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CONCEPT DIFFICULTY IN SECONDARY SCHOOL CHEMISTRY – AN INTRA-PLAY OF GENDER, SCHOOL LOCATION AND SCHOOL TYPE

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Abstract

This study focused on addressing underperformance in chemistry in Anglophone West African countries. The main purpose of the study was to determine if factors such as gender, school location and ownership impact students' perception of the difficulty of chemistry concepts and to suggest how these difficult concepts can be made easy to learn from the perspectives of the students. A mixed-methods approach was adopted. Participants were 1,292 chemistry students from nine public and 12 private secondary schools in Nigeria and Ghana with about three-quarters of the schools from urban areas. About 51% of the participants were females. Twenty-four students were interviewed to gather qualitative data. The Difficult Concept in Chemistry Questionnaire (DCCQ) and the Difficult Concepts in Chemistry Interview Guide (DCCIG) were used for data collection. The test-retest reliability coefficient of the DCCQ was 0.88. We found a slight difference in the perception of male and female students while school type came as a major determinant factor on students' perception of difficult concepts in chemistry, just as school location. Phobia for calculations came out as a major cause of difficulty in the top five perceived difficult concepts. Findings on causes of learning difficulties were reported as well as suggestions for improvement as viewed by the students. Recommendations were made for improving the teaching and learning of chemistry in Anglophone West African schools.

Keywords – Chemistry, Difficult concept, Gender, School type, School location.

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1. Introduction

Research in science education has long been focused on two major areas; improving students' performance (Koksal & Berberoglu, 2014; Lau & Lam, 2017.); and winning more students to science (Rogers, 1964; Troxel, 1975; Lyons, 2007; Cleaves, 2011; Eam, Keo, Leng, Song & Khieng, 2019). The convergence of these studies focused on identifying the traditionally perceived difficult concepts in the science curricular. Studies have reported that it is these difficult concepts that impede students' performance in science and consequently lead to students' loss of interest in science (Lazarowitz & Penso, 1992; Maatman, 1995; Pinarbasi & Canpolat, 2003; Sözbilir, 2004). On this pane and among other regions of the world, Africa is the most hit (Okebukola, Oladejo, Onowugbeda, Awaah, Ademola, Odekeye et al., 2020). Therefore, to win the long-coming battle of underperformance of African students in science, attract more students to study science and ultimately ensure that we are on track to achieving the deliverables of Agenda 2063 which rely much on scientific advancement within Africa, there is an urgent need to shift the research gaze at this convergence. This is the problem that this study desired to solve.

Evident within the literature, are studies that have focused on this convergence but have narrowed their objectives to a mere listing of difficult concepts in science subjects, just as in phase one of this study (Oladejo, Okebukola, Olateju, Akinola, Ebisin & Dansu, 2022). The list of such difficult concepts has also been previously published in biology (Johnstone & Mahmoud, 1980; Lazarowitz & Penso, 1992) as well as in chemistry (Maatman, 1995; Pinarbasi & Canpolat, 2003; Sözbilir, 2004). This study, therefore, attempts to cater for the deficiencies of previous studies by probing the causal factors for concept difficulty in chemistry from the students' perspective with a sharp focus on the five concepts perceived as most difficult by sampled students in Nigeria and Ghana as reported in Table 1. This is an improvement beyond the mere listing of such concepts. It provides insight for classroom teachers on how to help the students learn these topics in ways that they (the students) feel will help them improve, not how the teacher feels. As noted by Oladejo, Akinola and Nwaboku (2021), students learn better when they are taught in ways they like to learn, after all, whatever pleases teaches effectively.

S/N	Difficult Concepts	Mean	Mean Rank
1.	Benzene and its Compounds	2.18	1st
2.	Nuclear Chemistry	2.17	2nd
3.	Salt analysis (qualitative analysis)	2.17	2nd
4.	Volumetric analysis (Titration)	2.16	4th
5.	Chemical equations and equilibrium	2.10	5th
6.	Alkanols, Alkanals and Alkanones	2.10	5th
7.	Acid-Base titration calculations	2.07	7th
8.	Solubility	2.02	8th
9.	IUPAC nomenclature	2.01	9th
10.	Lipids, soap and detergent	1.95	10th
11.	Electrolysis	1.93	11th
12.	Oxidation and Reduction (Redox reactions)	1.90	12th
13.	Chemical bonding	1.89	13th
14.	Hydrocarbons	1.86	14th
15.	Electronic configuration	1.75	15th
16.	Gas laws	1.73	16th
17.	Separation techniques	1.73	16th
18.	Atomic structure and theories	1.72	18th
19.	Metals, Non-metals and their compounds	1.70	19th
20.	Kinetic theory of matter	1.65	20th
21.	Acids, bases and salts	1.64	21st
22.	Periodic Table	1.56	22nd

Table 1. Ranking of difficult concepts in senior secondary chemistry (Oladejo, Okebukola, Olateju et al., 2022)

On the other hand, the volume of studies addressing topic difficulty in science is sparse in Africa, compared with studies in similar research conducted in Australia (Garnett & Treagust, 1992), Europe (Blanco & Garrote, 2007; Cimer, 2012; Şahin & Yağbasan, 2012; Kaltakci-Gurel, Eryilmaz & McDermott,

2016) and North America (Ralph & Lewis, 2018). This study also attempts to fill this gap. On account of Africa's low performance in science relative to other regions of the world (Onowugbeda, Okebukola, Agbanimu, Ajayi, Oladejo, Awaah et al., 2022), the weak attention by researchers in probing concepts that the students find difficult to learn in science, beyond mere cataloguing, is a yawning gap in the literature. More to it is that as teachers and researchers, we assume to know it all and hence, help our students to think out solutions to their problems. Who says our answers are the best? What conviction do we have that the students will prefer the solutions from our thought forms? Would it not be better to allow the students to think for themselves while we play our roles as a guide by the side? Is it not s/he who wears the shoe that can truly tell where and how much it pinches and what remedy to seek? It is against this background that we focused on the students' suggestions on how these topics can be made easy to learn.

While the end goal of our quest is to see a significant upturn in chemistry learning in Africa, however, given that some slight differences exist in the structure of science curriculum across the regions on the continent following the current education structure of each country or sub-region (for example in Kenya to complete the senior secondary curriculum for chemistry, a student spends four academic sessions; Form 1 to 4, whereas in Nigeria, such student spends only three sessions; SS1-3), we have limited the scope of our search to West African countries that operate the West African Senior School Certificate Examinations (WASSCE) syllabus. Five Anglophone countries in the western region of Africa that operates the WASSCE syllabus: Ghana, Nigeria, Sierra Leone, Liberia, and the Gambia. We must emphasize here that the scoping of this study to Anglophone West African countries that operate WASSCE does not infer that chemistry syllabuses for secondary schools across Africa vary so widely in terms of content coverage (For example Botswana, Egypt, Kenya, Namibia, and Uganda).

