years of teacher education preparation. Their teacher education preparation lack practical-based teaching, mentorship and in-service training could equip teachers with practical-based teaching. In-service training was not noted to be intensive enough and even when they were it was not centered on teaching QA. Novice teachers have problems with teaching QA compared to experienced teachers. Laboratory technicians and assistants to support teachers were almost absent in the schools, and the role of laboratory assistant is different from that of laboratory technician in teaching QA.
   iii. Time resources in the form of extended time, period allocation, and time management affected the effective teaching of QA by teachers in the schools. Time allocation for teaching QA was not enough and not part of the teaching time table, so teachers scheduled extended time for effective teaching. Selected schools sanctioned extra time

for teaching QA. Extended time, a condition for effective teaching of QA and lack of space called for extended time, and schools used four periods instead of six periods recommended by the teaching syllabus.

iv. School-type resource was a hidden factor under available resources for effective teaching of QA by teachers. Well-endowed schools had enough and fresh reagents, equipment and laboratory space, PTA and alumni offered support in equipping chemistry laboratory for teaching QA in the well-endowed schools but not same in the less-endowed schools.

2. The findings on the exploration of the pedagogy, subject matter knowledge of chemistry teachers and the context within which they teacher QA produced the following:

   i. the content and concept of qualitative analysis were not difficult for teachers to teach to students. Teaching QA became difficult only when students lacked the basics of QA, and that not much about QA was explicit in the curriculum. Weak instructional approach made the concept and content of QA difficult, and practical-based approach made it less difficult to teach. The difficult aspects of QA were formation of complex ions, distinguishing between gelatinous and chalky precipitate and addition of acid. Language contributed to difficulties on QA, and good teaching experience could be ~~a solutiona~~ a solution to difficult aspects of QA~~.~~

   ii. the context of the syllabus (chemistry curriculum) was identified as a problem for teaching QA to students. Qualitative analysis was not specified under any unit (topic) but spread throughout the syllabus. Thus, teachers needed to be resourceful to teach QA. Teachers needed to consult other curriculum materials to appreciate the context of QA, and the context of teaching QA can be deduced from the suggested activities in the syllabus. The chemistry syllabus is explicit on the year of introduction of the QA, instructional strategy for teaching QA, and topics under which QA should be taught to students.

3. The findings from the exploration of how teachers teach QA to students in senior high schools are:

   i. experienced and novice teachers narrated how they teach QA systematically, highlighting on the content and pedagogical knowledge of teachers, from preliminary test, confirmatory test through to flame test.

   ii. the planners of the chemistry curriculum recommended participatory teaching and learning approaches as the best approach for teaching QA. Teachers used variety of instructional approaches such as demonstration, individual-based activity learning, and cooperative learning approach. The selection of instructional approach was based on resource availability.

   iii. teachers use cooperative learning approaches in teaching practical lessons on QA. They employ this approach when the class size is large.

4. The findings on how teachers explore qualitatively other factors affecting the teaching of QA are:

a. Management and financial support were the major factors affecting the teaching of QA. This is because school administration provided finances for chemicals, reagents and other equipment, scheduled time table, organised co-curricular activities, sited laboratories away from regular school blocks, refurbished and replaced broken equipment, and provided the needed chemicals and reagents during final examinations.

b. School culture was another major factor that affected the teaching of QA to students. This is because the well-endowed schools had strong PTA and alumni that support in equipping science laboratories, and organised extended class during evening times but not in the less-endowed schools. Students were ready to meet teachers for extended time in well-endowed schools.

Conclusion

Upon the findings from the study on teachers' problems in teaching QA, have shown that the resources available affected several schools. Some of the material resources available in some of the schools focused on chemicals and apparatus which are lacking in most category B and C schools, with the exception of few grade A schools which can boast of having adequate chemicals and apparatus. The study has added to the literature that time as a resource for teaching QA was inadequate, which results in teachers finding extra time to cover the content, thereby teaching on weekends, and using prep time to supplement the teaching of practical works. More importantly, Human resource in the form of laboratory technician and assistance is lacking in most schools, which increases teachers' workload in preparing the laboratory for practical work. This again affects the instructional strategies used by teachers and not teaching certain process skills

The study has shown that the content in QA is not too difficult to teach neither the concepts used in QA but, what makes the concept and content difficult to teach are sometimes lack of resources in lesson delivery and the supporting staff deficit such as laboratory technicians and assistants in helping to teach QA. The study has added to the literature that the syllabus posed a major difficulty for teachers, especially novice teachers who will require an experienced teacher in tutoring them since the syllabus does not provide a clear guideline on how to teach QA. With the required teacher knowledge of the pedagogy and content, the context of the school influences how effective the teacher will teach QA to students.

