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ARE CHEMISTRY TOPICS DIFFICULT TO LEARN? THE STANCE OF GHANAIAN SENIOR HIGH SCHOOL STUDENTS

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Abstract

The study explored the chemistry topics in the Ghanaian Senior High School curriculum that students found difficult to learn, as well as the reasons for those difficulties. The study's participants (96) were all third-year science students at a well-endowed school chosen at random from the Central Region's well-endowed schools. Students were given a three-point Likert scale questionnaire containing topics from the Ghanaian chemistry syllabus. A focus group discussion was held with students to determine the reasons for their opinions on the topics. The final stage involved observing chemistry lessons at the school. According to the study's findings, approximately 66.7% of the chemistry topics examined were difficult for students. Students attributed their reasons to poor teaching techniques, a lack of practical activities, and an absence of extra tuition. The findings also revealed that, despite the teachers' subject matter mastery, their lessons are more teacher-centered with little interaction. Furthermore, assignment-based summative assessment was the most commonly used in the classroom. The study suggests that chemistry teachers use variety of teaching methods such as hands-on activities, assess student understanding through a variety of methods and also offer extra help and support to students who may be struggling.

Keywords: Chemistry**,** curriculum**,** difficult topics, teaching techniques.

INTRODUCTION

Chemistry is a complex subject that covers a wide range of topics, from the basic principles of atoms and molecules to the more advanced concepts in organic chemistry, biochemistry, and physical chemistry. Chemistry is often regarded as being challenging to teach and learn (Bertels & Bolte, 2015; Johnstone, 2000; Ronkainen, 2015). It is often perceived as challenging because it involves understanding complex concepts and relationships between different elements and compounds. The majority of students in Ghanaian classrooms acknowledge chemistry as one of the most difficult academic disciplines. This is due to the fact that the high school chemistry curriculum typically includes a lot of abstract ideas (Taber, 2002). In Ghana, chemistry is taught in great detail in science classes. This is due to the fact that many science-focused courses in Ghanaian universities and colleges require it as a prerequisite for study. Throughout the years, reports have indicated that Ghanaian Senior High School students have struggled with their chemistry grades (Ampiah, 2001). Chemistry Chief Examiners Reports (CER) data from the West Africa Examination Council (WAEC) over the years indicate that students struggle with some fundamental chemistry concepts. Chemical equations and substance formulas are typically difficult for students to write (WAEC, 2001; 2004; 2005). Questions on organic chemistry are not attempted by students (WAEC, 2002; 2003; 2004; 2005; 2006). For the most part, students lack basic laboratory skills and knowledge and hence perform

poorly in qualitative tests (WAEC, 2005; 2006; 2008). There are several reasons why students may struggle or fail in chemistry. Many students may struggle to understand the complex concepts and principles of chemistry, which can make it difficult to grasp the material and perform well on exams. Chemistry requires a strong foundation in math, particularly in areas such as calculus and statistics. If students have not mastered these skills, it can make it difficult for them to understand the mathematical concepts used in chemistry. Some students may not have effective study habits and may not devote enough time or effort to mastering the material. Chemistry also includes a lot of lab work, which can be difficult for some students. If students are not comfortable with the hands-on aspect of the subject, it can negatively impact their performance. Some students may have difficulty understanding the language or nomenclature used in chemistry, which can make it difficult to understand the concepts and perform well in examinations. Some students may not have access to the resources or support they need to succeed in chemistry, such as a good teacher, tutoring or study materials. Some students may not be engaged in the subject matter and may not find it interesting. This lack of interest can make it difficult to stay motivated and focused.