Our comparative analysis of sampled chemistry curricular and syllabuses across the regions on the continent shows that the objectives and aspirations of chemistry education at the secondary school level share very strong similarities. So much so that if a student completes a chemistry curriculum from a given country on the continent (particularly within the east, west, or southern region), it is safe to say that such a student would have completed at least 90 to 95% of the curriculum of any other country within the region, keeping all other factors (such as teachers' competence, and well-resourced laboratory) constant. A true reflection of this observation is the cross-regional students' admission (from Nigeria to South Africa/Tanzania; from DRC to Burundi/Kenya and from Benin to Cote d'Ivoire) into universities within the continent without a need for remedial classes except for language barrier.

Therefore, we are hopeful that the findings from this study will stimulate replication in other regions in addition to the applaudable efforts such as the EPFL-supported project in Tanzania; the mobile science laboratory kits project in Zambia; the mobile lab for science learning in Burundi, Togo and other countries under the umbrella of the East African communities; and the early science learning project in Nigeria and Ghana which are being implemented across the continent to facilitate and catalyze the attainment of goal 2 of the AU's Agenda 2063 which borders around building well-educated citizens who are skilful in science, technology, and innovation.

1.1. Determinants of Students Learning in Chemistry

Further on our interest to dig deeper beyond a mere listing of concepts/topics that students perceived difficult to learn, we noted that previous studies on concept difficulties in chemistry have hardly examined the impact of such variables as school type, school location and gender of students on topics perceived to be difficult in science. Yet, these variables have been implicated in previous studies (Banerjee, 2016; Breakwell & Beardsell, 2016) to impact students' achievement in science. Our choice of gender, school type and location was prompted by what the literature echoes and our first-hand field experiences. Most experimental studies that have been conducted in the last two decades in Nigeria and most other countries in Africa on students' performance in chemistry and other STEM subjects have always factored gender as a moderating variable that may influence the possible effects of their interventions.

This is especially so because several studies at different times and places have established differences in the performance of chemistry students in secondary schools based on gender, and usually in favour of the males (Adu-Gyamfi & Elikem-Vorsah, 2022; Boachie, Quansah & Oppong, 2021; Kyado, Achor & Adah, 2021). This is to the extent that in recent times, there have been studies dedicated to closing this variance in students' performance based on gender (Abdullahi, Abubakar, Abubakar & Aliyu, 2019; Oladejo et al., 2021; Gongden, John & Gimba, 2019; Naidoo & Sibanda, 2020; Ramnarain & Ramaila, 2018). Viewing from a gender-based lens, therefore, we asked, could the female students be experiencing more difficulties (perceived or real) in learning chemistry than the males? To be sure, and to also contribute to the ongoing efforts in ensuring/promoting equity in participation and performance in chemistry and by extension in STEM professions in Africa, we decided to approach this study from three angles including gender.

In Nigeria like most other parts of Africa, school type is characterised by funding source/ownership. Schools that are fully funded by the government (Federal, State or Local government) are popularly known as public schools while those that are paid for, and owned by individuals, groups, or organisations are commonly called private schools. Given the level of development in most African countries, and the usually very inadequate budget allocation meant for funding these public schools, most of them, particularly those in the suburban and rural areas, are usually in sorry states in addition to over population. According to Tuitoek, Yambo and Adhanja (2015) the poor performance of public school students can be accounted for by a lack of learning resources for both teachers and students. In a recent study by Isaac (2022) which affirms the better performance of private school students just as noted by Famuwagun and Ojobola (2021), she reported that the better performance of private school students in chemistry in comparison with their public-school counterparts was mainly due to infrastructural deficit and lack of learning materials and resources. Although, very qualified teachers usually occupy the government-owned school much more than the private schools can account for, however, these teachers are incapacitated by a few factors including unsatisfactory stipends, overpopulation, and ineffective quality assurance measures, so much so that the effect of the teachers' qualifications do not always reflect in the academic performance of their students (Oladejo, Nwaboku, Okebukola & Ademola, 2021).

Conversely, Aziaka and Ikwut (2018) in a comparative study of students' performance in biology and chemistry argued that public school students are better at achievement in chemistry than students from the private schools. This inconsistence but informative results prompted our interest in this variable (school type) as we suspected an unresolved midpoint between these two-legged findings. Given the quality of teachers in public schools and the availability of learning resources in private schools, could there be a sharp difference in the concepts that these students (private vs public) would perceive as difficult? We conjectured that private school students may be experiencing difficulties in theory/calculation-based concepts/topics, while students in government-owned schools may have challenges with concepts involving laboratory activities.

Singly or in composite, school factors such as school location have long been recognized as a potential determinant(s) of students' achievement in and attitude to learning science and mathematics (Ajai, 2018; Amusa, Ayanwale, Oladejo & Ayedun, 2022; Bizimana, Mutangana & Mwesigye, 2021; Christian, 2014; Jahnu & Mohmo, 2001; Mkpaoro & Nwagu, 2019). Over the years, several studies within the African regions have also established that chemistry students in rural schools have lesser opportunities to learn compared to their colleagues in schools located in the cities or urban areas and hence, the latter often achieve higher in learning and examinations (Christian, 2014; Ernest, Wushishi & Chado, 2018; Oginni, Awobodu, Alaka & Saibu, 2013). This is especially so because, on both human and capital resources, the rural schools get lesser attention than schools in urban areas. What piqued our interest in this variable is that while a gradual narrowing of the gap in achievement in chemistry due to gender is being observed, the long coming divide (in achievement in chemistry) between rural-urban schools remains almost unaltered. Therefore, there is a need to look at the problem from another side and rethink the strategies for changing the narratives.

The significance of the study to the African science education community and the socio-economic development of the continent is worthy of expatiation. Africa's share of contribution to the global STEM literature is paltry. From 2003 to 2012, sub-Saharan Africa's (SSA) share of global research ranged from 0.44% to 0.72% and citations to SSA articles relative to global citations, ranged between 0.06%- 0.16%

(World Bank, 2016). Doubtlessly, if science is not approached by students with some foreboding because of the difficulty in its content, the ranks of quality scientists and science educators and researchers will swell. In turn, this will catalyse research in STEM and ensure that Africa is not a bystander in contributing to global development through research.

We also advance the proposition that with science topics that are perceived as difficult identified and made easy by the outcomes of studies such as this, more students will be attracted to science and a heightening in performance achieved. This will translate to a hike in the production of much-needed science professionals such as agriculturists, medical practitioners, oil and solid mineral explorationists and science teachers in the right quantity and quality to bolster the socio-economic development of the countries in focus and the African continent in general.

1.2. What is Topic or Concept Difficulty?

In this paper, "topic" and "concept" are used interchangeably. In the West African Senior School Certificate Examinations syllabus and the science curriculum of the countries operating the WASSCE syllabus, the label "topic" is commonly used as a descriptor of what students are expected to learn. For instance, acids, bases and salts are listed as topics in the senior secondary chemistry curriculum in many African schools, whereas in the curriculum literature (Driver & Easley, 1978), these "topics" are often labelled as "concepts" (Gilbert, Bulte & Pilot, 2011). We have the concept of acidity, basicity and salt formation which are subsets of the topics of acids, bases and salts. We stress that it is not the intention of this paper to undertake an academic hair-splitting of the two labels as we have operationally defined both topic and concept as components of the subject matter in the school curriculum that students are expected to learn.