The study has shown that teachers used variety of instructional approaches such as demonstration, individual-based activity learning, and cooperative learning approach in teaching QA to students. Teachers have good knowledge of how the concept of QA should be presented to students and tried as much as they could to implement that. The selection of instructional approach was based on resource and that, teacher’s only used cooperative learning approaches to solve the problem of large class size in relatively small space of chemistry laboratory.

The study has shown that there are other factors either than the available resources that contribute to the teaching of QA to students qualitatively. For some instances, school management support, financial support, teacher professional development, and school culture. The management support in practical work in most schools were identified as positive as a result of the granting of chemicals and apparatus to some schools upon request. The study has added to the literature that school culture is a factor that qualitatively affects the effective teaching of QA to students. The school culture of grade A schools, unlike the grades B and C schools, makes it possible for the lesson to be organized during preps or weekends to supplement regular teaching timetable.

Recommendations

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

a. The Ghana Education Service should regularly inspect the physical conditions of the school laboratories and provide the needed support in terms of materials and equipment since the selected schools had insufficient material resources for teaching QA to students.

b. As mentorship and in-service training could equip teachers as well as laboratory technicians and assistants with the needed skills and knowledge for teaching QA to students, the Ministry of Education through the Ghana Education Service should institute termly training of those personnel on effective teaching of QA.

c. School managers should factor time for teaching practical works (QA) on the timetable to meet the six periods recommended by the chemistry syllabus since only four periods were allotted on the timetable reducing the contact hours teachers need to effectively teach practical lessons.

d. Since teachers identified the context of the chemistry curriculum as a difficulty to teaching QA, chemistry teachers should be orientated in workshops by chemistry educators and researchers to understanding why QA will always be spread under appropriate units in the curriculum.

e. As planners of the chemistry curriculum recommended participatory teaching and learning approaches for teaching QA, teacher education institutions should be training teachers to select and use variety of participatory approaches in teaching QA.

f. Heads of schools should pay serious attention to the role of school culture since school-type, PTA, and alumni plays vital role on the teaching of QA to students in the well-endowed schools.

Suggested Areas for Future Research

The study explored the teaching of QA using a qualitative approach. However, the study did not consider a mixed method or a quantitative method in exploring how chemistry teachers teach QA to students. It is, therefore, recommended that further research be conducted into teaching of QA using a mixed methods approach.

Also, the study explored how teachers teach QA to students in the SHS. However, the study did not explore teacher's conceptual understanding of QA. It is, therefore, recommended that further research be conducted into teacher's conceptual understanding of QA.

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APPENDICES

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APPENDIX A

TEACHER INTERVIEW SCHEDULE ON TEACHING QUALITATIVE ANALYSIS

This interview schedule is designed to explore with chemistry teachers in a face-to-face interview on how to teach QA in SHS. The purpose is to get in-depth first-hand knowledge on their teaching of QA. The expectation of this interview will be for teachers to share their experiences freely with the strongest assurance of confidentiality as stipulated in my consent form. Please, teachers, are free to opt-out of the study at any time of the study. Transcribed audiotapes will be sent to teachers for their approval and any materials that will form part of the final study will have their consent.

A. Bio-Data for teachers

1. Please, what is your name?
2. How long have you been teaching in this school?
3. How long have you been teaching QA?
4. What is your academic/Professional qualification?

B. What problems do teachers have in teaching qualitative analysis?

1. How do you see the teaching of QA in SHS?

   Prompt 1: is it unclear to teach? Why?

   Prompt 2: does it involve a lot of process skills? Why?

   Prompt 3: is it tedious to teach? Why?

