GhanaianSenior High School Students' Performance and Perception of Difficult Chemistry Topics

Abstract

Keywords: *chemistry performance, perceived topic difficulty, perception of chemistry, senior high school, levels of chemical representation.*

This study investigated students' perceptions of difficult chemistry topics and how it relates with students' performance in chemistry. A quantitative approach was adopted using a cross-sectional survey design. The sample consisted of sixty (60) form 2 chemistry students.Two senior high schools that offer a general science programme were purposively selected,then, thirty chemistry students were selected from each school using a simple random sampling. It was found that only five out of the twenty-three topics (21.7%) were perceived to be easy by the students, whiles 78.3% were perceived to be difficult. The topics perceived as easy were basic safety laboratory practices, the particle nature of matter, atomic structure, chemical bonding and hybridisation, and the shapes of molecules. However, the topics perceived to be difficult for the students were: amount of substance and the C-12 scale; solutions, stoichiometry, and chemical equations; nuclear chemistry; enthalpy changes and bond enthalpies; periodic chemistry; rate of chemical reactions; transition metal chemistry; acids, bases, and the concepts of pH and pOH; electrochemical cells; solubility; organic chemistry; redox reactions, and balancing redox reactions; chemical equilibrium; hydrolysis of salts; and acid-base titration and redox titration. The study found that students have a moderate perception of chemistry ($M = 3.30$, $SD = 0.61$). However, it was found that students held positive perceptions on the dimensions of value of chemistry. The held moderate perception in the dimension of gender, interest and fear of chemistry. The students held negative perceptions in characteristics of chemistry dimension. There was no significant difference in perceptions of difficult chemistry topics between males ($M = 3.025$, $SD = 0.36$) and females ($M = 2.98$, $SD = 0.417$), $t(58) = 0.356$, $p = 0.723$. Again, there was no significant difference in the perception of students towards chemistry between males ($M = 3.22$, $SD = 0.60$) and females ($M = 3.54$, $SD = 0.61$), $t(58) = -1.83$, $p = 0.07$. The multiple regression analysis revealed that perceived chemistry topic difficulty and perception of chemistry did not significantly predict chemistry performance. Thus, there is a relationship between chemistry performance, perceived chemistry topic difficulty and perception of chemistry, however, this relationship is not significant ($F [2, 57] = 2.420$, $p = 0.098$). The coefficient of determination ($R^2 = 0.078$) indicates that 7.8% of variation in students' chemistry performance can be explained by students' perceived chemistry topic difficulty and students' perception of chemistry. Chemistry teachers should use interactive learning approaches and inquiry-based learning to involve students in fostering curiosity and exploration. The study recommends that Chemistry teachers can utilise technology tools such as interactive simulations, virtual labs, and multimedia resources to enhance learners' understandingand be able to relate and transition between the levels of representations of chemistry.

1.Introduction:

“Chemistry plays an important role in the development of a country”(Emendu & Emendu, 2017; Samuel et al., 2010). Udogu (2010) described chemistry as a body of knowledge that stands in a central position among the basic sciences. Knowledge of chemistry is very crucial in modern life.However,it proves to be a difficult subject for students. The complex and abstract nature of chemistry makes the study of the subject difficult for students (Gabel, 1999; Treagust & Chittleborough, 2001; Taber, 2002). These difficulties that students experience is related to the multiple levels of representation that are used in chemistry teaching to describe and explain chemical phenomena. Johnstone (1993) distinguished three levels of chemical representation of matter: the macroscopic level, the sub-microscopic level, and the symbolic level (Ramnarain & Joseph, 2012).

Chandrasegaran et al. (2007) describe these three levels of representation relevant to the understanding of chemistry concepts as: (1) macroscopic representations describe properties of tangible and visible phenomena in the everyday experiences of students when observing changes in the properties of matter (e.g. colour changes, pH of aqueous solutions, and the formation of gases and precipitates in chemical reactions), (2) submicroscopic (or molecular) representations provide explanations at the particulate level in terms of atoms, molecules and ions, and (3) symbolic representations involve the use of chemical symbols, formulas and equations, as well as molecular structure drawings, diagrams, models and computer animations to symbolize matter (cited in Ramnarain & Joseph, 2012).

