Research Article

EDUCATIONAL POINT
An International Peer-Reviewed Journal

https://www.educationalpoint.net
ISSN: 3062-1011 (Online)

Teaching organic chemistry at the high school: Which factor predicts most of the difficulties?

Isaiah Atewini Asaki [1*], Kenneth Adu-Gyamfi [1]

[1] University of Cape Coast, Department of Science Education, GHANA
* Correspondence: isaiahatewini@gmail.com

CITATION: Asaki, I. A., & Adu-Gyamfi, K. (2025). Teaching organic chemistry at the high school: Which factor predicts most of the difficulties?. *Educational Point*, *2*(1), e117. https://doi.org/10.71176/edup/16251

ARTICLE INFO

Received: 28 Jan 2025
Accepted: 26 Mar 2025

OPEN ACCESS

ABSTRACT

Literature reports, chemistry teachers in Ghanaian high schools struggle conceptually in teaching organic chemistry. Pre-tertiary exposure, professional collaboration, professional competence, and tertiary exposure have been identified as the factors accounting for these challenges. This research studied the factor(s) that predict most of the teachers' conceptual difficulties in teaching organic chemistry in high school. The findings can help researchers, Ministry of Education (MOE), Ghana Education Service (GES), and Teacher Education provide in-service teachers with necessary intervention or professional development and materials to improve organic chemistry teaching and learning. In a cross-sectional survey, 71 teachers were randomly sampled from 114 chemistry teachers teaching organic chemistry at the high school for the study. Data collected with tests and questionnaires were organised quantitatively and analysed using means, standard deviation and multiple regression. It came to bare that teachers have difficulties in organic chemistry and that the factors accounting for these difficulties are pre-tertiary exposure, tertiary exposure, professional collaboration and professional competence and the most predictive factor was tertiary exposure. Pre-tertiary exposure involves experiences and knowledge acquired before tertiary education, while tertiary exposure involves experiences and knowledge acquired during tertiary education. Professional collaboration involves continuous engagement in professional groups, sharing experiences, and knowledge, while professional competence involves using teaching resources and acquiring in-service training. The recommendation is for chemistry educators and researchers to develop innovative instructional strategies for effective teaching of organic chemistry at the tertiary level.

Keywords: conceptual difficulties, organic chemistry, partial understanding with misconceptions, prediction, teachers

INTRODUCTION

Over decades, organic chemistry, one of the branches of chemistry has caught the attention of chemistry educators and researchers (Adu-Gyamfi & Anim-Eduful, 2022; Adu-Gyamfi & Asaki 2022; Anim-Eduful & Adu-Gyamfi, 2021; 2022; Ellis, 1994; Gendjova et al., 2022; Johnstone, 1991; O'Dwyer & Childs, 2017). There are well over 20 million known synthetic and natural organic compounds. A number significantly greater than the

approximate 100,000 recognised inorganic compounds. This might be because of its relevance (Chang & Goldsby, 2016). Organic chemistry is the chemistry of the compounds generated by carbon and other elements, such as those found in living beings, their products, and anywhere else carbon is found (Chang & Goldsby, 2016; Clayden et al., 2012; Solomons et al., 2016). An exception to this is the trioxocarbonates, carbides, bicarbonates, and cyanides that contain carbon but do not exhibit the properties of carbon compounds (Inikori, 2004). It is asserted that when one has a thorough comprehension of organic chemistry, then one has the power to change society (Solomons et al., 2016). Organic chemistry offers potential for drug synthesis, computer processor, engineering, cancer research, understanding biochemical processes, and life extension and improvement, while also addressing issues like cancer and ageing. Simply, "it can do almost anything" (Solomons et al., 2016, p. 1)

Despite the importance of organic chemistry, teachers as the agent of change (Nbina, 2012), expected to impart organic chemistry knowledge to learners, are bedevilled with conceptual difficulties in organic chemistry concepts (Adu-Gyamfi & Asaki, 2022, 2023). Thus, attention must be paid to how the concepts in organic chemistry are taught to enable us to maximise these numerous benefits. To achieve this, teachers with sufficient knowledge in the subject content are required to provide the correct concepts to students (Omwirhiren & Ubanwa, 2016; Sibomana et al., 2021) because teachers' knowledge has been identified as an essential part of quality instruction and student learning (Gendjova et al., 2022). Having a strong foundation of subject-matter expertise is one of the most important characteristics of a successful scientific instructor (Mizzi, 2013) because it has a relationship with students' learning (Sadler & Sonnert, 2016). Teachers' subject matter expertise is a prerequisite for excellent scientific education, but it is not the sole necessity (Abell, 2007; Kind, 2009). That is, a teacher's great academic achievement in a specialized topic does not guarantee successful teaching.

