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Research Article

Factors contributing to teachers' conceptual difficulties in teaching high school organic chemistry

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ABSTRACT

Some research works have showed that Ghanaian teachers, teaching chemistry in the senior high school, have conceptual difficulties in organic chemistry. This research explored the factors contributing to teacher's conceptual difficulties on teaching organic chemistry to high school students. Through explanatory sequential mixed methods design quantitative data were collected using questionnaire and qualitative data, using semi-structured interviews. The questionnaire was responded to by 71 teachers teaching chemistry in 31 schools, and six teachers, purposively selected, interacted with researchers through interviews to triangulate any quantitative findings. From the quantitative data, four factors, tertiary exposure, professional collaboration, professional competence, and pre-tertiary exposure emerged. These factors were then used as themes to guide the analysis and presentation of results from the qualitative data. To inform further research, it is recommended that chemistry educators and researchers should examine the four factors that predict most of the teacher conceptual difficulties on organic chemistry.

Keywords: conceptual difficulties, teachers, teaching organic chemistry

INTRODUCTION

One of the components of senior high school chemistry is organic chemistry. Organic chemistry is a chemistry of the structure, properties, reactions of compounds containing carbon (Sibomana et al., 2021) and the preparation of carbon-containing compounds (Chang & Goldsby, 2016; Miheso & Mavhunga, 2020), except oxides of carbon (CO_2 and CO), carbonates (CO_3^{2-}), hydrogen carbonate (HCO_3^-), carbides (C^{4-}), and cyanides (CN^-). In simple terms, organic chemistry is the chemistry of hydrocarbons and their derivatives (Omwirhiren & Ubanwa, 2016). Many compounds of carbon exist because it is tetravalent; has a catenation tendency; can form isomers, long chains, branched chains, ring structures; can form single and multiple carbon-carbon bonds; and can combine with other elements (Ameyibor & Wiredu, 2006; Chang & Goldsby, 2016; Petrucci et al., 2017). Within this diverse number of compounds can be found similarities in type of structure and chemical reactions. By structure, carbon compounds can be classified as aliphatic, alicyclic, aromatic, and heterocyclic (Ameyibor & Wiredu, 2006). In terms of chemical reactions, organic compounds are classified based on the presence of functional group (Chang & Goldsby, 2016). Ameyibor and Wiredu (2006) reported that when a carbon-containing molecule is written as *R-OH*, then all *R-OH* are similar, they are alcohols. Though $R\text{-}NH_2$ are also similar, they are different from the alcohols. They are amines. The *-OH* and $\text{-}NH_2$ are called functional groups, being an atom or a group of bonded atoms, which gives an organic compound its characteristic chemical properties (Ameyibor & Wiredu, 2006; Chang & Goldsby, 2016; Petrucci et al., 2017). The simplest organic compounds are the hydrocarbons (Petrucci et al., 2017). Hydrocarbons are categorized as saturated (that is, alkanes), unsaturated (that is, alkenes and alkynes), and aromatic hydrocarbons (that is, benzene rings or similar features) (Ebbing & Gammon, 2017). Other organic compounds, such as the alkanols, alkanoic acids, alkyl alkenoates, amines, and amides are derived from the hydrocarbon by altering the carbon-carbon bond or substituting other atoms (Ameyibor & Wiredu, 2006). These are derivatives of hydrocarbons (Ebbing & Gammon, 2017). It is worthy of note that each family of organic compound has the same general molecular formula and functional group.

From literature on chemistry, the teaching and learning of organic chemistry is difficult (Miheso & Mavhunga, 2020; Sana & Adhikary, 2017). The difficulties stem from the fact that it is abstract (Taber, 2002). To teach this abstract concept will require teachers to use multiple representations (Olaleye, 2012). Using multiple representations is one effective way to teaching abstract concepts, such as organic chemistry (Carolan et al., 2008; Haslam et al., 2009) because it captures the student's attention in the learning process (Harrison & Treagust 1999). When a teacher uses oral explanation followed by a model, illustration, concept map, or graph, then there are multiple representations (Olaleye, 2012).

Empirical studies support the fact that Ghanaian senior high school (SHS) teachers and students have difficulties in organic chemistry (Adu-Gyamfi et al., 2012, 2013, 2017; Anim-Eduful & Adu-Gyamfi, 2021; Hanson, 2017). For instance, in Adu-Gyamfi et al. (2012), students had difficulties in writing structural formulae of hydrocarbons (alkanes, alkene, and alkynes), alkanols, alkanoic acids, and alkyl alkenoates. In a related study, the results obtained by Adu-Gyamfi et al. (2017) in the IUPAC nomenclature of organic compounds revealed that students could not name branched and substituted hydrocarbons, alkanols (both primary and tertiary), diols, alkanoic acids, and alkyl alkenoates. The difficulties in naming emanated from the students' inability to identifying the number of carbon atoms in the parent chain, as well as their inability to identify the substituents or functional groups. Regardless of the school-type: well-endowed or less-endowed, empirical study shows students demonstrated weak performance in both IUPAC naming and writing of structure of hydrocarbons and their derivatives (Adu-Gyamfi et al., 2013). Although Adu-Gyamfi et al. (2012, 2017) reported difficulties of students in IUPAC naming and writing of structural formula of organic compounds, teachers' difficulties in the teaching of the IUPAC nomenclature have not been given much attention in the literature

In their recommendation**,** Adu-Gyamfi et al. (2017) reported the need to shift focus from students to teachers to find out the chemistry teacher's difficulties in teaching organic chemistry. Thereafter, Anim-Eduful and Adu-Gyamfi (2021) found that teachers demonstrate conceptual difficulties on detection of functional groups. These conceptual difficulties are in the form of misconceptions and factual difficulties. Therefore, this current research explored the number of factors accounting for any teacher conceptual difficulties in teaching organic chemistry to SHS students. Consequently, the research question formulated to guide this research was: "How many factors account for teacher conceptual difficulties in teaching organic chemistry to senior high school students?"

Cimer (2007) identified six main principles of [chemistry] teaching to include dealing with students' existing ideas and conceptions (Adu-Gyamfi et al., 2020). This requires teachers to assist learners construct their understanding and knowledge, assist learners activate their prior knowledge and conceptions, be aware of and in the light of scientifically accepted knowledge, modify, change, or develop them further. In doing so, teachers develop general pedagogic principles and content knowledge. That is, in teaching students, chemistry teachers also increase their content and pedagogical knowledge during the preparation and engagement with students (Taber, 2021). Cimer (2007) emphasized that teaching strategies and activities such as discussions (Omwirhiren, 2015), small group activities, practical work, and using ICT facilities can be employed to help achieve this principle. Effective [chemistry] teaching according to Cimer (2007) includes the teacher encouraging students to apply new concepts and skills into different contexts, teacher demonstrating knowledge of the content during teaching, and being conscious of the professional demands in teaching (Adu-Gyamfi, 2020).