“Chemical concepts or theories cannot be easily understood if the learner does not understand the underlying concepts” (Coll & Treagust, 2002; Nicoll, 2001). Ogembo (2012) agreed that the background of the students, and negative perceptions toward chemistry, are the major causes of students’ poor performance in chemistry. Again, despite the significant role of chemistry education in national development, research has reported that students around the world are reluctant to choose chemistry-related majors (Avargil et al., 2020; Wang et al., 2021) cited in Gong et al. (2023). “Understanding factors that influence student choice of chemistry majors remains an important task for researchers, educators, and policymakers wishing to increase student interest in chemistry” (Gong et al., 2023). “The difficulties encountered by students in learning chemistry range from human factors to the intrinsic nature of chemistry” (Enero Upahi & Ramnarain, 2019). “To enhance students’ understanding of chemistry, there is a wide consensus within the community of chemistry educators on the importance of and need to integrate different levels of representations in chemistry teaching and learning resources" (Enero Upahi & Ramnarain, 2019).

2. STATEMENT OF THE PROBLEM

Students perceive chemistry as abstract, difficult to learn, and unrelated to the world (De Vos et al., 2002; Osborne & Collins, 2001). Chemistry is perceived as difficult because of its specialised language, mathematical and abstract conceptual nature, and the amount of content to be learned (Gabel, 1999). This is exacerbated by the requirement for quick transmission of thought across the macroscopic, sub-microscopic, and symbolic levels (Johnstone, 1999; Gafoor & Shilna, 2013).Understanding of chemistry demands meaningful teaching (Sirhan, 2007). Research found evidence of misconceptions, rote learning, and certain areas of basic chemistry that are still not understood(Sirhan, 2007).

"The manner in which chemistry is taught also contributes to the learning difficulty students experience in the subject" (Ramnarain & Joseph, 2012). "One of the essential characteristics of chemistry is the constant interplay between the macroscopic, sub-microscopic and symbolic levels of thought, and it is this aspect of chemistry learning that presents a challenge to students" (Treagust et al., 2003).

Johnstone (1991) asserts that most chemistry instruction in high school and college chemistry courses takes place at the symbolic level, and students do not understand the relationship between the symbolic and the other two levels. Students struggle to interpret a chemical reaction to the microscopic level, and instead memorize what is being presented at the symbolic level in terms of chemical equations and mathematical relationships (Gabel, 1999). "In order for students to have a deep understanding of chemical concepts, they not only need to translate concepts using all three levels of chemical representation, but also be able to transit across levels" (Ramnarain & Joseph, 2012).

Conceptual understanding in chemistry is the ability to explain chemical phenomena through the use of macroscopic, molecular, and symbolic levels of representation (Johnstone, 1993; Wu et al., 2001; Gafoor & Shilna, 2013). When relationships are formed among these three levels of representation, students understand chemistry better (Sanger, Phelps, & Fienhold, 2000). At the macroscopic or phenomenal level, properties can be seen and measured. At the sub-microscopic level, the molecular structures of the particles cannot be seen. The symbolic level is how a chemical formula represents a substance. However, students have difficulties creating links across these levels (Gafoor & Shilna, 2013). The degree to which a student can comprehend a topic is referred to as topic or concept difficulty. Topic difficulty ranges from the least difficult, where the learner progresses in the concept from rote to meaningful learning (Novak, 2002; Grove & Bretz, 2012), to the most difficult, where the learner encounters challenges in learning the concept meaningfully (Oladejo et al., 2023). According to Cañas and Novak (2014), concept difficulty refers to the ease or difficulty of attaining an understanding of the concept.

Research found that students perceive organic chemistry as a difficult topic (Halford, 2016; Hanson, 2016; Nartey & Hanson, 2017; Childs & Sheehan, 2009; Jimoh, 2004; Johnstone, 2006). For example, Hanson (2016) reported that Ghanaian students do not understand the nature of matter and cannot connect the three representational levels of matter.According to Hanson (2017), most students cannot understand these levels of thought well and thus form a weak foundation for further study of organic chemistry concepts. Adu-Gyamfi et al. (2013) also found that Ghanaian senior high school students performpoorly in naming and writing of the structure of organic compounds. Studies revealed that senior high school students perceived the classification of organic compounds as difficult to understand (Davis, 2010; Donkoh, 2017).