Topic or concept difficulty is the extent to which a concept or topic can be comprehended by a learner. The spectrum stretches from "least difficult" where the learner very readily progresses the concept from rote to meaningful learning (Novak. 2002; Grove & Bretz, 2012) to the polar end of "most difficult" where the learner encounters challenges from meaningfully learning the concept. Cañas and Novak (2014) have implied it to mean the easiness or difficulty in attaining a concept. Weak attainment is associated with the difficulty of the concept. In this case, the individual finds difficulty with sorting into general rules or classes, induced by impediments to the transition from rote to meaningful learning. If fully achieved, the person finds the concept easy.

1.3. Why Focus on the Top Five Most Difficult Concepts?

Our inability to cater for all the identified concepts at a go made us resolved at the top-most five, in this study. Other pertinent reasons include that the West African Examinations Council (WAEC) and National Examinations Council (NECO) always parade these concepts. Records have it that in the last 10 years, these concepts particularly numbers two to five have not failed to feature in the students' regional final examination (see WAEC Chief Examiner's report, West African Examinations Council, 2017, 2018; 2019; 2020). Second, the poor performance of students in these concepts has also been established in the literature: organic compound (benzene - Nartey & Hanson, 2021); nuclear chemistry (Abamba, Efe & Esiekpe, 2021); salt analysis (Omoniyi & Torru, 2019); volumetric analysis/titration (Tiimub, Kwara, Tiimob & Jackline, 2021) and chemical equation and equilibrium (Dansu, 2022).

As noted by Oladejo and Ebisin (2021), the laboratory plays a central role in the learning of chemistry and a lot of benefits accrue from learning activities that take place in it. Credit to this, is why the examinations bodies will always test the students' understanding of laboratory/practical work in chemistry. In WASSCE, the quantitative and qualitative analyses make up about 30% of the student's assessment (score) in chemistry. Assessors have noted that a student's failure in this paper, narrows the possibility of such student earning a credit pass or higher grade in the examination, thus, students' performance in this paper will have a significant overall effect on their final grade (Okebukola, Suwadu, Oladejo, Nyandwi, Ademola, Okorie et al., 2020b). Consequently, we hypothesized that providing a possible way out of difficulties experienced by students in these targeted concepts will be a good starting point.

Overall, in Africa, of the three secondary science subjects- biology, chemistry and physics, chemistry is the subject that over 90% of post-secondary science professional and academic courses required for enrolment. For such professional courses as agriculture, medicine, nursing, pharmacy, geology and engineering, chemistry is compulsory for aspiring students. For academic courses such as a honours degree in all the science disciplines including biochemistry, biology and microbiology, a credit-level pass in chemistry is required. Thus, a student's success in chemistry translates to success in virtually every other science-based course or subject. More to it is the importance of chemistry in the production of human resources to drive the economies of African countries. The economies of many African countries are liquid and solid mineral-based such as oil and gas, diamond, gold, bauxite, iron, steel, and copper. For the exploration and exploitation of these minerals, well-trained persons with a chemistry background are needed. Hence with the challenges impeding the progress of chemistry education out of the way, Africa can be assured a more purposeful pathway to development and in some way, the attainment of some of the Sustainable Development Goals (e.g., Goals 2, 3, 6, 7, 9, 14 and 15).

1.4. Research Questions

Having established the chemistry concepts that secondary school students find difficult to learn in the perceived order of difficulty (see Table 1) in the first phase of this study, the current endeavour, therefore, sought answers to the following questions:

1. Will there be statistically significant differences in the perception of (a) male and female students; (b) students in urban and rural schools; and (c) students in public and private schools of difficult concepts in chemistry?
2. What specific difficulties do students have with learning the top five perceived most difficult topics in chemistry (Table 1)?
3. What are the possible causes of or factors responsible for these difficulties?
4. How can these difficult concepts be made easy to learn from the perspectives of the students?

2. Methodology

A mixed-method (explanatory sequential) design was adopted to collect data for this study. Two instruments were developed: Difficult Concepts in Chemistry Questionnaire (DCCQ) and the Difficult Concepts in Chemistry Interview Guide (DCCIG). Two West African countries, Ghana and Nigeria were selected for the study. This was based on two considerations. Both countries use the same WAEC chemistry syllabus and hence, are comparable in terms of the primary goal of the study- investigate topics/concepts that students find difficult to learn. It would have been a weakness of the study if the countries selected did not operate the same chemistry syllabus for the senior school certificate examination.

Secondly, of the five countries operating the same chemistry syllabus in anglophone West Africa, Ghana and Nigeria make up about 70% of chemistry students enrolled in senior secondary schools. The two countries have not less than 12% of the chemistry students enrolled in secondary schools in sub-Saharan Africa. This provides some assurance that the sample of the study from the two countries will depress the possibility of committing type 1 error. Participants in this study were 1,292 senior secondary school class 3 (SS3) chemistry students from nine public and 12 private senior secondary schools in Nigeria and Ghana. This class of students (final year) was considered appropriate because, at the time of data collection, the students had covered about 98% of the curriculum requirement for secondary school chemistry. About 51% of the respondents were females. Three-quarters of the schools are in urban areas, the rest being rural located. Twenty-four (12 males and 12 females) randomly selected students were interviewed from the 58 participants who indicated a willingness to participate in the interview sessions through the consent form that accompanied the questionnaire. The interview responses form the qualitative data for the study.

2.1. Instrumentation

The DCCQ was used to collect quantitative data for the study. It had five sections. Section A collected demographic data. Section B had 22 topics (see Table 1) drawn from the new chemistry syllabus used, as stated earlier, by all schools in Nigeria and Ghana. The section had a three-point rating scale of very difficult, moderately difficult and not difficult. Section C sought to know from the respondents, the factors influencing their perception of the difficulty of the topics. This section has a listing of reasons for the difficulties, derived from a pilot study and placed on a four-point rating scale of strongly agree (SA), agree (A), disagree (D) and strongly disagree (SD). Section E sought their suggestions for improvement.

Validation of DCCQ was conducted by a team of 12 experts in science and technology education. Upon endorsement of validity, the test-retest reliability coefficient of the instrument after two weeks of administration was found to be 0.88. The Difficult Concepts in Chemistry Interview Guide (DCCIG) was the qualitative instrument used to elicit responses from the randomly selected interviewees. The instrument contained three basic questions; list any five concepts you consider most difficult to learn in chemistry, please explain why you find each of these concepts difficult to learn, please suggest ways by which these concepts can be made easy for you to learn.