To be able to teach organic chemistry with ease, requires that the teacher understands the concepts, terms and principles in organic chemistry otherwise there will certainly be difficulties in the learning process and how they will apply the content in teaching (Duda et al., 2020). It is incumbent on prospective teachers to explore educational examples and concepts systematically in order to establish at least an innate comprehension of correct concepts about learning and teaching. Teachers need to express these concepts clearly as well as have the opportunity to re-discover them with similar examples and problems before they are able to use these concepts to plan their instruction and understand model-based explanations. Teachers are able to 'activate' their conceptual knowledge while teaching and to be able to connect theory to practice (von Aufschnaiter & Rogge, 2010). Prospective teachers should be encouraged, to expose and articulate openly their conceptions about the physical world as this will make them aware of the elements of their own conceptions and to facilitate the search for teaching interventions conducive to their conceptual development (Valanides, 2000). von Aufschnaiter and Rogge (2010) noted that using just few examples to demonstrate concepts about science concepts will, similar to students, result in teachers learning the appropriate descriptions without understanding them conceptually.

In preparing teachers in subjects with many terms and concepts [such as organic chemistry], educational technology and laboratories should be used to enhance their conceptions of the terms (Kartal et al., 2011). Kambouri (2010) explained that teachers need to first clarify their personal understanding of science concepts to enable them to apply their knowledge in their work in order to feel secure with their content knowledge and pedagogic skills to teach each topic effectively (Taber, 2021). Otherwise, one will be regarded as having 'bad chemistry' when the individual does not have correct understanding of the chemical principles and not being aware his/her misconceptions (Kay & Yiin, 2010).

RESEARCH METHODS

Research Design

Explanatory sequential mixed methods research design was used to collect quantitative and qualitative data from teachers teaching organic aspects of SHS chemistry. In this research design, a questionnaire was first used to collect quantitative data on factors that influence teacher's conceptual difficulties on organic chemistry they taught to their students. Thereafter, exploratory factor analysis was conducted to identify the factors. Some teachers were, then, selected based on their respectively responses on the questionnaire and the emerging factors from the exploration for interviews. The purpose of the interviews was to help triangulate and explain the quantitative results. The quantitative results were presented independent of the qualitative results. However, the findings from the qualitative results were used to explain the findings from the quantitative results. This helped to paint a clear picture of factors accounting for teacher's conceptual difficulties in teaching organic chemistry to their students in the SHS.

Sample and Sampling Procedures

The target population, 114 teachers, the research drew conclusion (McCombes, 2020) and made generalization on using the sample results (Johnson & Christensen, 2014) composed of professionals and non-professionals, experience, and novice teachers, categorized into 92.1% male and 7.9% female science teachers in 31 schools in the Upper East Region of Ghana. Upper East was one of the regions with low students' performance on high school chemistry. In the Upper East Region, there were 37 high schools of which 31 schools offered students chemistry as one of the subjects under the General Science Program. Hence, for the purposes of this research, the accessible population was teachers teaching chemistry in the 31 science-based schools.

There were 114 teachers teaching chemistry in the 31 schools as of the time of this research. Of the 114 teachers, 88 were sampled through simple random procedure. This gave a fair representation of teachers to be involved in the research as we were not interested in any teacher characteristics aside teaching chemistry in the school. During the data collection period, 71 teachers responded to the questionnaires and return them to the researchers. Consequently, there were 71 teachers involved in this research from the Upper East Region of Ghana. The demographics of the teachers involved in this research are presented in **Table 1**.

Of the 71 teachers, six were purposively selected for interviews. Because the six were among teachers whose responses were worth following up. That is, three professional teachers and another three non-professional teachers whose responses in the survey seemed to suggest that they had weak or very good grades in organic chemistry courses they took in the university.

Table 1. The demographics of selected teachers (n=71)

Demographic	N	%
Gender		
Male	66	93.0
Female	5	7.0
Professional qualification		
Professional	44	62.3
Non-professional	27	37.7
Academic qualification		
Chemistry (major)	32	45.1
Chemistry (minor)	39	54.9
Teaching experience		
0-5 years	32	45.1
6-10 years	20	28.2
11-15 years	13	18.3
16-20 years	4	5.6
Above 20 years	2	2.8

Research Instruments

A set of self-developed questionnaire (teachers' difficulties on organic chemistry questionnaire, TDOCQ) was used to collect data on the factors causing the conceptual difficulties of teachers in teaching organic chemistry. TDOCQ consisted of 63 items involving two sections, A and B. Section A was made up of six items requiring teachers to provide their demographic data on gender, age, qualification, teaching experience and class size. Section B consisted of 57 closed ended items on a five-point Likert scale (from lowest level of perception, 1 to highest level of perception, 5). The 57 items looked for the factors accounting for teacher conceptual difficulties on teaching organic chemistry (**Appendix A**).

Also, a semi-structured interview guide, interview guide on teachers' difficulties on organic chemistry (IGTDOC) consisting of seven basic items constructed by the researchers was administered to teachers. The seven items included issues on understanding the teachers' experience in high school, the university, their practice (as a chemistry teacher), their professional development, their belief about chemistry teaching and their familiarity with the curriculum they were implementing, and reference materials for teaching organic chemistry (**Appendix B**). The responses from IGTDOC helped to triangulate the responses obtained from the TDOCQ.

Validity and Reliability of Research Instruments

To ensure the questionnaire accurately measures what was intended (Patton, 2007), TDOCQ was given to two experienced English teachers who are also West Africa Examination Council (WAEC) Examiners to read through and correct grammatical related problems that might invalidate the instrument. Again, to ensure the face and content validity of the instrument, TDOCQ was given to three experience chemistry teachers who were also WAEC examiners to read and make their inputs. Thereafter, it was given to a senior lecturer in the Department of Science Education, University of Cape Coast, to critique and make suggestions which was used to modify the instrument before a pilot test on it. The pilot test enabled the researchers to modify the research instrument to help elicit the right responses. To ensure that the questionnaire was fit for purpose, the reliability coefficient for the items was calculated using Cronbach alpha coefficient of reliability. A reliability coefficient of .91 was obtained and so the instrument was considered appropriate as it indicated that the TDOCQ was reliable. After the pilot study two items (that is, items 13 and 35) were deleted.