Research has overly paid attention to conceptual difficulties teachers have in organic chemistry (Adu-Gyamfi & Asaki, 2023; Anim-Eduful & Adu-Gyamfi, 2021, 2022; Nartey & Hanson, 2021; O'Dwyer & Childs, 2017) with little or no focus on the most predictive cause of the difficulties. For instance, O'Dwyer and Childs (2017) examined solely how teachers and students perceived organic chemistry. Similarly, Nartey and Hanson (2021) also focused on the perception of learners and teachers about organic chemistry as well as finding out the most difficult topics as perceived by the teachers and students. But these studies failed to find out the factors contributing to this perception nor the most predictive factor. However, finding the most predictive cause would aid researchers and educators to further investigate those factors to come out with intervention that would lead to effective teaching of organic chemistry in the Senior High School (SHS). Other stakeholders of education such as MOE, GES, National Council for Curriculum and Assessment (NaCCA) and the Teacher Education would have empirical basis of providing in-service teachers with the needed professional development and materials to aid the teaching and learning of organic chemistry. Besides, in a developing country such as Ghana, with scarce resources but desiring quality education including having quality teachers, researching on the most predictive factors on chemistry teachers' conceptual difficulties will provide evidence to inform policy making as well as know where to start allocating resources as far as teaching of organic chemistry is concerned.

Rationality

Studies conducted in Ghana revealed that teachers have conceptual difficulties in organic chemistry (Adu-Gyamfi & Asaki, 2022, 2023; Anim-Eduful & Adu-Gyamfi, 2021). For instance, the work of Anim-Eduful and Adu-Gyamfi (2021) on functional group detection conducted with 47 in-service chemistry teachers using a convergent mixed method found that teachers had conceptual difficulties in functional group detection which were established as alternative conceptions and factual difficulties. Similarly, the study by Adu-Gyamfi and Asaki (2022) on conceptual difficulties in teaching high school organic chemistry with 71 in-service chemistry teachers established that they had conceptual difficulties in organic chemistry. Their difficulties were

preconceived notions, conceptual misunderstandings, and factual difficulties. Again, Adu-Gyamfi and Asaki (2023) conducted a study using explanatory sequential mixed methods on 71 teachers for the quantitative and six teachers for the qualitative to find out the factors that contributed to teachers' conceptual difficulties. It was found that the factors that contributed to the teachers' conceptual difficulties were "pre-tertiary exposure, professional competence, professional collaboration and tertiary exposure" (p. 49).

As the professional collaboration focuses on how teachers develop their knowledge in both content and pedagogy through their continuous engagement and participation in professional groups, sharing experiences and knowledge, Adu-Gyamfi and Asaki (2023) explained that tertiary exposure concerned the experiences and knowledge an individual teacher had from his or her university education. Additionally, pre-tertiary exposure was defined as the teachers' experience and knowledge gained prior to enrolling in university, and professional competence was defined as the teachers' capacity to teach organic chemistry using instructional materials and whether they have received professional development training to support their organic chemistry instruction (Adu-Gyamfi & Asaki, 2023).

However, among these factors, there has not been any research helping to establish which of them predict most of the teachers' conceptual difficulties. Thus, this study sought to examine the factor(s) which predicted most the teachers' difficulties in teaching high school organic chemistry. The overarching question that guided the study was:

RQ: Which factor(s) predict most of the conceptual difficulties teachers have in teaching organic chemistry to senior high school students?

Teacher Preparation

In the context of Ghana, teacher preparation follows through three stages. The first stage is building on the teacher's content knowledge from the elementary level to the senior high school level. The major focus at this stage is content knowledge development. Stage two is initial preparation in both content and pedagogy which takes place either at the colleges of education or the universities. At this level, the teacher builds on their content knowledge by taking general and specialised courses in the interest area in which they seek to teach (Asare & Nti, 2014). The third stage involves professional development training. At this stage, the teacher either engages in further studies or in-service training (Asare & Nti, 2014). Adu-Gyamfi and Asaki (2023) described these stages as Pre-tertiary exposure, tertiary exposure, and professional collaboration and competency as first, second and third stages respectively.