Chemistry education should enable students to develop positive attitudes towards chemistry (Rüschenpöhler & Markic, 2020). Several attributes, including academic aptitude, prior knowledge, self-efficacy, self-confidence and study skills, influences students' choice of chemistry (Leong et al., 2021). Perception of topic difficulty could also affect students' attitude towards chemistry, perception and choice of chemistry at higher levels.

The topic difficulty of chemistry has been the subject of numerous research; however, this study examined topic difficulty and perception according to gender, and the relationship between students' performance in chemistry, their perception of chemistry and perceived difficult chemistry topics. Thus, the study sought to answer the following questions:

1. What are students perceived difficult topics in chemistry?
2. What is the perception of students towards chemistry?
3. Is there any statistically significant difference in perceived difficult chemistry topics between males and females?
4. Is there any statisticallysignificant difference in perceptions of chemistry between males and females?
5. Is there any statistically significant relationship between performance in chemistry, perception and perceived difficult chemistry topics?

3. RESEARCH HYPOTHESIS

- $H_0$1: There are no statisticallysignificant differences in the students' perceived difficult chemistry topics between males and females.
- $H_0$2: There is no statisticallysignificant difference in perception of chemistry between males and females.
- $H_0$3 There is no statistically significant relationship between performance in chemistry, perception and perceived difficult chemistry topics.

4. LITERATURE REVIEW

4.1. Chemistry Topic Difficulty

Conceptual understanding of the concepts of various topics in chemistry is a requirement for the good performance of students in examinations, which guarantees the realisation of learning objectives. Chemistry students should be able to investigate and verify scientific information and communicate scientific ideas as part of their academic experience. These essential elements of a high school chemistry curriculum will help students make informed decisions about relevant scientific issues (ACS, 2012).Students' perceptions of difficult chemistry topics have attracted serious attention**.** For instance,Agogo and Onda (2014) identified mass-volume relationships, reactivity series, hydrocarbons, and organic chemistry as difficult topics.

Again, according to Agogo and Onda (2014), students found chemistry concepts as abstract, coupled with inadequate practical activities, a lack of instructional materials, poor knowledge of mathematical aspects of chemistry, language problems, a lack of textbooks, poor teachers' understanding of concepts, and an overcrowded classroom. Uchegbu et al. (2016) also found that students perceived gas laws, mass-volume relationships, hydrocarbons, and alkanols as difficult topics in senior high school chemistry. Omiko (2017) identified students' difficulties in nuclear chemistry, metals and non-metals and their compounds, rates of chemical reactions, qualitative analysis, and acid-base reactions. Gongden et al. (2011) found that students perceive chemical reactions, balancing of redox reactions, electrode potential and electrochemical cells, laws of electrolysis, chemical equilibrium, solubility, and IUPAC nomenclature of organic compounds as difficult.

4.2. Levels of Representations in Chemistry

According to the American Chemical Society (ACS), to promote scientific literacy, the chemistry curriculum should expose and engage learners in activities that involve problem solving and critical thinking (ACS, 2012). However, acharacteristic of chemistry is the constant interplay between the macroscopic and microscopic levels of thought (Bradley & Brand, 1985).Theinterplay between macroscopic and microscopic worlds is a source of difficulty for many chemistry learners (Sirhan, 2007). Students should acquire an appreciation for the interactions of matter at the macroscopic level, the atomic level (ACS, 2012).

There are three levels of chemical representation — macroscopic, symbolic and sub-microscopic — that are directly related to each other (Johnstone, 1982). The macroscopic level is the observable chemical phenomena that can include experiences from students' everyday lives, such as colour changes, observing new products being formed and others disappearing. In order to communicate about these macroscopic phenomena, chemists commonly use the symbolic level of representation that includes pictorial, algebraic, physical and computational forms such as chemical equations, graphs, reaction mechanisms, analogies and model kits (Treagust et al. 2003). The sub-microscopic level of representation, based on the particulate theory of matter, is used to explain the macroscopic phenomena in terms of the movement of particles such as electrons, molecules, and atoms. These sub-microscopic entities are real but they are too small to be observed, so chemists describe their characteristics and behaviour using symbolic representations to construct mental images (Treagust et al. 2003).