On IGTDOC, second author read the questions exactly as written and in the same order to all interviewees. Alteration in wording, context, and emphasis was based on the pre-set questions and responses of each teacher. To ensure accurate capture of responses from the teachers, audio recording of the responses was made. This helped the researchers to play back during the transcribing of data. The interview had the merits of allowing the researchers to compare responses, get complete data for each teacher, and reduce interviewer effects and bias (Johnson & Christensen, 2014). The interview therefore was used to offset inherent weaknesses of the TDOCQ.

Data Collection Procedures

Second author first made a cross-sectional survey with teachers teaching chemistry in the 31 schools using TDOCQ. Moving from one school to another and town to another took about four weeks. After the four weeks, the teachers' responses on TDOCQ were scored and analyzed. As it were, there were some revealing issues, and we needed to follow it up with interviews. Six teachers selected purposively interacted with second author through the use of IGTDOC. The interviews lasted six days as each teacher was scheduled for a single day with respect to his or her convenience.

Data Processing and Analysis

The teachers' rating on the TDOCQ was explored through exploratory factor analysis to establish the factors accounting for teacher conceptual difficulties in teaching organic chemistry. This help to answer research question on factors contributing to teacher's conceptual difficulties in organic chemistry. Data from IGTDOC was transcribed, segmented and open-coded and constantly compared to generate themes. The researchers made meanings from the explanations given by the six teachers to arrive at the themes. These themes were used to explain the findings of the factor analysis. That is, the qualitative factors from IGTDOC were used to triangulate that of the quantitative factors from TDOCQ.

RESULTS

Factors Accounting for Teachers' Conceptual Difficulties in Organic Chemistry

The research question sought to explore the number of factors that account for teachers' conceptual difficulties in teaching organic chemistry to SHS students. To be able to explore this, the selected teachers responded to the questionnaire (TDOCQ). In order to determine the factors that accounted for the teachers' conceptual difficulties in teaching senior high organic chemistry, a principal component analysis was conducted on the 57 items on TDOCQ. To begin with, the Kaiser-Meyer-Olkin (KMO) measure was verified to be .548 with the Bartlett's test for sphericity (3.716E-28) being significant (p=.00, df=1,596). With KMO above .50 and Bartlett's test for sphericity being significant, the researchers were convinced of conducting factor analysis (Ayuni & Sari, 2018; Hair et al., 2014). Based on Kaiser criterion of 1, the data was reduced to 16 components loadings with 78.54% cumulative explanation of variance. The results in **Table 2** show that the data have been reduced to 16 components with eigenvalues above 1.0.

Table 2. Extraction of sums of squared loadings

Component	Total	% of variance	Cumulative %
1	13.100	22.983	22.983
2	5.830	10.227	33.210
3	3.984	6.989	40.199
4	3.111	5.459	45.657
5	2.524	4.429	50.086
6	2.204	3.866	53.952
7	1.849	3.244	57.197
8	1.763	3.094	60.290
9	1.624	2.849	63.139
10	1.520	2.667	65.806
11	1.430	2.508	68.34
12	1.345	2.360	70.674
13	1.224	2.148	72.821
14	1.138	1.997	74.819
15	1.094	1.920	76.738
16	1.025	1.798	78.536

To justify how many components should be retained given that the 16 components gave a cumulative factor loading of 78.54%, the scree plot was examined. **Figure 1** shows the results of the scree plot.

According to Pallant (2007), in examining the scree plot to determine the factors to retain, one needs to look for the elbow in the shape of the plot and consider only components that are above it for retention. As seen in **Figure 1**, only the first 6 components (component 1, 2, 3, 4, 5, and 6) were retained as the factors that were likely to account for teachers' conceptual difficulties in teaching high school organic chemistry. Aside the

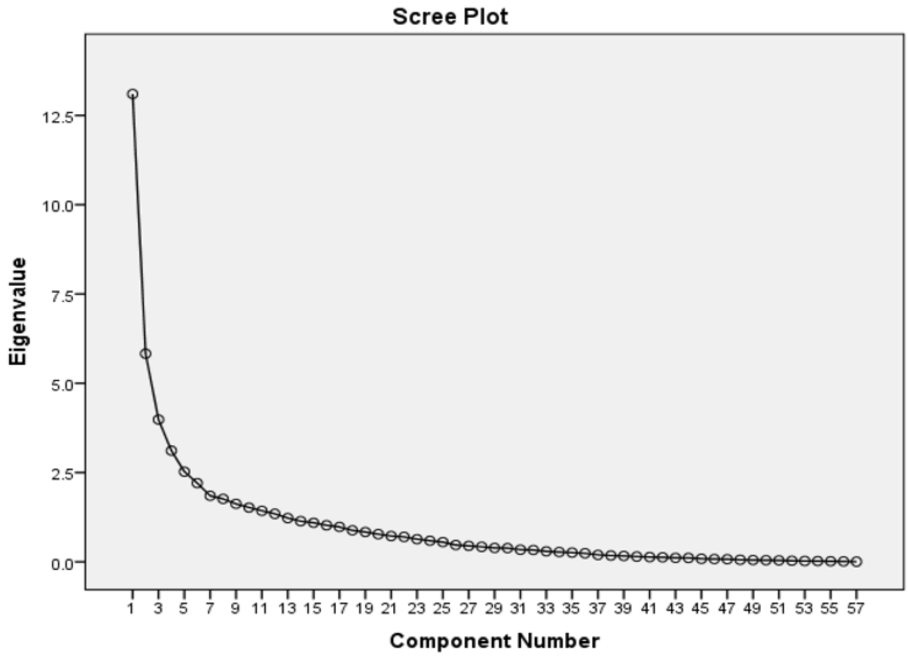

Figure 1. An illustration of components to retain on factors accounting for teacher difficulties in organic chemistry

six components being above the elbow in the shape, they explain more (53.95% cumulative explanation) of the variance than the other components.

To be sure whether the six components were worth retaining, a parallel analysis (PA) was conducted (Ledesma & Valero-Mora, 2007). The actual eigenvalues from the principal components analysis (PCA) were compared with the criterion values from the PA. A decision was made to accept eigenvalues of the PCA greater than the criterion value of the PA, and less values rejected (Cokluk & Kocak, 2016; Ledesma & Valero-Mora, 2007; Pallant, 2007). The results on the comparison of the PCA and PA are presented in **Table 3**. The results from **Table 3** show that only four factors instead of the six factors were to be retained. Because only the four factors have their eigenvalues greater than the criterion values from the parallel analysis. Therefore, only four factors were retained for the determination of the conceptual difficulties teachers have in teaching high school organic chemistry.