The teaching methodology, the instruction language, and the availability of after-school support services can all have an impact on the difficulties that students encounter in the chemistry classroom (Chiu, 2005). Due to a lack of time for practical activities in many schools' chemistry curricula, some chemistry teachers still struggle to effectively engage students in the teaching and learning process (The New Times, 2017). The absence of adequate laboratory procedures is one of the key elements that negatively impacts secondary school students' academic success in chemistry (Tassew, 1997). According to Temechegn and Sileshi (2005), students should be engaged actively in the classroom. Instead of dominating the classroom, the teacher should serve as a facilitator and listener. Teachers frequently employ a teacher-centered approach in order to cover the content of chemistry during the time allotted on the school calendar (Byusa, Kampire, & Mwesigye, 2020). Geddis and Roberts (1998) identified teacher-developed beliefs as being crucial to their later adoption of a teacher-centered approach. These beliefs were formed while teachers were exposed to lectures during training. However, the limitations of this passive teaching method for chemistry education are numerous (Tenaw, 2015). Studies have shown that students frequently do not find chemistry studies to be as relevant and that they are not always sufficiently interested in chemistry [Gilbert, 2006; Rocard, et al., 2007; Sjoberg, & Schreiner, 2010]. It is necessary to implement pertinent pedagogical innovations in chemistry education to pique students' interest in the subject (Pernaa, et al., 2022). Essiam (2019) proposed the use of routine in-class tests as a creative strategy for encouraging students to learn chemistry. He believed that frequent testing would encourage students to learn on a regular basis. Blonder and Mamlok-Naaman's (2019) suggestion is to use current research cases as context. The modern method demonstrates to students how scientific knowledge is produced while teaching about the nature of science (Blonder & Mamlok-Naaman, 2019). Studies have also emphasized the use of computer-assisted instruction in the classroom (Appiah & Essiam, 2022; Karehka, 2012). According to Carson (2012), using instructional technology to teach chemistry allows students to study at their own pace and across a variety of subjects, which increases their level of motivation. Nevertheless, one of the most important aspects of any chemistry curriculum is the level of students' conceptual understanding. Literature demonstrates that students' perceptions directly affect how well they perform in chemistry (Jimoh, 2005; Mahajan & Singh, 2005).

A significant body of research from international studies demonstrates that students generally struggle to learn and comprehend chemistry concepts. The kinetic theory of matter (Stavy, 1995; Taylor & Coll, 1997), electrochemistry (Garnett & Treagust, 1992; Sanger & Greenbowe, 1997), and chemical bonding (Taber, 2002; Coll & Treagust, 2003) are a few examples of these concepts. There are also others, such as atomic structure (Harrison & Treagust, 1996), chemical change and reactivity (Zoller, 1990), intermolecular forces (Barker & Millar, 2000), mole concept (Gilbert & Watts, 1983), and acids and bases (Drechsler & Schmidt, 2005; Lin & Chiu, 2007). Other concepts include solubility and solubility equilibrium (Pinarbasi & Canpolat, 2003; Raviolo, 2001) and chemical equilibrium (Banerjee, 1991). Similar to the studies mentioned above, the authors decided to explore the chemistry

classroom to identify topics in Ghanaian Senior High School chemistry curriculum that students felt were difficult to learn as well as the reasons for those difficulties.

METHOD

This was exploratory study carried out in a well-endowed Senior High School in the Central Region, Ghana. The school was chosen at random from a group of well-endowed schools in the region. In Ghana, a school is said to be well-endowed if it has enough teachers, facilities, and instructional materials. According to studies, students who attend schools with more resources typically outperform their counterparts who attend schools with less resources (Atuahene & Owusu-Ansah, 2013). The participants of the study (96) were all third-year science students in the school. In order to be in a better position to provide accurate information about their chemistry education, third-year science students were specifically chosen because they have covered more topics on the syllabus than their juniors. About the goal of the study, conversations were had with the students and their chemistry teachers. They were all given the assurance that both their identities and those of the school would be kept secret when they volunteered to participate in the study. The study was conducted in three phases.

The first phase consisted of design and administration of questionnaire to students. A three-point Likert scale questionnaire consisted of topics in the Ghanaian Chemistry syllabus was constructed. Students were to indicate their options in the Likert scale with responses ranging from 1 = Not difficult, 2 = Uncertain, and 3 = difficult. To validate it, the questionnaire was initially distributed to the chemistry teachers in the school who were instructing this particular group of students. Teachers verified the topics' inclusion in the Ghana Education Service-approved chemistry syllabus as well as their prior instruction of students in order to ensure that the content was valid. The reliability coefficient was then determined to be .73 after the questionnaire was piloted in a school with a comparable setting. When an instrument has a reliability coefficient of .73, it is good and will produce reliable results. Students were given the questionnaire, and after the information was gathered and analyzed using SPSS, each item's means and standard deviation were calculated. Student focus groups discussions made up the second stage of the study. Out of the sample, twenty-eight students offered to take part in the discussion. The purpose of the discussion was to learn from the students about the reasons why they thought the topics were challenging. Audio of the conversation was captured, and it was verbatim transcribed. The information gleaned from the discussions was analyzed in detail and presented thematically. The third stage involved observing the chemistry lessons that were given to the study's participants by their teachers.