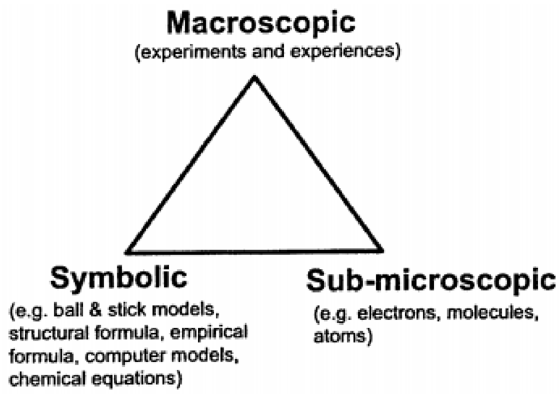

Fig.1 *Johnstone's Levels of Chemical Representations(Treagust et al., 2003).*

Johnstone (1991) suggested that one reason science was difficult for students was that it involved what he termed 'multilevel thought'. Students are expected to think about very different concepts at the same time (Taber, 2013). Johnstone (1991) posits that learners are usually asked to make sense of teaching about three levels of thought: the macro, the sub-micro and the symbolic levels (Taber, 2013). Johnstone illustrated his point with a triangle with the three apices labelled as macro, sub-micro, and 'symbolic'.

Explanations ofthe macroscopic observable chemical phenomena rely on the symbolic and sub-microscopic level of representations(Treagust et al., 2003). At the microscopic level, chemical phenomena are explained by the arrangement and motion of molecules, atoms, or subatomic particles. Chemistry at the symbolic level is represented by symbols, numbers, formulas, equations, and structures(Treagust et al., 2003). Understanding microscopic and symbolic representations is especially difficult for students because these representations are invisible and abstract, while students' thinking relies heavily on sensory information (Wu et al., 2001).

The interactions between these levels are important characteristics of chemistry learning and necessary for comprehending chemical concepts. Therefore, if students possess difficulties at one level, it may influence the other (Sirhan, 2007). According to Johnstone (1991), the nature of chemistry concepts and the way the concepts are represented make chemistry difficult to learn. Thus, the effectiveness of chemistry teaching depends on the teacher's ability to communicate and explain abstract and complex chemical concepts, and on the students' ability to understand the explanations (Treagust et al. 2003).

Chemical representations play an important role in helping learners to understand chemical contents. Since chemical representations serve as a tool to create a mental model of the unseen sub-microscopic level, they play an important role in helping learners to understand and learn chemistry, but present a significant challenge to learners (Taskin et al., 2015). Because of this significant challenge, national and international studies have shown that students have remarkable difficulties (Taskin et al., 2015). Meaningful understanding of chemistry includes the ability of an individual to think simultaneously at macroscopic, sub-microscopic and symbolic levels, and the competence to translate between the different levels of chemical representations (Gkitzia et al., 2020).Thus, chemistry teachers must present new information at an appropriate level for the learner to understand.

5. METHODOLOGY

5.1. Design and Approach

The study adopted a quantitative approach, using a cross-sectional survey design. Survey research is 'the collection of information from a sample of individuals through their responses to questions' (Check & Schutt, 2012, p. 160). This type of research allows for a variety of methods to recruit participants, collect data, and utilise various methods of instrumentation (Ponto, 2015).

5.2. Sample and Sampling Techniques

The target population was senior high school chemistry students in the Kassena-Nankana municipality of the Upper East Region of Ghana. The sample consisted of sixty (60) form 2 chemistry students offering general science (39), home science (6) and agricultural science (15).Two senior high schools that offer a general science programme were purposively selected. Then, thirty (30) students were selected from each school using simple random sampling technique.

5.3. Instruments

Two instruments were used to collect data. These are the difficult chemistry topics questionnaire (DCTQ), and the chemistry perception questionnaire (CPQ).The difficult chemistry topics questionnaire (DCTQ) was developed by the researcher. The questionnaire consisted of twenty-three (23) chemistry topics drawn from the Ghanaian Senior High School chemistry syllabus. Students were required to indicate the level of difficulty on a five-point Likert scale. The options are very difficult (1), difficult (2), neutral (3), easy (4), and very easy (5). Thus, higher scores indicate that the topic is not difficult, and low scores indicate that the topic is difficult. The reliability of the DCTQ was determined by calculating the Cronbach alpha reliability coefficient, which was 0.79.