2.2. Procedure for Data Collection

After seeking permission from school authorities to conduct the study (principals of public schools and in some cases of private schools, the proprietor) the researcher team ensured a friendly atmosphere in all the schools wherein the respondents felt relaxed and ready to participate (this was achieved with the help of the school chemistry teacher in some cases, particularly in the public schools). The purpose of the exercise was said to the students as already indicated on the questionnaire and they were told that participation is strictly voluntary. We ensured that each participant signed the attestation statement on the questionnaire which expressed freedom of participation and willingness to do so under the authority of the school. The information which was not readily available to the respondents (such as teacher's qualification and years of experience) was provided on a general note. This phase of the data collection lasted about two weeks.

The Difficult Concepts in Chemistry Interview Guide (DCCIG) was used to interview the selected students. The interview took place a day after the administration of the questionnaire. This was according to the time allocated to us by school authorities so as not to deprive the students of other learning activities, hence, we used the long-break period to conduct the interviews except for two students who were absent on that day. Each interview session took about 10 minutes. The conversations were recorded with the consent of the schools and the students.

3. Data Analysis and Findings

IBM-SPSS Version 23 was used to analyze the data generated from the questionnaires. In the data coding process for the first phase of this study, not difficult was scored 1, moderately difficult=2, and very difficult=3. For each respondent, it was then possible to get a difficulty score for each of the concepts which ranged between 1 and 3. After the initial raw analysis of the three-point scale of not difficult, moderately difficult and very difficult and the four-point scale of strongly agree, agree, disagree and strongly disagree, for the purpose of this study, the data was clustered into difficult or not difficult and yes or no for parsimony (see Table 2 and Figure 1). This was achieved via data transformation.

The mean rank method (Okebukola, 1990) was used to answer the main research question of the study. This involved a two-step process. The first step was, to sum up, the difficulty scores of all the respondents for each topic, and then divided the sum by the number of respondents. This gave us the mean difficulty score for each topic. The second step was to rank the 22 topics in the questionnaire in order of the mean difficulty scores. This resulted in the ranking from 1st (most difficult of the 22 topics) to 22nd (least difficult) as perceived by chemistry students in the sample as shown in Table 1.

To address the first research question in this phase of the study, data collected from the categorical data which are of interest to this study (gender, school location and school type) were cross-tabulated in percentages. Chi-square statistic was then applied to the cross-tabulated data. For the first segment of the question which sought to find out if there are statistically significant differences in the perception of male and female students in the level of difficulty of the topics in the chemistry curriculum, we present our findings in Table 2.

S/N	Chemistry concepts	Male		Female		Chi square
		Difficult	Not difficult	Difficult	Not difficult	
1	Benzene and its Compounds	78.0	22.0	80.9	19.1	1.68
2	Nuclear Chemistry	80.5	19.5	79.4	20.6	0.26
3	Salt analysis (qualitative analysis)	81.3	18.7	75.5	24.5	6.51*
4	Volumetric analysis (Titration)	78.9	21.1	73.5	23.5	5.21*
5	Chemical equations & equilibrium	75.0	25.0	77.4	22.6	1.09
6	Alkanols, Alkanals and Alkanones	77.2	22.8	72.9	27.1	4.37
7	Acid-Base titration calculations	72.4	27.6	74.1	25.9	0.49
8	Solubility	74.0	26.0	72.2	27.8	0.55
9	IUPAC nomenclature	68.6	31.4	71.3	28.7	1.12
10	Lipids, soap and detergent	71.1	28.9	65.4	34.6	4.87*
11	Electrolysis	65.1	34.9	70.7	29.3	4.66*
12	Oxidation and Reduction (Redox	62.8	37.2	63.2	36.8	0.01
13	Chemical bonding	67.5	32.5	65.3	34.7	0.70
14	Hydrocarbons	61.4	38.6	56.7	43.3	2.96*
15	Electronic configuration	53.3	46.7	57.1	42.9	1.96
16	Gas laws	54.4	45.6	51.7	48.3	0.91
17	Separation techniques	48.3	51.7	52.3	47.7	2.94
18	Atomic structure and theories	55.7	44.3	52.6	47.4	1.19
19	Metals, Non-metals and their	56.5	43.5	52.9	47.1	1.62
20	Kinetic theory of matter	50.9	49.1	51.0	49.0	0.00
21	Acids, bases and salts	51.2	48.8	48.0	52.0	2.47
22	Periodic Table	44.3	55.7	43.2	56.8	0.18

Table 2. Crosstabulation of perception of the difficulty of chemistry concepts by male and female students

The results confirmed that of the 22 topics, only five showed gender differences. These are salt analysis (qualitative analysis), volumetric analysis (titration); lipids, soap and detergent; electrolysis; and hydrocarbons. While benzene and its compounds remain the most difficult concepts for the female students (80.9%), salt analysis is perceived as most difficult by the male students (81.3%). The second component of the first research question probed possible urban/rural differences. The results of the chi-square test are shown in Table 3.

S/N	Difficult concepts	Rural		Urban		Chi square
		Difficult	Not difficult	Difficult	Not difficult	
1	Benzene and its Compounds	83.3	16.7	78.2	21.8	3.80*
2	Nuclear Chemistry	76.2	23.8	81.2	18.8	3.87*
3	Salt analysis (qualitative analysis)	83.3	16.7	76.7	23.3	6.23*
4	Volumetric analysis (Titration)	80.2	19.8	74.8	25.2	3.84*
5	Chemical equations & equilibrium	79.9	20.1	75.0	25.0	3.15*
6	Alkanols, Alkanals and Alkanones	80.2	19.8	73.4	26.6	8.88*
7	Acid-Base titration calculations	74.3	25.7	73.0	27.0	0.22
8	Solubility	75.2	24.8	72.3	27.7	1.03
9	IUPAC nomenclature	78.3	21.7	67.2	32.8	14.32*
10	Lipids, soap and detergent	70.9	29.1	67.3	32.7	1.46
11	Electrolysis	71.5	28.5	66.8	33.2	2.51
12	Oxidation and Reduction (Redox reaction	68.4	31.6	61.2	38.8	5.42*
13	Chemical bonding	73.7	26.3	63.9	36.1	10.43*
14	Hydrocarbons	62.8	37.2	57.7	42.3	2.67
15	Electronic configuration	62.5	37.5	52.8	47.2	9.22*
16	Gas laws	57.3	42.7	51.6	48.4	3.13*
17	Separation techniques	55.4	44.6	48.6	51.4	4.76
18	Atomic structure and theories	62.5	37.5	51.3	48.7	12.34*
19	Metals, Non-metals and their compound	54.8	45.2	54.6	45.4	0.00
20	Kinetic theory of matter	62.8	37.2	47.0	53.0	24.48*
21	Acids, bases and salts	58.8	41.2	46.4	53.6	15.08*
22	Periodic Table	43.0	57.0	44.0	56.0	0.09

Table 3. Chi-square analysis of concepts perceived as difficult by students in rural and urban schools

We found that most of the observed differences between students of private and public schools were statistically significant ($p<.001$). The result also showed that nuclear chemistry was perceived as the most difficult concept (81.2%) by students from urban schools while benzene and its compounds and salt analysis (83.3%) were topmost on the list of students from rural schools. The third component of research question one sought to find out if there will be a statistically significant difference in perception of difficult concepts in chemistry by students in private and public schools. Table 4 presents our findings. In only 7 of the 22 topics did we find statistically significant differences in perception of difficulty. These are benzene and its compounds; nuclear chemistry; alkanols, alkanals and alkanones; acid-base titration calculations; solubility; electronic configuration; and gas laws. In most cases, students in rural areas had higher perceptions of difficulty.