Table 3. Comparing eigenvalues from PCA to criterion values from PA

Component number	Actual eigenvalue from PCA	Criterion value from parallel analysis	Decision
1	13.100	3.582631	Accept
2	5.830	3.260844	Accept
3	3.984	3.024871	Accept
4	3.111	2.889640	Accept
5	2.524	2.678252	Reject
6	2.204	2.556111	Reject

A factor analysis was conducted again with only the four factors. Inspection of the communalities of the various items revealed some extremely low communalities. Thus, items whose communalities were below .3 were deleted and a re-run of the factor analysis was conducted. The re-run after the deletion of the items gave a KMO value of .712 and a Bartlett's test for sphericity (1.598E-18) to be (df=861, ρ=.000). To aid in the interpretation of the retained components, Varimax rotation was conducted (Pallant, 2007). Factors which loaded below .5 as well as those with cross loadings were deleted. From the varimax rotation as shown in **Table 4**, factor1 explained 27.01%, factor 2 explained 12.20%, factor 3 explained 8.44% and factor 4 explained 5.60%. However, the total variance explained remained the same 53.32% as obtained from the initial analysis. The reliability of the factors was determined to be .93 for factor 1, .85 for factor 2, .77 for factor 3, and .88 for factor 4. The factor loadings together with variance explained and Cronbach alpha of the components are shown in **Table 4**.

Table 4. Factors evolving from component matrix on teachers' conceptual difficulties on teaching organic chemistry

Statement	1	2	3	4
In the university I took several organic chemistry related courses	.821			
I was taught organic chemistry comprehensively in the university	.820			
In the university, my organic chemistry lecturer taught to my understanding very well	.7.85			
In the university, I was patiently taking through my organic chemistry-related courses	.749			
I had good grades in organic chemistry courses in the University	.728			
As a teacher, I read ahead of each organic chemistry lesson to prepare as my students ask challenging questions in class	.716			
I had interest in organic chemistry in the university	.709			
The nature of organic chemistry questions set by WAEC indicates that I learnt enough from the university to help my students	.692			
I read books on chemistry to enable me to broaden horizon of my knowledge to prepare for my lessons	.692			
In the university organic chemistry is broad	.658			
As a teacher, I have textbooks in organic chemistry that I make revision from	.626			
As a teacher, the reference textbooks I use are those recommended by the chemistry syllabus	.501			
As a teacher, I am part of a teacher study group(s) that meet regularly, in face-to-face meetings, to discuss chemistry to help broaden my knowledge in organic chemistry discipline		.890		
As a teacher, I am part of a teacher study group(s) that meet regularly, in face-to-face meetings, to discuss chemistry to help broaden my knowledge in organic chemistry pedagogical approaches		.820		
As a teacher, I visit teacher resource center, which provides professional development materials on content of organic chemistry		.724		
As a teacher, I engage in intensive activities in which I spend a concentrated period of time working in a lab or industrial setting with professionals in organic chemistry		.619		
As a teacher, I receive mentoring, coaching, lead teaching, or observation, in a one-on-one situation in organic chemistry, usually in the classroom		.610		
As a teacher, I attended workshop on content of organic chemistry once in a year			.725	
As a teacher, I have received in-service training on content (subject matter) of organic chemistry			.721	
I easily use models and graphics to teach organic chemistry			.699	
The professional development program I attended placed emphasis on hydrocarbon			.579	
Currently, I am part of a teacher collaborative or network, that is connecting teachers regionally, nationally, or internationally in organic chemistry			.514	
My teachers back then in senior high school taught organic chemistry to us very well				.846
Organic chemistry aspect was my favorite area in the senior high school				.800
I developed interest in organic chemistry at the senior high level				.759
I had opportunity in solving problems in organic chemistry on regular basis in senior high school				.745
Senior high school chemistry was interesting to learn				.601
% variance explained	**27.01**	**12.20**	**8.44**	**5.60**
Cumulative % variance explained	**53.32**			
Cronbach's alpha	**.927**	**.852**	**.772**	**.875**

All the items in each component were thoroughly read and assigned a theme. The themes assigned to the four factors retained are tertiary exposure, professional collaborative learning, professional competence, and pre-tertiary exposure.

Tertiary Exposure

Tertiary exposure is about the experiences and knowledge an individual teacher had from his or her university education. From **Table 5**, the results indicate an average mean of 3.54 (Std.=1.230) for the items showing high level of perception amongst teachers. This is an indication that the participating teachers had sound content knowledge and experiences of their university education needed to have a sound content knowledge of organic chemistry they teach to students in the SHS.

Table 5. Teachers' level of perception on their tertiary exposure

Statement	LWP		LP		P		HP		HHP		M	Std.
	N	%	N	%	N	%	N	%	N	%		
In the university organic chemistry is broad	2	2.8	4	5.6	11	15.6	21	29.6	33	46.5	4.11	1.049
I read books in organic chemistry to enable me to broaden horizon of my knowledge to prepare for lectures	3	4.2	4	5.6	11	15.5	23	32.4	30	42.3	4.03	1.108
I had good grades in organic chemistry courses in the university	3	4.2	6	8.5	23	32.4	19	26.8	20	28.2	3.66	1.108
I was taught organic chemistry comprehensively in the university	8	11.3	5	7.0	20	28.2	12	16.9	26	36.6	3.61	1.347
The nature of organic chemistry questions set by WAEC indicates that I learnt enough from the university to help my students	3	4.2	11	15.5	21	29.6	20	28.2	16	22.5	3.49	1.132
In the university I took several organic chemistry courses	7	9.9	14	19.7	15	21.1	13	18.3	22	31.0	3.41	1.369
In the university, my organic chemistry lecturer taught to my understanding very well	8	11.3	8	11.3	20	28.2	20	28.2	15	21.1	3.37	1.256
I had interest in organic chemistry in the university	12	16.9	13	18.3	16	22.5	10	14.1	20	28.2	3.18	1.457
In the university, I was patiently taking through my organic chemistry-related courses	7	9.9	19	26.8	20	28.2	13	18.3	12	16.9	3.06	1.241
Average											**3.54**	**1.23**

Note. LWP: Lowest perception; LP: Low perception; P: Perception; HP: High perception & HHP: Highest perception

For instance, 76.1% of the 71 teachers at a mean of 4.11 (Std.=1.049) highly perceived content of organic chemistry as broad in the university. Of the 71 teachers 74.7% at a mean of 4.03 (Std.=1.108) highly perceived reading organic chemistry textbooks to broaden their knowledge horizon as they prepare for chemistry lectures in the university. Of the 71 teachers, 53.6% at a mean of 3.61 (Std.=1.347) highly perceived comprehensive teaching of organic chemistry in the university and that, 55.0% teachers at a mean of 3.66 (Std.=1.108) highly perceived to have had good grades in organic chemistry courses in the university. The grades of teachers in organic chemistry courses are something the current study could not probe further.