Following from these stages, Ghana's Ministry of Education (MOE) has identified several challenges faced by pre-tertiary teachers, including senior high school chemistry teachers. These include outdated and exam-focused teacher education, isolated pre-service curriculum, and no official minimum criteria for instructors. These factors limit the development of essential teaching skills and hinder the understanding of student concepts (MOE, 2018).

These aforementioned challenges imply teachers often lack Pedagogical Content Knowledge (PCK) to effectively teach chemical concepts like organic chemistry (Park & Oliver, 2008; Shulman, 1987; Veal, 2004). As they progress through secondary to tertiary levels, they should acquire knowledge of students' learning of chemistry, the chemistry curriculum, chemistry concepts and processes, pedagogy for teaching and assessing chemistry, and various illustrations of chemical ideas (Olaleye, 2012).

However, Loughran et al. (2012) argued that teachers often lack subject matter knowledge, leading to challenges, and students' misconceptions. Mabejane and Ravanis (2018) suggested that teachers should not only know what to teach based on the curriculum but also teach what should be taught and how to effectively use that understanding. Shulman's statement "to teach is first to understand" (Shulman,1987, p. 14) informs a teacher's content knowledge, which encompasses understanding basic concepts and facts underlying

subject matter structures. Academic content knowledge (PCK) referred to by Gess-Newsome et al. (2019) is not just the amount of knowledge but also the quality and implementation of that knowledge (Abell, 2008). However, the use of PCK can be flawed, especially when it includes inaccurate science content information (Smith & Banilower, 2015). MOE (2018) highlighted the insufficient emphasis on teaching skills obtained through classroom practice and the lack of systematic follow-up, organized help, mentoring, and continuous professional development for teachers are critical issues to be looked at.

Research shows that teachers' developmental stages often present specific needs and crises that require professional development (Eros, 2011). This can improve their knowledge, confidence, and attitude towards teaching, fostering a positive attitude towards science learning (Bautista, 2023; Olaleye, 2012; Supovitz, et al., 2000). However, chemistry teachers often lack access to valuable professional development, such as university courses, seminars, and observational visits. This lack of resources and opportunities for both novice and experienced teachers, especially in high-poverty schools, highlights the need for more teacher assistance and resources to address these issues (Buczynski & Hansen, 2010)

It thus appears that Ghana's Ministry of Education as well as researchers in chemistry education agree that pre-tertiary teachers face difficulties in teaching the various subjects including chemistry of which organic chemistry is part (MOE, 2018; Nartey & Hanson, 2021; O'Dwyer & Childs, 2017). Since there are a myriad of problems contributing to the difficulty in teaching chemistry and more so organic chemistry, it is prudent that a study be conducted to determine the most predictive factor(s) which will inform government priority in its quest to finding solutions to the problems. It will be more useful as Ghana sets herself into working with a new curriculum. On that basis, this research focused on identifying the most predictive factor causing chemistry teachers difficulties in teaching high school organic chemistry.

METHODOLOGY

A quantitative research methodology, namely a cross-sectional survey design, was used in the study. Because the data was gathered from a sample of chemistry teachers at one moment in time, this design was selected (Creswell & Creswell, 2018). By examining a sample of the population, a survey design once more offered a numerical depiction of the population's trends, attitudes, or opinions (Creswell & Creswell, 2018). Teachers answered a questionnaire and took organic chemistry diagnostic tests as part of this survey. On the day of data collection, each school was administered the test first, followed by the questionnaire.

Sampling and Sampling Procedure

The study was carried out in the Upper East Region of Ghana. The region came to exist as an autonomous region following the division of the Upper Regions in 1983 under the Provisional National Defense Council (PNDC) regime which was preceded by the carving out of the Upper Regions in July 1, 1960. It is now one of the 16 regions of Ghana, which lies between longitude 0° and 1° W and latitudes 10° 30" North and 11° North. It has an estimated population of 1.3 million people and occupies 2.7% of the total land area in the country (Ghana Statistical Service, 2021). The region was described as a border region as it shared a boundary in the north with Burkina Faso, and the east with the Republic of Togo. The region had relatively flat land with fewer hills with grassland and only one rainy season. The major occupation was agriculture (Ghana Statistical Service, 2019). Although it was a region with diverse ethnic groups with their respective local languages, the English language was the official language of communication and instruction in the region. In the 2020/2021 academic year, 114 chemistry teachers who have been teaching organic chemistry in the 31 schools offering chemistry in the region were considered.