The second question in this study sought to x-tray the specific difficulties that students have with learning the top five perceived most difficult topics in chemistry as reported by Oladejo, Okebukola, Olateju et al. (2022). Responses from the interviews were winnowed and summarized based on the preponderant views. We ensured to probe the students on specific aspects of each of the five topics. Here are some excerpts.

Benzene and its compound: *I like the shape of the benzene, it is hexagonal. I also know that it has three double and single bonds. My major problem with it is that the naming is somehow difficult. It is not like the naming of other organic compounds. I think why it is difficult for me is because our teacher just rushed the topic, he didn't explain it very, very well and when I try to read it on my own, I don't understand. Again, I am not sure if there is any difference between benzene double bond and that of alkene.*

Nuclear chemistry: *For me and my friends, our challenges with nuclear chemistry are in calculation of half-life of a radioactive element, radioactive disintegration, radioactive decay series, rate of radioactivity decay because our teacher did not teach us. We were only asked to form the note from out textbooks and submit for marking*.

Salt analysis: *How to perform the test for gases is easy because we have the note, but we are yet to do some of the practical and we understood it. Colour of compounds or salts and confirmatory test for anions and cations. This aspect is difficult because we have not really been taught.*

Volumetric analysis: *Acid-base titration is easy because our teacher taught us the practical, we also understand how to calculate molar concentration and atomic mass. Some aspects like calculating percentage purity and water of crystallisation are still difficult. It is also difficult to get endpoint sometimes. Redox titration is difficult because we did not get the practical very well and our teacher did not explain it very well because we don't have much time.*

Chemical equations and equilibrium: *The definition or meaning of chemical equilibrium and Le Chatelier's principle is easy because it is self-explanatory. The difficult parts include equilibrium constant because of the derivation of the formula. It is somehow complicated and difficult to understand. Haber process and Arrhenius theory. Difficult to plot the graph of percentage yield of ammonia gas at various pressure and temperature as well as the properties of a system existing equilibrium.*

S/N	Chemistry concepts	Private		Public		Chi square
		Difficult	Not difficult	Difficult	Not difficult	
1	Benzene and its Compounds	75.7	24.3	81.5	18.5	6.09*
2	Nuclear Chemistry	74.8	25.2	82.7	17.3	11.41*
3	Salt analysis (qualitative analysis)	77.9	22.1	78.5	21.5	0.07
4	Volumetric analysis (Titration)	75.9	29.1	76.3	23.7	0.02
5	Chemical equations & equilibrium	76.6	23.4	76.0	24.0	0.05
6	Alkanols, Alkanals and Alkanones	69.8	30.2	77.8	22.2	11.69*
7	Acid-Base titration calculations	69.1	30.9	75.6	24.4	6.29*
8	Solubility	77.3	22.7	70.8	29.2	6.25*
9	IUPAC nomenclature	68.4	31.6	70.8	29.2	0.78
10	Lipids, soap and detergent	65.8	34.2	69.5	30.5	1.86
11	Electrolysis	68.7	31.3	67.6	32.4	0.16
12	Oxidation and Reduction (Redox reaction)	62.7	37.3	63.2	36.8	0.03
13	Chemical bonding	66.2	33.8	66.4	33.6	0.00
14	Hydrocarbons	61.6	38.4	57.6	42.4	1.97
15	Electronic configuration	49.9	50.1	58.2	41.8	8.15*
16	Gas laws	60.5	39.5	49.0	51.0	15.62*
17	Separation techniques	47.7	52.3	51.7	48.3	2.53
18	Atomic structure and theories	52.8	47.2	54.8	45.2	.51
19	Metals, Non-metals and their compounds	54.5	45.5	54.7	45.3	0.00
20	Kinetic theory of matter	53.6	46.4	49.5	50.5	2.06
21	Acids, bases and salts	47.9	52.1	50.5	49.5	2.74
22	Periodic Table	44.6	55.4	43.3	56.7	0.21

Table 4. Crosstabulation of perception of the difficulty of chemistry concepts by students in private and public schools

The third research question sought answers to possible causes of the difficulties experienced by the sampled students in learning chemistry at the senior secondary school level. In addition to the qualitative data gathered from selected students, Figure 1 shows findings of possible causes of difficulties.