However, to confirm the findings on tertiary exposure six teachers who participated in the interviews were asked to describe their experience in learning chemistry in the university. All teachers interviewed shared a similar view of good exposure to the study of chemistry, particularly organic chemistry in the university. In one instance the teachers interviewed explained that chemistry courses were interesting in the university. The excerpts are:

> "In the university, in the introductory chemistry it was interesting and that made me to take some chemistry courses to broaden my knowledge" (Eva, a teacher).

> "… in the university it was interesting than the SHS level" (Fred, a teacher).

> "My interest was in chemistry because my grades in chemistry was better than the other subjects" (Evelyn, a teacher).

The chemistry courses in the university were interesting and teachers interviewed attributed it to quality of professors in teaching chemistry-related courses. The excerpts are:

> "At the university, I must say studying chemistry was good because we had lecturers who had good knowledge in the subject matter, and they took us through series of topics that we were supposed to learn. We really developed interest in chemistry" (James, a teacher).

> "… we had one chemistry lecturer very exceptional. Our time chemistry was compulsory for first year before you now major. He handled the introductory part of organic. How he handled us made me to pursue it further to see how it goes …" (Fred, a teacher).

Evelyn, a teacher interviewed, on the other hand, explained though not all professors handling chemistry were good at it. She mentioned that

> "... we had a lecturer but the way he handled it. He did not use practical approach in lecturing..." (Evelyn, a teacher).

The teachers interviewed perceived learning organic chemistry in the university was challenging because of their weak foundation in the concept. The excerpts are:

> "... organic chemistry at the university was a challenge because of the weak foundation, but because it was semester bases, we managed to go through. Chemistry program in general, to be frank, some organic chemistry courses were challenging though others were better" (George, a teacher).

> "As for the university, it was okay. Chemistry in general at the university in first year is introduction to (general) chemistry and physical chemistry and the other ones. The organic aspect too, the first part of the organic, you know we didn't do anything like naming of ketones ... we went straight to reaction mechanism, then the other functional groups. The only challenging aspect was synthetic methodology. It was tough. Synthetic chemistry is not something I want to remember. Even though we managed to pass it" (James, a teacher).

Again, 87.4% of the 71 teachers at a mean of 3.66 (Std.=1.108) highly perceived they had good grades in organic chemistry courses, implying that they might have understood the concepts very well. Results from the interview, however, did not resonate with the teachers' perception of having good grades. Some were a bit skeptical in talking about their actual performance in the organic chemistry in the university. For instance,

> "I had average performance throughout the university" (Charles, a teacher).

James, a teacher indicated that

> "I cannot remember the grades, but the grades changes based on the semester. I did not get A or B+ in any of the organic chemistry courses."

Some of the teachers admitted obtaining low grades, but blame the low grades obtained to a poor start in the SHS. George mentioned that

> "The foundation was already weak. Even though I did my best, but I cannot compare the grades in organic chemistry to others. To some extent my grades were not the best."

This is a deviation from their perception that they were taught comprehensively, as well as taking a number of organic chemistry courses and having good grades. The results from the teachers interviewed sharing their actual experience of the grades obtained to how the concepts were taught. Evelyn explained that

> "We had lecturers, but the way they handled it affected my grades; it was not practical. We learnt the theory with no practical."

Perhaps this admission of obtaining low grades might explain why within the same reference range, only 64% of the 71 teachers at a mean of 3.18 (Std.=1.457) had interest in organic chemistry.

Professional Collaboration

Professional collaboration explains how the teachers develop their knowledge in both content and pedagogy through their continual engagement and participation in professional group, sharing experiences and knowledge. The means of perception of the groups of items under professional collaboration are presented in **Table 6**.

Table 6. Teachers' level of perception on professional collaboration

Statement	LWA		LA		A		HA		HHA		M	Std.
	N	%	N	%	N	%	N	%	N	%		
As a teacher, I visit teacher resource center, which provides professional development materials on content of organic chemistry	29	40.8	18	25.4	15	21.1	6	8.5	3	4.2	2.10	1.161
As a teacher, I receive mentoring, coaching, lead teaching, or observation, in a one-on-one situation in organic chemistry, usually in classroom	31	43.7	20	28.2	15	21.1	3	4.2	2	2.8	1.94	1.040
As a teacher, I engage in intensive activities in which I spend a concentrated period of time working in a lab or industrial setting with professionals in organic chemistry	37	52.1	16	22.5	9	12.7	8	11.3	1	1.4	1.87	1.108
As a teacher, I am part of a teacher study group(s) that meet regularly, in face-to-face meetings, to discuss chemistry to help broaden my knowledge in organic chemistry pedagogy	34	47.9	20	28.2	13	18.3	2	2.8	2	2.8	1.85	1.009
As a teacher, I am part of a teacher study group(s) that meet regularly, in face-to-face meetings, to discuss chemistry to help broaden my knowledge in organic chemistry discipline	36	50.7	20	28.2	11	15.5	4	5.6	0	0	1.76	0.918
Average											**1.90**	**1.047**

The results revealed that the mean professional collaboration was found to be 1.90 (Std.=1.047). This shows that the teachers who participated in this study did not engage in professional collaboration. For example, 78.9% of the 71 participants at a mean of 1.76 (Std.=.918) lowly perceived that they were part of a teacher study group(s) that met regularly, in face-to-face meetings, to discuss chemistry to help broaden their knowledge in organic chemistry discipline and that 76.1% of the 71 teachers at a mean of 1.85 (Std.=1.009) lowly perceived that they met to help broaden their knowledge in organic chemistry pedagogy. Of the 71 teachers, 74.6% at a mean of 1.87 (Std.=1.108) lowly perceived that they spent a concentrated period of time collaborating with professionals in organic chemistry in laboratories or industrial settings. Also, of the 71 teachers, 71.9% at a mean of 1.94 (Std.=1.040) lowly held the view that they had received mentoring, coaching, lead teaching, or observation, in a one-on-one situation in organic chemistry, usually in the classroom, and 66.2% teachers at a mean of 2.10 (Std.=1.61) lowly perceived that they do visit teacher resource centers, which provide professional development materials on content of organic chemistry.

To further explore the professional collaboration as a factor accounting for teachers' conceptual difficulties in organic chemistry, some of the teachers who participated in the interviews were asked to share their experience. The excerpts are:

> "We do not collaborate. Looking at the structures and the way organic chemistry is, it will be good we collaborate or share ideas, but we don't do that. Although you can look at it, understand and teach but collaboration will make it easier. Teaching organic chemistry is not really easy" (Evelyn, a teacher).