The Chemistry Perception Questionnaire (CPQ) used in this study was adapted from Wells (2003). The CPQ consisted of 23 items on a five-point Likert scale, with options ranging from strongly agree, agree, neutral, disagree, and strongly disagree. The CPQ has five subscales: value of chemistry, gender, interest in chemistry, fear of chemistry, and characteristics of chemistry. Characteristics of chemistry are the perception of inherent characteristics of chemistry. Interest is the perception of one's ability in chemistry. Fear of chemistry is the perception of anxiety concerning chemistry. Gender is the perception that one's gender influences one's ability to learn chemistry. The value of chemistry is the perception that chemistry is important for individuals or society. The development of the CPQ instrument involved experts in establishing both content and construct validity. Cronbach's alpha reliability of the CPQ was calculated to be 0.81 (Wells, 2003).

Students' performance in chemistry was obtained from their end-of-second semester examination results. The students were graded based on the Ghana Education Service grading system. The total score of each student consisted of 50% school-based assessment (SBA) and 50% of end-of-semester examination (NACCA, 2018).

SBA systemstandardized the practice of internal school-based assessment in all schools in Ghana(NACCA, 2018).

5.4. Data Analysis

The data was analysed using SPSS version 26. Both descriptive and inferential statistics were used to analyse the datafrom the DCTQ and the CPQ. Students' perceptions were categorised and interpreted as either positive perception, moderate perception, or negative perception based on the mean score categories. Also, chemistry topic difficulty was organised as difficult, somewhat difficult, and not difficult (Table 1).

Table 1: Categories of topic difficulty and chemistry perception

Variable	Mean score	Interpretation
Perception	1.00-2.90	Negative
	3.00-3.50	Moderate
	3.60-5.00	Positive
Topic difficulty	1.00-2.90	Difficult
	3.00-3.50	Somewhat difficult
	3.60-5.00	Not difficult

5.5. Data Collection Procedures

Before data collection, permission was sought from school authorities to conduct the study. The researchers ensured a friendly atmosphere so that the respondents felt relaxed. This was achieved with the help of the school chemistry teachers. The purpose of the study was explained to the students, which was also indicated on the questionnaire. They were told that participation is strictly voluntary. The data collection process took one week.

6. RESULTS AND DISCUSSION

6.1. Demographic Characteristics of Participants

Table 2 shows the sex and age distribution of the students. Most of the students (73.3%) were males, while 26.7% of them were females. Ninety percent of the students age between 16-20 years.

Table 2: Sex and age distribution of respondents

Sex	**frequency**	**Percent**
Male	44	73.3
Female	16	26.7
Total	60	100
Age		
15-15	5	8.3
16-20	54	90
21-25	1	1.7
Total	**60**	**100**

6.2. Students' Perceptions of Difficult Chemistry Topics

Table 3 presents the descriptive statistics of perceived difficult topics in chemistry. It was found that only five out of the twenty-three topics (21.7%) were perceived to be easy by the students. The remaining topics (78.3%) were perceived to be difficult. Among the topics perceived not to be difficult were basic safety laboratory practices (M = 4.22, SD = 1.14), particle nature of matter (M = 4.10, SD = 0.99), atomic structure (M = 4.00, SD = 0.99), chemical bonding (M = 3.57, SD = 1.11), and hybridisation and shapes of molecules (M = 3.47, SD = 1.13). The topics perceived by students as difficult includeamount of substance and the C-12 scale; solutions; stoichiometry and chemical equations; nuclear chemistry; enthalpy changes and bond enthalpies; periodic chemistry; rate of reactions; transition chemistry; acids, bases, and the concepts of pH and pOH; electrochemical cells; solubility, organic chemistry, redox titration, redox reactions, chemical equilibrium, balancing redox reactions, hydrolysis of salts, and acid-base titration.