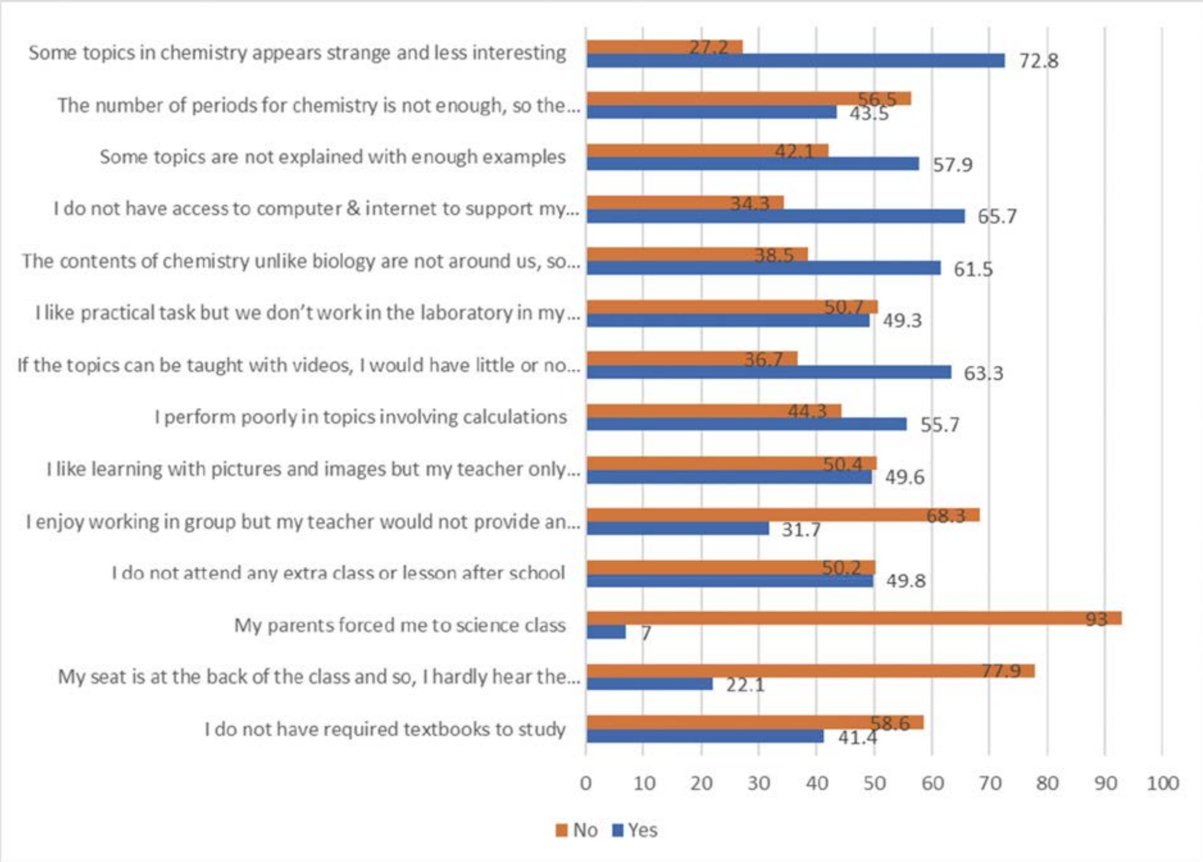

Figure 1. Reasons for perceived difficulty in chemistry concepts

The items in Section E of DCCQ to which more than 50% of the students in the sample gave as reasons for perceived difficulty are "I perform poorly in topics involving calculations" (55.8%); "If the topics can be taught with videos, I would have little or no difficulty" (63.2%); "The contents of chemistry, unlike biology, are not around us, so I hardly remember them" (61.3%); "I do not have access to computer & internet to support my learning after school like my friends" (65.7%); "Some topics are not explained with enough examples" (57.9%); and "Some topics in chemistry appear strange and less interesting" (72.9%).

The fourth research question inquired about the way out of making these chemistry concepts easy for students to learn. The students were unanimous in asking for help with calculations, more time for chemistry lessons on the school timetable, extra lessons after school hours, detailed explanations with concrete examples, and exposure to practical experiences in the chemistry laboratory.

4. Discussion of Results

This study investigated concepts in the new chemistry curriculum for secondary school students that are perceived as difficult based on gender, school location and school type/ownership. Overall, the cluster of the ten most difficult concepts found in this study agrees in part with those found by Opeke (1998) in studies carried out on the chemistry curriculum of the last twenty years. Nuclear chemistry continues to be perceived as a difficult topic since it was introduced into the chemistry curriculum of West African schools in the mid-1970s. Also found by previous studies to be in the league of difficult topics are chemical equations and equilibrium and acid-base titration calculations (Opeke, 1998; Uzezi, Ezekiel & Auwal 2017).

It is worth noting that in contrast, our study found oxidation and reduction (redox reactions) which had consistently been perceived as difficult by students operating the old chemistry syllabus to be easy. This is a refreshing development in view of the importance of redox reactions to the understanding of chemistry as a subject. A possible reason for the shift from being a difficult topic to one that is perceived as easy is the accent given to redox reactions in chemistry teacher preparation over the last twenty years. It can be speculated that with a deeper understanding of redox reactions, teachers were able to teach redox reactions to students to a level that promoted comprehension. Over time, redox reactions largely eased off the difficult concept zone to the easy concept zone. No doubt, several other factors could have interplayed to explain this shift (Agogo & Onda, 2014).

The first research question of the study focused on gender difference in how chemistry students perceive topics in the new chemistry curriculum to be difficult. Table 2 shows that in about 90% of the topics, statistically significant gender differences were not recorded. No pattern emerged in favour of male or female students from our results. Of the top ten topics perceived to be most difficult, relative to female students, male students found the following topics to be more difficult - nuclear chemistry, salt analysis (qualitative analysis), volumetric analysis (titration), alkanols, alkanals and alkanones, solubility, and lipids, soap and detergent. On the other hand, female students, relative to their male counterparts, perceived the following topics to be difficult- benzene and its compounds, chemical equations and equilibrium, acid-base titration calculations, and IUPAC nomenclature. Thus, being female or male may not be a significant factor in difficulties experienced in learning chemistry concepts.

The results obtained on rural and urban school students' perception showed that in over 60% of the 22 concepts examined, students from urban schools had fewer learning difficulties compared to their mates in rural schools. The chi-square analysis revealed a significant difference in the perception of the difficulties in 14 concepts out of 22 (including the first six most difficult concepts) in favour of students from urban schools. A similar trend was also observed between students from private and public schools. However, the sampled public-school students perceived solubility, electronic configuration, and gas laws as less difficult to learn compared to their colleagues from the private schools (see Tables 3 and 4). The difference in perception that is observed between private and public school students and rural and urban school students can generally be traced to lack of or inadequate provision of learning resources, class (over) population, teachers' motivation, parents' economic status and opportunity to learn after school.

The second research question sought the specific difficulties that students have with learning the top five perceived most difficult topics in chemistry as identified in the first phase of this study (Oladejo et al., 2022). Since most previous studies terminated their quest at the level of mere listing of the perceived difficult concepts, it was a key objective of this study to dig deeper and probe the aetiology of the difficulty. We went about this via a qualitative pathway, interviewing students and analysing the chemistry curriculum and other relevant documents. As noted in the results section, several interesting findings emerged. We will focus on discussing five of the topics found to be difficult, starting with the most difficult, that is, benzene and its compounds. In the chemistry curriculum, students are expected to learn the structure, and physical and chemical properties of benzene and describe the bonding in benzene and the way its typical reactions differ from those of the alkenes.

In addition, they are to learn resonance in benzene, stability leading to substitution reactions; addition reactions: hydrogenation and halogenation; and compare reactions with those of alkenes. The textbooks commonly used by chemistry students give the structural representation of benzene as a six-carbon ring (represented by a hexagon) which includes three double bonds. Each of the carbons represented by a corner is also bonded to one other atom, which is hydrogen. The double bonds are separated by single bonds, so we recognise the arrangement as involving conjugated double bonds. An alternative symbol uses a circle inside the hexagon to represent the six pi electrons. Given this summary of the demands of the curriculum on the topic, why did students in the study find it the most difficult to learn? Interview data narrowed to the complexity of equations relating to reactions of benzene.

> One of the students "Tunde" (male; 15 years; public school) reported that: *What I find difficult in benzene and its compound is the equations in which benzene and benzene-like compounds undergo. Their reactions are complex.*

What are these complex reactions that "Tunde" was referring to? They include equations for sulphonation, alkylation and acylation of benzene, and halogenation of benzene. From his responses and those of other students, we noted that weak preparation in balancing chemical equations and in depicting ionic structures can explain the phobia for the chemical reactions of benzene. Another dimension to the difficulty with benzene and its compounds was provided by "Adekola" a 15-year-old male student at a private school. "Adekola" confirmed that not all aspects of the topic are difficult to learn and narrowed to those he perceived to be difficult. He responded as follows to our interview question as to why benzene and its compounds was a difficult topic to learn:

The structure of benzene is quite easy because it is represented as a hexagon, and it has double bonds. Use of benzene is equally easy because it relates to everyday life. But the chemical properties of benzene and to name the compounds are difficult because our teacher did not give us proper explanation, the topic was not taught very well, and it is difficult to understand by oneself.