> "No. doing it will be good. Sometimes not necessarily organic chemistry, but we discuss science teaching in general" **(**Charles, a teacher).

Professional Competence

Professional competence is about the teachers' ability to use teaching resources to teach organic chemistry and whether they have received in-service trainings to help their teaching of organic chemistry. The means of perception of the groups of items under professional competence are presented in **Table 7**.

Table 7. Teachers' level of perception on professional competence

Statement	LWP		LP		P		HP		HHP		M	Std.
	N	%	N	%	N	%	N	%	N	%		
I easily use models & graphics to teach organic chemistry	22	31.0	14	19.7	17	23.9	14	19.7	3	4.2	2.46	1.247
The professional development program I attended placed emphasis on hydrocarbon	29	40.8	16	22.5	15	21.1	6	8.5	5	7.0	2.18	1.257
As a teacher, I have received in-service training on teaching content (subject matter) of organic chemistry	30	42.5	20	28.2	11	15.5	3	4.2	7	9.9	2.11	1.282
As a teacher, I attended workshop on content of organic chemistry once in a year	41	57.7	16	22.5	7	9.9	4	5.6	3	4.2	1.76	1.114
Currently, I am part of a teacher collaborative or network, that is connecting teachers regionally, nationally, or internationally in organic chemistry	48	67.6	11	15.5	6	8.5	5	7.0	1	1.4	1.59	1.008
Average											**2.13**	**1.225**

The results show that the average mean of perceived professional competence was found to be 2.13 (Std.=1.225). This low mean is an indication that teaches in this study do not have the resources nor have received any in-service training to enrich their competence on teaching organic chemistry using the available resources. For example, of the 71 teachers, 50.7% at a mean of 2.46 (Std.=1.247) lowly perceived that they could use models and graphics to teach organic chemistry. Of the 71 teachers, 80.2% at a mean of 1.76 (Std.=1.114) lowly perceived that once in a year, they attended workshop that placed emphasis in organic chemistry content neither have 70.7% teachers (M=2.11, Std.=1.282) received any in-service training on the content of organic chemistry. More so, 63.3% of the 71 teachers at a mean of 2.18 (Std.=1.257) lowly perceived that they have had a professional development program that focused on the hydrocarbons.

To further explore the teacher professional competency, the teachers interviewed share their views on it. All the six teachers shared a similar view of not receiving any professional development on the teaching of organic chemistry. The excerpts are:

> "No, since I came to this school there is no in-service trainings" (Fred, a teacher).

> "Not at all. What I am doing is my own understanding" (James, a teacher).

Hence, teachers in the SHS in the Upper East Region of Ghana were not engage in professional development activities that build and sustain their competence in teaching organic chemistry, and this could account for their conceptual difficulty in teaching organic chemistry to their students.

Pre-Tertiary Exposure

Pre-tertiary exposure describes the teachers' experience and knowledge acquired before entering the university. It explains how well they were engaged or taught in the SHS. The means of perception of the groups of items under pre-tertiary exposure are presented in **Table 8**.

Table 8. Teachers' level of perception on their pre-tertiary exposure

Statement	LWP		LP		P		HP		HHP		M	Std.
	N	%	N	%	N	%	N	%	N	%		
Senior high school organic chemistry was interesting to learn	6	8.5	9	12.7	24	33.8	17	23.9	15	21.1	3.37	1.198
Organic chemistry aspect was my favorite area in the senior high school	17	23.9	15	21.1	15	21.1	16	22.5	8	11.3	2.76	1.347
I developed interest in organic chemistry at the senior high level	21	29.6	17	23.9	13	18.3	10	14.1	10	14.1	2.59	1.410
My teachers back then in senior high school taught organic chemistry to us very well	21	29.6	16	22.5	14	19.7	11	15.5	9	12.7	2.59	1.369
I had opportunity in solving problems in organic chemistry on regular basis in senior high school	17	23.9	21	29.6	18	25.4	10	14.1	5	7.0	2.51	1.206
Average											**2.76**	**1.306**

The results showed that the average mean of pre-tertiary exposure was 2.76 (Std.=1.306). This indicates that teachers fairly had knowledge and experiences of their pre-tertiary education needed to have a sound content knowledge in organic chemistry to teach it to students in SHS. For instance, 78.8% of the 71 teachers at a mean of 3.37 (Std.=1.198) fairly perceived SHS organic chemistry was interesting to learn with 54.9% (M=2.76; Std.=1.347) of the 71 teachers fairly perceived that organic was their favorite aspect of chemistry. However, of the 71 teachers, 52.1% at a mean of 2.59 (Std.=1.369) fairly perceived that they were taught organic chemistry very well in the SHS making 53.5% teachers at a mean of 2.59 (Std.=1.410) fairly developed interest to learn organic chemistry further. Moreover, 53.5% of the teachers at a mean of 2.59 (Std.=1.410) fairly perceived that they were given opportunity to solve organic chemistry problems in SHS. This implies that though teachers found it interesting to learn organic chemistry, but they were not well exposed to organic chemistry at the pre-tertiary level.

To seek clarity on this finding, six teachers were interviewed to share their experience on their learning of organic chemistry in days of their pre-tertiary education. All teachers interviewed shared a similar experience of not having a good exposure to organic chemistry in particular. Teachers considered that chemistry was difficult in the SHS to them when they were students. The excerpts are:

> "In those days it was very difficult" (Eva, a teacher).
>
> "In my SHS, I had a challenge with chemistry" (James, a teacher).
>
> "Back in my SHS days, studying chemistry was hard" (Charles, a teacher).

This is because there were no permanent teachers teaching chemistry in the SHS when the teachers who were interviewed were students in SHS. The excerpts are:

> "For three years we didn't have a chemistry teacher. We went outside the school to look for a part time teacher who will come as and when he was free" (Eva, a teacher).
>
> "… later we had a chemistry teacher who was always giving excuses (I am going to bank, market, etc.) whenever it was time for chemistry" (James, a teacher).
>
> "… for us because we didn't have a permanent chemistry teacher" (Charles, a teachers).

Since the schools had no chemistry teachers back then, they relied on national service personnel (being fresh graduate from the university) to support the teaching of chemistry, and this phenomenon does not hold today as our visit to the schools involved in this current research had permanent chemistry teachers. The excerpts are:

> "As we had no chemistry teacher, organic chemistry was introduced to us by some national service personnel who organized extra class for us" (James, a teacher).
>
> "We depended on some national service personnel. If we were students who were not serious, we would not have passed. We virtually studied on our own" (Charles, a teacher).