Table 3: Descriptive statistics of perceived difficult chemistry topics

sn	**Statement**	**N**	**M**	**SD**

1	Basic safety laboratory practices	60	4.22	1.14
2	The particle nature of matter	60	4.10	0.99
3	Atomic structure.	60	4.00	0.99
4	Chemical bonding	60	3.57	1.11
5	Hybridisation and shapes of molecules.	60	3.47	1.13
6	Amount of substance and the C-12 Scale	60	3.33	1.22
7	Solutions	60	3.25	1.11
8	Stoichiometry and chemical equations.	60	3.22	1.06
9	Nuclear Chemistry	60	3.18	0.85
10	Enthalpy Changes and bond enthalpies	60	3.15	1.05
11	Periodic Chemistry	60	3.02	0.95
12	Rate of reactions	60	2.88	1.09
13	Transition Chemistry	60	2.72	0.98
14	Acids, bases and concept of pH and pOH	60	2.70	1.05
15	Electrochemical cells	60	2.64	1.11
16	Solubility	60	2.63	1.19
17	Organic chemistry	59	2.63	1.14
18	Redox titration	60	2.60	1.04
19	Redox reactions	60	2.54	1.22
20	Chemical equilibrium	60	2.42	1.08
21	Balancing redox reactions	60	2.42	1.20
22	Hydrolysis of salts	60	2.38	1.11
23	Acid-Base titration	60	2.27	1.06
	Overall mean	**60**	**3.01**	**0.37**

Similar to the findings of this study, Kindu et al. (2016) reported that students perceive chemical bonding, thermodynamics, chemical equilibrium, and reaction kinetics as difficult. Adu-Gyamfi et al. (2017) reported that students have difficulties with the IUPAC naming of organic compounds. Similar studies revealed that high school students perceived the classification of organic compounds and petroleum as difficult to understand (Davis, 2010; Donkoh, 2017). Jimoh (2010) found that senior high school chemistry students perceive the particulate nature of matter, chemical combination, gas laws, energy level of atoms, qualitative and quantitative analysis, rate of chemical reactions, chemical equations, non-metals and their compounds, thermochemistry, and nuclear chemistry as difficult topics.

In a similar study, Agogo and Onda (2014) reported that students perceive mass-volume relationships, reactivity series, ionic theory, and organic chemistry as difficult topics. Also, Uchegbu et al. (2016) found that students perceived gas laws, mass volume relationships, hydrocarbons, and alkanols as difficult topics. Omiko (2017) found that students have difficulties in nuclear chemistry, metals and their compounds, non-metals and their compounds, rates of chemical reactions, qualitative analysis, and acid-base reactions. Again, Gongden and Lohdip (2011) found that students perceive chemical reactions, balancing of redox reactions, electrode potential and electrochemical cells, laws of electrolysis, chemical equilibrium, solubility, and IUPAC nomenclature of organic compounds as difficult. Nartey and Hanson (2017) reported that almost half of the student sampled saw organic chemistry as a difficult topic.

6.3. Perception of Students Towards Chemistry

Table 4 presents the descriptive statistics of students' perceptions of chemistry.

Table 4: Descriptive statistics of students' perception of chemistry

sn	Statement	*N*	*M*	*SD*
1	Chemistry is useful for solving problems of everyday life.	60	3.97	0.94
2	Chemistry positively impacts society.	60	3.97	0.92
3	Everyone should know some chemistry.	60	3.82	1.03
4	Chemistry is easier for males.	60	3.65	1.29
5	Males are better at chemistry than females.	60	3.57	1.28
6	Chemistry is interesting to me.	60	3.53	1.20
7	I do not like chemistry.	60	3.52	1.17
8	Only Chemists need to know chemistry.	60	3.50	1.17
9	I cannot do chemistry.	60	3.42	1.27
10	Chemistry is mainly for males.	60	3.40	1.32
11	I do not have enough math background to do well in chemistry.	60	3.37	1.31
12	Chemistry makes me nervous.	60	3.30	1.32
13	Chemistry is more difficult for females.	60	3.28	1.45
14	I get anxiety just thinking about chemistry.	60	3.27	1.25
15	Chemistry is boring to me.	60	3.25	1.37
16	Just hearing the word chemistry scares me.	60	3.08	1.41
17	Chemistry has too much math.	60	3.07	1.40
18	Chemistry has too much memorisation.	60	3.07	1.22
19	Chemistry requires the learning of too many unrelated facts.	60	2.88	1.25
20	Chemistry is too abstract.	60	2.87	1.17
21	Chemistry has too many concepts or ideas.	60	2.82	1.23
22	You must have a scientific mind to do well in chemistry.	60	2.78	1.19
23	Chemistry is too difficult.	60	2.73	1.36
	Overall mean	**60**	**3.30**	**0.61**