The naming of compounds of benzene stood out as Adekola's difficult zone. This view is not uncommon as many chemistry students have difficulty with the IUPAC nomenclature that the chemistry curriculum insists is the acceptable way of naming chemical compounds and of which benzene compounds are laden. The matter of weak content knowledge of benzene and its compounds by the teacher expressed in the inability to satisfactorily explain the concept to students also came out in Adekola's explanation of factors impeding meaningful learning of the concept.

Nuclear chemistry came out as the second topic that students in the sample find difficulty with. The new chemistry curriculum demands that students should learn the types and nature of radiations: alpha, beta particles and gamma radiation; radioactivity: induced/stimulated; nuclear reactions: fission and fusion in nuclear reactions; effects and application of radioactivity; binding energy, neutron-proton ratio, and half-life; calculations involving half-life. Of all these aspects of the concept, which stand(s) out as the most difficult and which ones are easy? We found answers in the responses to our interview of the students as already indicated in the result section. For example, Bolakele, a 15-year-old female student from a public school said:

The meaning of radioactivity and the types of radiation are quite easy because we have been taught. The definition of alpha particle, beta particle and gamma particle are equally not difficult. Also, uses of radioisotopes because it is applied in different work area like medical field and industries. Our challenges are in calculation of half-life of a radioactive element, radioactive disintegration, radioactive decay series, rate of radioactivity decay, concept of nuclear fission, fusion and binding energy.

Calculation of the half-life of a radioactive element is a challenge for "Bolakale" and as our qualitative data show, for many of the students. How is half-life calculated that students find difficulty with understanding the process? Half-life (symbol t1⁄2) is the time required for a radioactive substance to reduce to half of its initial value. It is calculated using two main methods, the first is using proportionality and the second is through any of the three equivalent derived formulae (see Osei, 2018). We can explain the difficulty of students with calculating half-life by the pervasive phobia of any activity that demands calculations and formulae (Ademola, Okebukola, Oladejo, Onowugbeda, Gbeleyi & Agbanimu, 2021). Even with simple formulae, many students abhor calculations. They would appear wired to fear any form of calculation. In chemistry examinations, students score the lowest in questions where calculations are involved (WAEC Chief Examiners' Reports, 2015-2019). It is worth noting that the other aspects of nuclear chemistry that students find difficulty with (as expressed by the interviewees) - radioactive disintegration, radioactive decay series, and rate of radioactivity decay, are coloured with calculations.

The third most difficult topic was salt analysis (qualitative analysis). This is about finding out the nature, constituents, and identity of salts. Qualitative analysis of inorganic salts means the identification of cations and anions present in the salt or a mixture of salts. This is typically a practical exercise which the curriculum demands should involve characteristic and confirmatory tests of the following cations with dilute NaOH(aq) and NH3(aq); NH4; Ca^{2+}; Pb^{2+}; Cu^{2+}; Fe^{2+}; Fe^{2+}; Al^{2+}; and Zn^{2+}; characteristic reaction of dilute HCl on solids or aqueous solutions and conc. H_2SO_4 on solid samples of the following: Cl^-; SO_3^{2-} ; CO_3^{2-} ; NO^{3-} and SO_4^{2-} . As the name implies and as provisioned in the chemistry curriculum, salt analysis is a hands-on activity. It involves carrying out a series of practical activities including flame test to show, for instance, potassium salts to yield a lilac colour, calcium brick red and sodium salts with golden yellow colour. It involves carrying out several chemical tests to reveal the anionic and cationic compositions of salts. These tests include solubility in water based on the following general solubility rules (see Osei, 2018).

The practical sessions on salt analysis should also cover reactions with nitric acid, sodium hydroxide, ammonia, sulphuric acid, hydrochloric acid and silver nitrate. If these practical exercises were carried out, where then lies the difficulty with salt analysis? Our interview data showed that some students lacked clarity about the reagents to use and how to use them for qualitative analysis while for many students, it is a complete lack of opportunity to carryout any practical. Ayinke (female, 15 years, private school) said: *"I don't understand salt analysis (qualitative analysis) because the reason for using the reagents/solutions and making inferences about the ion present are not too clear"*. Most of the students interviewed as exemplified by "Nneka" - a 15-year-old female student from a public school confirmed that she and her colleagues had difficulty with salt analysis because they did not have practical sessions for conducting these analyses. This outcome tallies with the quantitative responses gathered from the students on why they found salt analysis difficult to learn.

The fourth topic perceived to be difficult by chemistry students in the sample is volumetric analysis (titration). In the new chemistry syllabus, students are expected to use standard solutions of acids and alkalis and the indicators- methyl orange, methyl red and phenolphthalein to determine the following: (i) concentrations of acid and alkaline solutions; (ii) molar masses of acids and bases and water of crystallisation; (iii) solubility of acids and bases; (iv) percentage purity of acids and bases; (v) analysis of $Na_2CO_3/NaHCO_3$ mixture by double indicator methods. They also expected to carry out redox titrations of the following systems to solve analytical problems: (i) acidic MnO^{4-} with Fe^{2+}; (ii) acidic MnO^{4-} with $C_2O_4^{2-}$; and (iii) I_2 in KI versus $S_2O_3^{2-}$. Where lies the difficulty with learning these concepts by chemistry students? Interview data pointed largely at difficulty with calculations. Nneka's response captured/summarized completely the submissions of other students on this concept

> Nneka a 15-year-old female student from a public school said - *Acid-base titration is easy because our teacher taught us the practical, we also understand how to calculate molar concentration and atomic mass. Some aspect like calculating percentage purity and water of crystallisation is still difficult. It is also difficult to get the endpoint sometimes. Redox titration is difficult because we did not get the practical very well and our teacher did not explain it very well because we don't have much time.*

The fifth in rank of the most difficult concepts is chemical equations and equilibrium. Just as we highlighted the details of the requirements of the new curriculum for the first four most difficult concepts, the curriculum requires students to learn chemical equilibrium to gain mastery in the following subheads:

- The concept of equilibrium systems;
- Equilibrium in reversible reactions;
- Equilibrium constant;
- Le Chatelier's principle; effect of change in temperature, pressure, concentration and of catalyst on a chemical system in equilibrium;
- The Haber's process and the contact process;
- Acid-base equilibrium; pH scale and indicators; and
- Buffer solutions.

We found out that the sampled students were familiar with this topic and have been taught by their teachers. Responses from the interview showed that students have a good mastery of the concept of equilibrium, reversible (forward and backwards) reactions and dynamic equilibrium. Le Chatelier's principle was also considered an easy aspect of chemical equilibrium. However, the majority of the interviewed students confirmed a lack of understanding of the principle. As we probed further, we found that not having practical sessions or experiencing the applicability of Le Chatelier's principle with respect to temperature, pressure, concentration, and catalytic effect on equilibrium state, showing how forward or backward reactions can be favoured was a major contributing factor to students' difficulty.