   Prompt 4: do students memorize concepts of QA? Why?

2. What instructional strategy do you use in teaching QA?

   Prompt 1: why this approach?

   Prompt 2: is it by group activities? Why?

   Prompt 3: is it by hands-on activities? Why?

   Prompt 4: is it by demonstration? Why?

3. How do you assess your teaching of QA in terms of workload?

   Prompt 1: is the content too much? Why?

   Prompt 2: is the time allocation to teach QA sufficient? Why?

   Prompt 3: are there enough instructional materials available for teaching QA? Why?

C. How do teachers assess their general pedagogy and content knowledge in QA?

4. What major concepts under QA do your students find difficult to understand?

   Prompt 1: are the concepts: "formation of the precipitate", "formation of complex salts" and "addition of acids" difficult to teach? Why?

   Prompt 2: do students readily understand these concepts? Why?

   Prompt 3: does the syllabus give directions as to how to teach these concepts? How?

   Prompt 4: do you need help in teaching these concepts? Why?

5. How do you get to know if students are following your instruction?

   Prompt1: how do you assess a student's conceptual understanding? Why?

   Prompt 2: do the assessments of students' conceptual understanding influence your teaching? How?

6. How do you handle a large class in practical lessons?

   Prompt 1: do you involve all students in hands-on group activities? How?

   Prompt 2: is the class size affecting your teaching? How?

D. In what contests do chemistry teachers teach qualitative analysis?

7. How do you see the nature of syllabus concerning QA?

   Prompt 1: it is the difficulty? Why?

   Prompt 2: is the syllabus clear? Why?

   Prompt 3: does the syllabus have a structured procedure to follow in teaching QA?

8. How do you see the period allocation for teaching QA affecting your practical work?

   Prompt 1: is the period allocation affecting your practical work? How?

   Prompt 2: how many times do you teach a practical lesson in a term? Why?

E. How do teachers explore factors affecting the teaching of QA?

9. How well resourced is your chemistry lab?

   Prompt 1: is your school category A, B, or C school?

   Prompt 2: is this affecting your school's lab infrastructure? How?

Prompt 3: is each student having a set-up to themselves during a practical lesson? Why?

Prompt 4: do you have issues with lab equipment and reagents? Why?

Prompt 5: are there other challenges you do have? Why?

Prompt 6: is there a lab technician in your school lab? Why?

10. How important do you see the school culture contributing to the quality of teaching and learning?

Prompt 1: is the Boarding/Day system affecting your school culture? Why?

Prompt 2: how is a single-sex school/co-ed school contributing to your school culture?

Prompt 3: Is there comparable performance between females to male students? How?

Prompt 3: are stakeholders such as Old Boys and Girls, Chiefs, NGOs supporting the school? How?

11. How is the school administration supporting practical lessons?

Prompt 1: is the administration providing support for practical work? How?

Prompt 2: what other factors do you see as contributing to the development of teaching and learning?

APPENDIX B

TEACHER OBSERVATIONAL SCHEDULE ON TEACHING QUALITATIVE ANALYSIS

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This interview schedule is designed to explore with chemistry teachers in a sit in class observation as an observer on how teachers teach QA in SHS. The purpose is to get in-depth first-hand knowledge on their teaching of QA. The expectation of this observation will be to corroborate with teachers on their shared experiences during the interview with the strongest assurance of confidentiality as stipulated in my consent form. Please, teachers, are free to opt-out of the study at any time of the study. Transcribed audiotapes will be sent to teachers for their approval and any materials that will form part of the final study will have their consent.

A. Lesson introduction

1. How is the teaching introducing the lesson?

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~~B.~~ Content Development

B.

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1. How is the teacher explaining procedural knowledge?

2. How is the teacher explaining the physical observation?

3. How is the teacher explaining chemical changes?

4. How is the teacher explaining the reagents used in QA?

C. Skill development

How is the teacher developing the skill of students?

1. Manipulative skills

2. Inferential skills

3. Propositional skills

D. Assessing learning effects

1. How is the teacher using questions?

2. How is the teaching assessing students' understanding?

E. Closure

1. How is the teacher closing the lesson?

F. The state of the lab