It was found that students have a moderateperception of chemistry (M = 3.30, SD = 0.61). However, on the dimensions, it was found that students held positive perceptions of the value of chemistry (M = 3.81, SD = 0.721). However, they held moderate perception in gender (M = 3.48, SD = 1.04), interest (M = 3.43, SD = 0.93) and fear of chemistry (M = 3.14, SD = 0.93). The students held negative perception of characteristics of chemistry (M = 2.88, SD = 0.686). Table 5 shows the descriptive statistics of the perception dimensions.

Table 5: Descriptive statistics of the dimensions of perception of chemistry

Dimension	*N*	*M*	*SD*
Value of Chemistry	60	3.81	0.721
Gender	60	3.48	1.041
Interest in Chemistry	60	3.43	0.941
Fear of Chemistry	60	3.14	0.938
Characteristics of Chemistry	60	2.88	0.686

6.4. Perceived Chemistry Topic DifficultyBased on Gender

Table 6 presents independent samples t-test of perceived topic difficulty by gender.

Table 6: Independent samples t-test of chemistry topic difficulty by gender

Sex	*N*	*M*	*SD*	*df*	*t*	*p*
Male	44	3.025	0.363	58	0.356	0.723
Female	16	2.98	0.417			

The results showed that there is no significant difference in perception of chemistry topic difficulty between males (M = 3.025, SD = 0.36) and females (M = 2.98, SD = 0.417), t (58) = 0.356, p = 0.723.Contrary to the findings of this study Musengimana et al., (2022) found that female students perceived chemistry to be less difficult than males. The female students' perception of chemistry difficulty, interest, and usefulness of chemistry are slightly positive than the males. Again, the females showed less positive attitudes towards chemistry than males (Musengimana et al., 2022).

Also, Ajayi and Ogbeba (2017) reported that girls exhibit a more positive attitude towards chemistry than their male counterparts. Tinklin et al. (2001) found that there were more girls than boys who perceived more scientific concepts as difficult to learn. However, similar to the findings of this study, Musonda (1991) found no differences based on gender in learners' perceptions of difficult chemistry topics.

6.5. Students'Perception of Chemistry Based on Gender

Table 7 presents an independent samples t-test of the perceptions of students towards chemistry by gender.

Table 7: Independent samples t-test of perception of chemistry by gender

Sex	*N*	*M*	*SD*	*df*	*t*	*p*
Male	44	3.22	0.60	58	-1.83	0.07
Female	16	3.54	0.61			

The results showed that there is no significant difference in students' perceptions of chemistry between males (M = 3.22, SD = 0.60) and females (M = 3.54, SD = 0.61), t (58) = -1.83, p = 0.07. However, several researchers found significant gender differences in interest in science (Krapp, 2002; Trumper, 2006; Elster, 2007). Logan and Skemp (2008) opined that these gender differences were most likely to be connected to pedagogical variables.

7. Relationship between performance in chemistry, perception and perceived difficulty

Multiple regression analysis was carried out to ascertain the relationship between students' performance in chemistry, their perception of chemistry and perceived topic difficulty**.** Table 8 presents the model summary of the multiple regression analysis.

Table 8. Model Summary of this study

Model	R	R^2	Adjusted R^2	SE of the Estimate
1	.280[a]	.078	.046	6.966

a. Predictors: (Constant), Chemistry perception, Chemistry topic difficulty
b. Dependent Variable: Chemistry performance

The R^2value of 0.078 indicates that 7.8% of variation in students' chemistry performance can beexplained by students' perceived chemistry topic difficulty and students' perception of chemistry.Table 9 presents the regression coefficients.

Table 9. Regression Coefficients of this study

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	*SE*	*Beta*	t	Sig.
1	(Constant)	68.44	8.356		8.191	.000
	Chemistry topic difficulty	2.844	2.434	.150	1.168	.248
	Chemistry perception	-2.952	1.480	-.255	-1.994	.051

a. Dependent Variable: Chemistry performance

The multiple regression analysis revealed that perceived chemistry topic difficulty (B = 2.844, p= 0.248) and perceptionof chemistry (B = -2.952, p = 0.051) did not significantly predict chemistryperformance. Thus, the regression model equation was:*Chemistry performance = 68.44 + 2.844 (Chemistry topic difficulty) -2.952 (chemistry perception).*Table 10 presents analysis of variance (ANOVA) results of the regression.