For instance, meaningful learning would have been achieved on the effect of a change in temperature on the equilibrium state if the teacher had carried out an experiment that involves the mixture of nitrogen (IV) oxide and dinitrogen (IV) oxide with the students. The students would have observed that at room temperature, the gaseous mixture is light brown in colour as both nitrogen (IV) oxide and dinitrogen (IV) oxide molecules are present in appreciable amount. While at 0ºC, the colour of the mixture becomes pale yellow as dinitrogen (IV) oxide predominates and at 100ºC, the mixture turns dark brown as most of the dinitrogen (IV) oxide molecules dissociate to nitrogen (IV) oxide molecules. This experience would have registered an indelible understanding in the students that the equilibrium of a reaction shifts when the temperature changes. Other aspects found difficult by the students in learning this concept are as expressed by Nasiru and Adesola.

> Nasiru (male; 15years old; private school student) revealed that *the definition or meaning of chemical equilibrium and Le Chatelier's principle is easy because it is self-explanatory. The difficult parts include equilibrium constant because of the derivation of the formula. It is somehow complicated and difficult to understand. Haber process and Arrhenius theory. Difficult to plot the graph of percentage yield of ammonia gas at various pressure and temperature as well as the properties of a system existing equilibrium.*
>
> Adesola (female, 16-year-old, public school student) *for me I can still manage to cope with of the aspect you have mentioned. My major area of concern lies in pH calculations using logarithm, Harber and Contact process. Again, though I have made several practices, but I still have a problem remembering how to prove the equilibrium constant.*

The submissions of Nasiru and Adesola have some common loop. They show a reflection of weakness in mathematics which may be attributed to poor background on the part of the students or that of the chemistry teacher. Experiences over the years have also shown that most chemistry teachers do not take students through these aspects thoroughly. They often skip with the intention of wanting to complete the scheme for the term before the set dates for the examination. In addition, one would wonder why students should have difficulty understanding Harber's process – a process that simply involves reacting hydrogen gas with nitrogen gas to produce ammonia and this is usually achieved in a ratio of 3:1:2. That is for every three moles of hydrogen gas, one mole of nitrogen gas is required to produce two moles of ammonia. Oftentimes, the difficulties students encounter in understanding concepts like this border around the teachers' choice of teaching method and/or instructional strategy.

Summary of students' interviews on difficulties associated with the learning of the first five concepts perceived as most difficult cumulated into three themes. These themes which were deduced by identifying the most common reasons for the difficulties as expressed by the participants are difficulty with calculations in chemistry, difficulty with equations of reactions and inadequate exposure to laboratory sessions. For theme one, as earlier stated, it has been observed that generally, most students (as some teachers) have a phobia for mathematics or learning activities involving calculations which is either due to poor background in mathematics (Adewusi 2020; Onyewuchi, 2020), the inability of the teacher to provide adequate explanation and examples, laziness and lack of concentration on the part of the students. For theme two, the difficulty encountered can be associated with inadequate knowledge of the teacher in subject matter, inadequate use of examples and illustrations, lack of learning materials by the students, and lack of opportunity to learn after school. While theme three echoes the lack of laboratories and/or inadequate reagents and apparatus in most schools.

On a general note, the results obtained from reasons for difficulty clearly showed that lack of modern learning facilities and timely access to information is a major contributing factor to the difficulties encountered by students. The majority of the students sampled for this study confirmed that lack of access to the internet and lack of audio-visual facilities (see Fig. 1) to make learning more appealing contribute to their difficulties. Corroborating the findings of this study is the submission of Okebukola, Suwadu et al. (2020) which revealed that factors contributing to students learning difficulties in science include teachers' lack of adequate content knowledge; poor interest in calculation-related concepts; lack of opportunity for in-service training or short courses; and the inability of school proprietors to provide necessary learning facilities.

To ease the difficulties identified by the students, suggestions for improvement borders around teachers' competency in concepts involving calculations, use of examples and illustrations, provision of a well-equipped laboratory for practical, infusion of practical hours on the school general timetable, procurement of learning materials for students, additional time for learning chemistry within the week which may include extension classes to cater for the shortage in class-time. The provision and use of new technologies for teaching and learning should also be embraced. It is worth stressing that not until these difficulties are addressed, the hope to significantly improve secondary school students' performance in chemistry will only remain a mirage.

5. Conclusions and Recommendations

The new senior secondary chemistry curriculum for anglophone West African schools came into use in 2014/2015. Since the beginning of its implementation, there have been few reported studies on the difficulty level of the content. There is no published study which conducted an in-depth probe of the aspects of the topics that students find difficulty with, in science, particularly in chemistry beyond mere cataloguing of the difficult topics. This is a huge gap in the literature that the present study attempted to fill. This effort is significant to the extent that our understanding of the aspects of the topics that students find difficulty with will guide teachers and other stakeholders in applying appropriate remediation.

Some important matters arose from our study through our interactions with the students. Most conspicuous among them is the teachers' competence in content and pedagogical knowledge. A good number of the students hanged the difficulties they have on their teachers. While we are not blind to the possibility of "blame-shifting," we consider it very important not to look away and that leaves us with some reflections. Would these concepts or topics have been perceived as difficult at all if the teachers are ground in them? Do the teachers truly possess the required methodology to help students break barriers to meaningful learning? Are the students themselves primed for learning? Our interview data further confirmed that generally, most students (and some teachers) have fright for mathematics or learning activities involving calculations. This made chemistry topics involving calculations leap to the top of the difficulty ranking table. We also found inadequacies in chemistry content knowledge of the teachers, inadequate use of examples and illustrations, lack of learning materials by the students, and lack of opportunity to learn after school as impediments to learning chemistry. While our intention is not to generalise beyond the sample of this study, based on our findings, we consider it expedient to offer the following recommendations:

1. Refresher courses should be organised for chemistry teachers on how to better deliver topics that are perceived as difficult to learn by students, especially the top 10. In such courses, emphasis should be on why students find such difficult concepts difficult to learn and how, from the point of view of the students, they can be taught to make the topics easy to learn.
2. Special attention should be paid to better resourcing science laboratories in rural schools. Experienced teachers should be motivated and incentivised to offer services in such schools.
3. Chemistry topics that girls found difficult to learn, relative to boys should be further probed to ascertain the nature of the difficulty and subsequently, apply remedial measures.
4. Remedial classes in mathematics are needed for both students and teachers to overcome the challenge of calculations which made some of the topics difficult to learn.

6. Ethical Statement

This study was conducted with due diligence to ethical considerations. School authorities were fully informed and involved in our engagements with the students. The students were equally made to understand the essence of the study and their involvement based on the authorities' approval. Schools' and students' participation were 100% voluntary without the researchers withholding any information.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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