RESULTS and DISCUSSION

A summary of means scores of the individual items (topics) and standard deviations are presented in Table 1 and described. The topics with means between 1. 80 to 3.00 were classified as difficult topics whilst those with means from 1.00 to 1.79 as not difficult topics. It can be seen from **Table 1** that 10 topics representing 66.7% of the topics responded to by students were perceived challenging. *The concept of acids and bases* was the most perceived difficult topic with mean score of 2.43 whilst *structure of the atom* is the most perceived easy (not difficult) topic by the students with the mean score of 1.20. The topics *structure of the atom, periodicity, the mole concept, nuclear chemistry* and *solubility of substance* were perceived by the students as not difficult.

It can be inferred from Table 1 that about 66.7% of the topics were perceived difficult to learn by students. It is also clear from the findings that mathematics is a crucial element of these regarded as difficult topics. In a separate studies Gongden, Gongden, and Lohdip (2011), Jack (2005), Jimoh (2003), Uchegbu, Oguoma, Elenwoke, and Ogbuagu (2016), and Uzezi, Ezekiel, and Auwal (2017) reported similar findings. According to aforementioned studies, students had trouble picking up on and comprehending chemistry concepts. Students believe that concepts like chemical bonds are challenging, which is supported by research by Coll and Treagust (2003) and Taber (2002).

Table 1. Perceived difficulty of chemistry topics

S/N	Topics	Mean	SD	Remarks
1	Structure of the atom	1.20	1.13	Not difficult
2	Periodicity	1.75	.67	Not difficult
3	Chemical bonds	2.30	1.34	Difficult
4	Hybridization and shapes of molecule	1.90	.77	Difficult
5	The mole Concept	1.53	.31	Not difficult
6	Solution stoichiometry	1.83	.47	Difficult
7	Nuclear chemistry	1.53	.68	Not difficult
8	Gases and Kinetic theory of matter	2.10	-91	Difficult
9	Energy changes and bond enthalpies	2.03	1.21	Difficult
10	Transition chemistry	2.35	.45	Difficult
11	Rate of reaction	1.80	.65	Difficult
12	Chemical equilibrium	2.23	1.10	Difficult
13	The concept of acids and bases	2.43	.98	Difficult
14	Buffer solution	2.18	.96	Difficult
15	Solubility of substances	1.75	1.32	Not difficult

According to studies conducted by Taylor and Coll (1997) and Stavy (1995), gases and the kinetic theory of matter are perceived as being challenging. Students reported difficulty with the concepts of acids and bases, which supports research by Drechsler and Schmidt (2005) and Lin and Chiu (2007). According to Banerjee's (1991) study, concepts like chemical equilibrium are also thought to be difficult. Five of the fifteen topics under investigation—or 33.3%—were thought to be not difficult. Students didn't find the topics of atomic structure, periodicity, the mole concept, nuclear chemistry, and solubility of substances to be particularly challenging. This result, however, contrasts with those of related studies on the mole concept conducted by Gilbert and Watts in 1983, the atomic structure by Harrison and Treagust in 1996, solubility and solubility equilibrium by Pinarbasi and Canpolat in 2003, and solubility and solubility equilibrium by Raviolo in 2001. The studies mentioned above detailed the challenges students felt they faced when learning those topics.

During the focus group discussion, students were asked to give reasons why chemistry topics are difficult. Table 2 presents the themes that emerged from their responses, which include poor teaching techniques, a lack of practical activities, and the absence of extra tuition.

Table 2. Perceived causes of difficultness of chemistry topics

	Main findings
1	Poor teaching techniques
2	Lack of practical activities
3	Absence of extra tuition

Poor Teaching Techniques

A boring chemistry lesson can be a frustrating experience for students. One of the main reasons for this is the lack of engagement in the class. When the material is presented in a dry and monotonous manner, it can be difficult for students to stay focused and retain information. The students complained about the manner in which chemistry is taught to them. The teacher struggles to engage the class. According to the students he does not provide answers to most questions for them to understand, and he is so monotonous that most of the students fall asleep when he enters the classroom. A student proclaimed:

"Our teacher does not teach well in class. He does not solve more questions for us to understand and he is so boring to the extent that when he comes to class most of us sleep. In fact, he does not teach us well".