Table 10. ANOVAresults of this study

Model		SS	df	MS	F	Sig.
1	Regression	234.910	2	117.455	2.420	.098[b]
	Residual	2766.340	57	48.532		
	Total	3001.250	59			

a. Dependent Variable: Chemistry performance
b. Predictors: (Constant), Chemistry perception, Chemistry difficulty

Overall, the regression model is not significant. Thus, there is a relationship between chemistry performance, perceived chemistry topic difficulty and perception of chemistry, however, this relationship is not significant (F [2, 57] = 2.420, p = 0.098).

However,in a study to determine the predictive effect of attitudes and reasoning abilities on academic achievement in physics-chemistry, Vilia et al., (2017) reported that attitudes towards chemistry are significant predictor of chemistry achievement. According to Johnson et al., (2022), student attitude toward chemistry may influence engagement and achievement in chemistry-related courses. There was a positive correlation between the cognitive and affective components of attitude among low-achieving students, but not among high-achieving students. Nurul et al., (2021) also reported that perception on the difficulty in studying organic chemistry was positively associated with chemistry achievement.

Fahd et al., (2022) in a study of causes of students' learning difficulties in secondary school chemistry: a study in context of content and assessment strategies, reported that students' perceptions about chemistry content are a cause of learning difficulties in chemistry, this could consequently affect their performance in chemistry. Çelik et al., (2009) reported that students' attitudes affected their achievement and comprehension of chemical equilibrium and nature of matter. Thangavel and Selvan (2024) reported that positive attitudes are associated with highchemistry performance. Nartey and Hanson(2021) opined that students' perceived difficulty in organic chemistry topics can have significant effects on learning.

8. Conclusion and Recommendations

The study found that the students perceive most of the chemistry topics to be difficult. However, they held moderate perceptions of chemistry. There are several strategies to improve the teaching and learning of chemistry in senior high schools and improve students' perceptions of chemistry. These strategies aim to enhance students' understanding, engagement, attitudes, perceptions and retention of chemistry. Chemistry teachers should pay attention to helping students to relate and transition between the levels of representations. Studies have shown that teachers have difficulty in interrelating macroscopic, sub-microscopic and symbolic conceptions properly.

Chemistry teachers should engage learnersthrough hands-on activities, experiments, and discussions. Chemistry teachers must encourage students to ask questions, investigate phenomena, and develop their own understanding of chemical principles and which will lead to improved performance (American Chemical Society, 2012). Again, chemistry teachers can utilise technology tools such as interactive simulations, virtual labs, and multimedia resources.

Teachers must recognise that students have diverse learning styles, interests, and abilities. Teachers must differentiate instruction by providing different modes of learning, varied resources, and flexible assessments. The Ghana Education Service should support ongoing professional development for chemistry teachers to enhance their content knowledge, pedagogical skills, and familiarity with current research in chemistry education. Students need to be provided with learning experiences to prepare them to grasp new materials by clarifying or correcting previously held. Chemistry teachers must link concepts so that the learner can make a coherent whole of the ideas. This allows for the development and learning of simple but meaningful concepts.

To improve chemistry performance, teachers should link the teaching of chemistry to the environment and context of students so that they do not see the subject as abstract. The Ghana Education Service and the National Council for Curriculum and Assessment (NaCCA) should provide infrastructure and apparatus for teaching chemistry at the senior high schools. The chemistry laboratory provides an excellent opportunity to relate the unseen microscopic world to the observable macroscopic world in which we live. Laboratory experiences promote teamwork, inquiry-based learning, hands-on activities, and exposure to standard laboratory equipment and technology (ACS, 2012).

Again, to improve students' performance and perceptions of chemistry, teachers should use hands-on laboratory activities and interactive multi-modal approaches in teaching chemistry. Finally, chemistry teacher education should focus on developing programmes and strategies on how to engage students in the relations between the multiple meanings in chemistry and transitions between them.

Disclaimer (Artificial intelligence)

Author(s) hereby declarethat NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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