The difficult nature of chemistry and absence of permanent teachers teaching the subject resulted in lack of students' interest in it. The excerpts are:

> "Some students did not register chemistry as an elective because in the presence of a teacher, … it was difficult and how about not having a teacher?" (Eva, a teacher).
>
> "I did not like the subject at all because of the way it was presented to us. The subjects I liked was physics and elective mathematics. The day our teacher will be in class with his presentation, we will not understand anything … I didn't dream of becoming a chemistry teacher. It was after secondary education we were informed the said chemistry teacher was a biology teacher who was asked to engage us" (James, a teacher).

According to the teachers interviewed, for those who had chemistry teachers then, faced the same challenge of not learning organic chemistry well as they could not cover the organic chemistry topics. Evelyn explained that

> "My chemistry teacher in senior high was very good and very systematic. He brought the subject down to our understanding. I must say that the only aspect we could not cover was the organic. We could not go deep but we went through the necessary ones, like the hydrocarbons, the alkanes, alkynes. What we didn't learn much was the benzenes, the aromatics and some of the practical involved–testing for some of the functional groups, alkanols".

Hence, the teachers interviewed did not get a good exposure to learning organic chemistry in their pre-tertiary education.

DISCUSSION

On pre-tertiary exposure, it came to bare that most of the teachers started their journey as chemistry teachers on a difficult mode. This could be that in their days as students at high school chemistry, there were not sufficient number of professional chemistry teachers to support them in learning organic chemistry. Even to date the examination council (WAEC) set few questions in organic chemistry and students could attain good grades in chemistry without answering organic-related questions. The weak pre-tertiary exposure could have had an influence in the learning and consequently their performance in organic chemistry in their tertiary levels. This is because teachers at all levels take advantage of previous and contemporary experiences of their students to direct their knowledge construction (Wosor, 2015). It beholds on chemistry educators to look at the kind of exposure SHS students have in organic chemistry prior to pursuing chemistry in the tertiary education as pre-service teachers. As it were students' knowledge construction in organic chemistry could be affected by their previous experiences (Hailikari et al., 2008). Pre-service teachers are like students and could hold on to their misconceptions (Von Aufschnaiter & Rogge, 2010), and if they have had misconceptions in organic chemistry from their pre-tertiary exposure, chemistry educators would need to challenge them to prepare teachers who will have little or no misconceptions in organic chemistry.

On professional competence, it is clear that most of the teachers after their initial training do not receive any professional development, including in-service training, workshops, and seminars. This finding is in line with Garcia and Weiss (2019) who claimed that teachers have limited access to some of the types of professional development that are highly valued and more effective. The finding further confirms earlier assertion of Buczynski and Hansen (2010) that the teachers most in need of professional development are those who do not already have a sound pedagogical content knowledge of their subject and do not have ready access to professional development opportunities. Novice and veteran teachers largely do not get the time and resources they need to study, reflect, and prepare on their practice. However, the teachers' professional competence is better enhanced by providing in-service programs as well as other professional development programs for them to help improve their content knowledge and pedagogy (Radford, 1998; Supovitz et al., 2000) and to increase the teachers' confidence to teach organic chemistry, while facilitating a positive attitude about the nature of organic chemistry teaching and student learning (Stein et al., 1999). It is, also, a vital mechanism for deepening teachers' content knowledge and developing teaching practice (Desimone et al., 2002) and consequently making them professionally competent. A lack of these support system will result in the conceptual difficulties of teachers on detecting the functional groups of organic compounds as have been revealed by Anim-Eduful and Adu-Gyamfi (2021).

Moreover, professional collaboration is a factor contributing to teachers' conceptual difficulties in teaching organic chemistry. Teachers lament they are unable to collaborate with other colleagues internally and externally. However, professional collaborations in the form of observational visits to other schools; participation in a network of teachers for the professional development of teachers (for example, participating in Ghana Association of Science Teachers, GAST seminars and workshops), individual or collaborative research in organic chemistry, and mentoring and/or peer observation and coaching (Organisation for Economic Co-operation and Development [OECD], 1998) could play a role in helping teachers work on their conceptual difficulties in organic chemistry. These professional platforms create the environment to allow for correction of misconceptions and building on the content and pedagogical knowledge of the individual teachers. If teachers are not able to engage in these platforms of professionals, then the misconceptions could remain unchallenged or deficiency in content (factual difficulties) cannot be erased. Consequently, teachers having conceptual difficulties in teaching organic chemistry to SHS students.

The finding that teachers' tertiary exposure is a factor contributing to teacher's conceptual difficulties is worthy of a note. Teachers need to be exposed to the chemistry program and no other programs with the view that they take some chemistry related courses otherwise they will be found wanting as a result of the limited content and pedagogy they will possess (Loughran et al., 2012). It is not really the matter of exposing them to several courses in organic chemistry but taking them comprehensively through specific area of learning (Rice, 2003) as well as exposing them to practical work. Because though teachers perceived to having good lecturers and being taught well, but this did not reflect in the grades obtained in the university as well as their conceptual understanding of the organic chemistry concepts.

CONCLUSION

This research involves 71 teachers who were selected through simple random sampling procedure to respond to a questionnaire, and some were interviewed. Through exploratory factor analysis, the research has showed that four factors contribute to the conceptual difficulties teachers have in high school organic chemistry. The four factors are tertiary exposure, professional collaboration, professional competence, and pre-tertiary exposure. There could be other factors which this study did not look into, but the contribution of this research cannot go unnoticed.

Implications

Based on the findings, it is recommended that chemistry educators and researchers should explore further any other factors that contribute to teachers' conceptual difficulties in high school organic chemistry. Also, chemistry educators and researchers should study further, which of the four factors (tertiary exposure, professional collaboration, professional competence, and pre-tertiary exposure) predict most of the teacher conceptual difficulties in high school organic chemistry. Finally, since pre-tertiary exposure and tertiary exposure were two of the factors contributing to teachers' conceptual difficulties in organic chemistry, the National Council for Curriculum and Assessment together with the teacher education universities should factor any instructional approaches that can challenge and overcome misconceptions in organic chemistry in any future reforms in education.

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APPENDIX A

Questionnaire on Factors Contributing to Teachers' Difficulties in Organic Chemistry

Dear teacher,

This questionnaire seeks your opinions and concerns about factors accounting for teachers' difficulties in teaching senior high school organic chemistry. You are required NOT to write your name and the name of your school. Your response(s) to this questionnaire will remain confidential and any comment made will not be personalized in this research. This information provided will be used to improve the teaching and learning of senior high school organic chemistry. By completing the questionnaire means you are consenting to take part in the research.

Please carefully read all the instructions in each section before giving your response(s).