The teachers don't spend enough time helping the students understand the concepts. They rush through the lesson delivery because they want to get through the majority of the syllabus with the students before they take the external exam. According to the students, some topics in the chemistry syllabus are not explained clearly enough for the students. The teachers "lecture" them as though they were college students. A student stated:

"My chemistry teacher does not teach some topics to my understanding. He lectures to us as if we are in the university. He teaches like we already know what he is teaching".

Students expressed dissatisfaction with how chemistry was taught to them. Nahkleh (1992) asserts that a lack of a proper introduction to fundamental chemistry concepts has an impact on students' capacity to comprehend more complex ideas. The responses from the students during the discussions indicate that their chemistry teachers are not tailoring the lessons to their comprehension. If the teacher does not use different teaching techniques such as multimedia, videos or images, it might be hard for students to stay focus and engage in the class. Moreover, if the class is always structured in the same way, or if the teacher always uses the same teaching methods, students may find the class boring. Lack of variety in teaching methods can make the class monotonous and uninteresting. To keep students motivated and engaged, teachers should make an effort to incorporate variety in their teaching methods, use real-world examples, and involve students in the learning process.

Lack of Practical Activities

Students struggled to recall their most recent visit to the chemistry lab for a hands-on lesson. The majority of lessons, in the opinion of the students, are taught in the classroom. The teacher shows them the lessons that call for activities. They claim that this hinders their ability to fully understand and learn the subject. Since the ideas are abstract, it is impossible to relate to them effectively without engaging in practical activities. Lack of practical activities can have a negative effect on a student's ability to learn and retain information. When learning is solely based on theoretical concepts, it can be difficult for individuals to fully understand and apply the information in real-world situations. This can lead to a lack of understanding and difficulty in problem-solving. One of the students reported:
"I don't understand the concepts of acids and bases and how is being taught makes it difficult. I have been taught the names of some acids and bases but I haven't seen them physically and also neutralisation reactions. I don't remember the last time I went to the chemistry laboratory".

The students felt that practical work should have started earlier before the final year, despite their teachers' assurances that it would start in the second term of the final year and continue until they wrote their external exams. Practical activities provide hands-on experience, which can enhance the understanding of theoretical concepts. They also allow for active learning, where students can apply what they have learned and see the immediate results of their actions. This can increase motivation and engagement in the learning process. A student stated:

"The teacher always does the demonstrations in class as we watch on. But I feel if he takes us to the laboratory very often I won't have any difficulty with the topics. Chemistry is a nice subject but is tough what I need is more practical work and activities".

Another student revealed:
"My problem with some of the topics would not have arisen if we have been doing practical activities. The second term is what we've been told the practical work would start and I hope we can make up the lost time".

Students bemoaned the absence of practical instruction. However, the use of experiments in science classes is a powerful strategy (Trna, 2014). The students believed that engaging in practical activities frequently would help them learn and comprehend chemistry concepts. This assertion is consistent with the findings of a related study done by Moyo (2018). Students, according to Moyo, think that carrying out experiments will help them remember chemistry concepts. Practical activities can help to develop a range of skills, such as teamwork, communication, problem-solving and critical thinking. These skills are essential for success in both personal and professional life. In summary, the lack of practical activities can hinder a student's ability to learn and retain information, limit the development of important skills, and decrease motivation and engagement in the learning process. It is important for teachers to incorporate practical activities into their teaching methods to ensure that students are well-equipped to succeed in the real world

Absence of Extra Tuition

Students bemoaned their inability to obtain chemistry tuition after the regular classes. They feel that obtaining extra tuition would give them the chance to review the concepts they found difficult to comprehend in the regular class. They would have the chance to ask for assistance from other chemistry instructors who are skilled examiners and can impart information in a way that is understandable to them. Extra tuition allows for a more personalized learning experience. In a traditional classroom setting, the teacher may not have the time or resources to cater to the individual needs of each student. Extra tuition, however, allows for one-on-one attention and the ability to focus on specific areas of difficulty for the student. A student proclaimed:

"Chemistry is broad and we don't get more time to study it. In some schools the teachers organise extra classes for them in the afternoon so they easily pass WASSCE but here in the school we don't do extra classes after school so some of us struggle to learn chemistry".