Section A: Background information

1. Municipality/district:
   ……………………………………………………………………………
2. Sex: Male [ ] Female [ ]
3. Age: 20 years or less [ ] 21-30 years [ ] 31-40 years [ ] 41-50 years [ ] 51 years and above [ ]
4. Qualifications: Tick [√]

	Chemistry (major)	Chemistry (minor)
Diploma in science education		
B.Ed science with major in chemistry		
B.Sc chemistry		
B.Ed chemistry		
M.Ed science education with major in chemistry		
MPhil chemistry		
MPhil science education with major in chemistry		
PhD chemistry		
Others specify ………………………………………………………		

5. Teaching experience as chemistry teacher:
   0-5 years [ ] 6-10 years [ ] 1-15 years [ ] 16-20 years [ ] 21 years and above [ ]
6. Number of students in chemistry class: ……………………………………………………………………………………………

Section B

Indicate your level of agreement (**from 1 to 5**) to the following statements on factors accounting for teaching and learning of organic chemistry. A rank of 1 is the lowest agreement and a rank of 5 is the highest agreement.

Tick [√] to show your level of agreement.

	Lowest to highest agreement ------→				
Statement	1	2	3	4	5
7. I studied elective chemistry in the senior high school					
8. Senior high school chemistry was interesting to learn					
9. Organic chemistry aspect was my favorite area in the senior high school					
10. My teachers back then in senior high school taught organic chemistry to us very well					
11. I developed interest in organic chemistry at the senior high school level					
12. My teacher at senior high school engaged us in laboratory to detecting organic functional groups					
13. I had opportunity in solving problems on organic chemistry on regular basis in senior high school					
14. As a teacher, I have textbooks on organic chemistry that I make revision from					
15. As a teacher, over 50% of my weekly chemistry teaching time is based on chemistry textbook					
16. As a teacher, the reference textbooks I use are those recommended by the chemistry syllabus					
17. As a teacher, I read topics on organic chemistry every week to update my knowledge					
18. As a teacher, I have received in-service training on content (subject matter) of organic chemistry					
19. As a teacher, I attend workshop on content of organic chemistry once in a year					
20. In my school we meet as chemistry teachers to share ideas on content (subject matter) that we teach to our students					

	Lowest to highest agreement ------→					
	Statement	1	2	3	4	5
21.	As a teacher, I read ahead of each organic chemistry lesson to prepare as my students ask challenging questions in class					
22.	I read books on organic chemistry to enable me to broaden the horizon of my knowledge to prepare for lectures					
23.	I was taught organic chemistry comprehensively in the university					
24.	I had good grades in organic chemistry courses in the university					
25.	I use internet to access information on organic chemistry					
26.	Recommended textbooks on organic chemistry for SHS are available for further reading					
27.	I use only the syllabus as the content on organic chemistry is enough					
28.	I read a lot on organic chemistry from the school library as it has a lot of textbooks on chemistry					
29.	Large class size affect how I teach organic chemistry					
30.	In one typical calendar week from Monday to Friday, I am formally scheduled to teach for more than two periods					
31.	Teaching organic chemistry requires much preparation before lessons					
32.	The school laboratory is well-resourced to help me teach organic functional group detection					
33.	I use computer to assist my teaching of organic chemistry					
34.	There are 3D models available for teaching organic chemistry					
35.	I easily use models and graphics to teach organic chemistry					
36.	I had interest in organic chemistry in the University					
37.	In the university my organic chemistry lecturer teaches to my understanding very well					
38.	In the university I took several organic chemistry related courses					
39.	In the university I had teaching practice on teaching organic chemistry					
40.	In the university my organic chemistry lessons were inquiry-based					
41.	In the university I was introduced to pedagogical approaches to teaching organic chemistry					
42.	In the university organic chemistry is broad					
43.	The nature of WAEC questions on organic chemistry requires that I read variety of organic chemistry textbooks					
44.	The topics under organic chemistry are abstract at all levels					
45.	The nature of organic chemistry questions set by WAEC indicates that I have learnt enough from the university to help my students					
46.	Students pass the WAEC examination by answering questions on organic chemistry very well					
47.	Organic chemistry is an integral part of senior high school chemistry					
48.	In the university I was patiently taking through my organic chemistry-related courses					
49.	The professional development programs I attended placed emphasis on hydrocarbons					
50.	The professional development programs I attended placed emphasis on benzenes					
51.	The professional development programs I attended placed emphasis on hydrocarbons derivatives					
52.	The professional development programs I attended placed emphasis on use of technology in instruction (e.g., computers)					
53.	The professional development programs I attended placed emphasis on use of models (e.g., ball-and-stick) for teaching organic chemistry					
54.	The professional development programs I attended provided information on how students learn organic chemistry					
55.	The professional development programs I attended placed emphasis on teaching methods in science (e.g., methods of teaching organic chemistry)					
56.	I have participated in within-district workshops that focused on organic chemistry					
57.	Currently, I am part of a teacher collaborative or network, that is connecting teachers regionally, nationally, or internationally on organic chemistry					
58.	I have taken part in an out-of-district workshops, provided by professional organizations (such as GAST), the ministry of education, or GES					
59.	As a teacher, I engage in internship activities, in which I spend a concentrated period of time working in a lab or industrial setting with professionals in organic chemistry.					
60	As a teacher, I receive mentoring, coaching, lead teaching, or observation, in a one-on-one situation on organic chemistry, usually in the classroom					
61.	As a teacher, I visit teacher resource center, which provides professional development materials on content of organic chemistry					
62.	As a teacher, I am part of a teacher study group(s) that meet regularly, in face-to-face meetings, to discuss chemistry to help broaden my knowledge in organic chemistry discipline					
63.	As a teacher, I am part of a teacher study group(s) that meet regularly, in face-to-face meetings, to discuss chemistry to help broaden my knowledge in organic chemistry pedagogical approaches					

APPENDIX B

Interview Guide on Teachers' Difficulties in Organic Chemistry

This interview guide is developed to assess factors accounting for teacher' difficulties in teaching senior high school organic chemistry. Teachers are assured of strict confidentiality and anonymity for all the information they provide.

1. Explain the experiences you had in studying chemistry in the high school.
2. Explain the experiences you had in studying chemistry in the university.
3. How long have you been teaching organic chemistry?
4. Explain the experiences you have had in teaching SHS organic chemistry.
   a. Challenges you face.
   b. How the challenges you face had affected your teaching of SHS organic chemistry?
5. What do you consider the most important in your planning to enable you facilitate your student learning of organic chemistry? And why?
6. What indicators do you consider as evidence of effective learning in organic chemistry?
7. How helpful are workshops/conferences on organic chemistry you had attended?