Students also complained about their inability to obtain extra tuition as a barrier to their chemistry studies. According to them, the nature of the subject and the volume of topics to be learned require extra contact hours to learn, but the school does not allow for extra tuition after normal lessons. According to the students, neither free nor paid extra tuition is permitted at the school by the administration. They don't have free periods for teacher consultations because the timetable is more packed in general. One of the students stated:

"The topics are more demanding and as such need more contact hours to learn but unfortunately we are not allowed to have extra classes. Moreover, we don't have free periods to contact our teachers for consultations and clarification".

However, studies show that extra tuition can help students learn better. In their study, Ha and Park (2017) found that extra tutoring had a positive effect on secondary school students' achievement. Zhang reported similar results (2013). According to Zhang, students who attend schools with higher educational inputs are more likely to benefit from private tutoring. Extra tuition can provide an

opportunity for students to learn at a faster pace. In a traditional classroom, the pace of learning may be determined by the teacher and may not suit the needs of all students. Extra tuition allows students to move at their own pace, which can be especially beneficial for students who are looking to advance quickly or those who have fallen behind in class. In summary, extra tuition offers several advantages such as a personalized learning experience, flexibility, exam preparation, and faster pace of learning. These benefits are some of the reasons why students may prefer extra tuition to supplement their regular classroom lessons.

Lesson Observation

The author observed the chemistry teachers' lessons in the two third-year General Science classes. The teachers were aware of the study's purpose and agreed to have their lessons observed. The author used the teacher's teaching approach, subject knowledge, teacher-student interaction, and assessment procedure as criteria for the observation. The lessons observed focused on the topic *electrochemistry*.

Table 3. Descriptive summary of lesson observation

	Main findings
1	Good knowledge of subject matter
2	lessons are more teacher-centered
3	Minimal teacher-student's interactions
4	Assessments are predominantly summative
5	Assignments are most used assessment procedure

Table 3 shows a descriptive summary of lesson observation. As can be seen from **Table 3**, the most common form of assessment used by teachers is summative, which was done at the end of the lesson in the form of assignments. Students were taught about redox reactions, electrochemical and electrolytic cells by their teachers. The lessons were delivered without a lesson plan. However, the teachers' knowledge of the subject was vast. The explanations of concepts were correct, but the lessons were more teacher-centered. Teachers relied heavily on lecture and demonstration methods of instruction. As observed, teacher-student interaction was minimal. Teachers were only lecturing or demonstrating while students looked on. Rarely were students called to the board to demonstrate how to balance redox equations. Few students asked questions during lessons because most were preoccupied with taking notes as the lessons progressed. Methods of teaching that include lectures and demonstrations. Chemistry instruction and learning in the school is more teacher-centered. The teacher-centered approach, according to Trilling and Fadel (2009), does not empower students' autonomous and life-long study skills. According to Table 3, most lessons are delivered through the lecture method, with only a few exceptions where the teacher demonstrated using limited materials. The lecture method of instruction does not promote critical thinking, interpretation, or self-regulation in students (Schraw & Robinson, 2011). Students acted as observers while lessons were being taught. There was little interaction between students and teachers in the classroom. According to Arthur, Gordon, and Butterfield (2003), positive teacher-student interaction is critical for effective teaching and learning. As observed in the classroom, the teachers were rushing to "complete the syllabus," ignoring the students' learning styles and pace. Students report that this attitude of teachers is one of the factors that makes learning chemistry difficult for them.

CONCLUSION

The study explored the chemistry topics in Ghanaian Senior High School curriculum that students found difficult to learn, as well as the reasons for those difficulty. According to the study's findings, 66.7% of the topics investigated were perceived as difficult by students. Students blamed their chemistry teachers' poor teaching techniques for the difficulties they encountered. The findings also revealed that lessons in the chemistry classroom were more teacher-centered, with little interaction between teachers and students. Students complained about absence of extra tuition and lack of laboratory practical work. Practical work in school was restricted to the final two terms towards their

final examination. Using poor method of teaching can negatively impact student learning and engagement. Poor teaching methods can include not differentiating instruction for diverse learners, not providing adequate feedback, using monotonous lecture-style teaching, and not providing opportunities for hands-on or active learning. To address this issue, chemistry teachers should strive to use a variety of teaching and assessment methods that are appropriate

Ethics and Conflict of Interest

The authors acted in accordance with the ethical rules in the research. The authors declare that they have no conflict of interest.

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