Table 1. Nature of respondents (N = 71)

Nature		Frequency (N)	Percentage (%)
Gender	Male	66	93.0
	Female	5	7.0
Age range	21–30 years	13	18.3
	31–40 years	43	60.6
	41–50 years	15	21.1
Teacher professionalism	Professional	44	62.3
	Non-professional	27	37.7
Academic discipline	Majored in chemistry	32	45.1
	Minored in chemistry	39	54.9
Teaching experience	0–10 years	52	73.3
	11–20 years	17	23.9
	Above 20 years	2	2.8

The study used online sample size calculation software, Creative Research System and two others available in geopoll.com/blog/sample-size-research and www.qualtrics.com/experience-management/research/determine-sample-size, to determine the sample size for a population of 114 teachers.

With a 95% confidence level, 88 was chosen for a population of 114 teachers, which was within Krejcie and Morgan's (1970) table of sample size for research activities. At the time of data collection, 71 out of 88 representing 80.7% of the teachers were available and consented to responding to the instruments. The nature of the respondents is presented in **Table 1**.

The data from **Table 1** shows that more males than females were sampled for the study. This striking gender imbalance, with a substantial overrepresentation of males was a reflection of the gender disparities in the population of chemistry teachers. Less female population existed in this study area. A high concentration of participants in their 30s suggests a middle-career demographic. There's less representation at the beginning (21–30) or nearing the end (41–50) of typical teaching careers. More of the teachers were professionals (62.3%), with fewer non-professionals, that is they studied chemistry but do not have professional training as a teacher of chemistry. Data on academic disciplines and teaching experience further provides indication of the diverse characteristics of the sample respondents.

Data Collection Instruments

Data collection was done using the Organic Chemistry Test for Chemistry Teachers [OCTCT]. OCTCT contained content questions on organic chemistry which was used to find out the difficulties the teachers had in organic chemistry concepts. Since the study focused was on finding the predictive factor, it was necessary to ascertain whether participants in this study showed difficulties in organic chemistry concepts. OCTCT with 32 items asked for the demographic data of respondents in the first part and the second part focused on content items including hydrocarbons, benzenes and the derivatives of hydrocarbons. The content items were organised in a two-tier – multiple choice in the first tier and tier two sought the justification of the selection of an option in the first tier. **Figure 1** shows the sampled test items on OCTCT.

OCTCT was developed after careful study of literature by the researchers. To ensure the content validity of the instrument, a table of specification (TOS) was used to help in the item construction process. TOS was used to ensure that the content of the high school curriculum aligned with the objectives. Again, to ensure the face validity of OCTCT items were compared with standardized items constructed by the West African Examination Council (WAEC) for the West African Secondary School Certificate Examination (WASSCE). The input of three chief examiners of chemistry and two senior lecturers of chemistry education was sought to help validate the test items. Two of the chemistry chief examiners had taught chemistry for 19 years at the high school level while working as chemistry examiners for 12 years. The other chemistry chief examiner had taught chemistry at the

Tier 1:
Benzenes have high .....than alkenes.

(a) instability
(b) melting point
(c) purity
(d) stability

Tier 2:
Provide reason: .....

Tier 1:
The maximum number of bonds that can be formed by each carbon in an organic compound is .....

(a) 1
(b) 2
(c) 3
(d) 4

Tier 2:
Provide reason: .....

Figure 1. Sampled test items on OCTCT

high school level for 15 years while working as a chemistry examiner for eight years. All three chief examiners were males and a minimum qualification of Master of philosophy degree chemistry or chemistry education. The two lecturers were all senior lecturers with research focus on chemistry education. They were males and had taught chemistry at some point at the high school level, college level and now at the university level. In terms of their research experience, the lecturers had engaged in chemistry education research for about a decade. Besides, OCTCT was presented to faculty of science education members for critique and suggestions for improvement. The faculty members comprised both senior and junior lecturers, professors and doctors. OCTCT was then pilot-tested and 0.86 was the reliability coefficient obtained from Kuder-Richardson 20 (KR20) using the Statistical Package for Social Sciences (SPSS).

OCTCT was scored using a scoring rubric modified from Sukarmin et al. (2017) in order to convert it into numerical data. According to this rubric, a teacher received a zero if they chose no option at all and failed to give a reason, a score for choosing the right option and giving the wrong explanation, a score for choosing the wrong option but providing the right explanation, and a score for choosing the right option with the right reason, for a total of two points.

Again, the questionnaire "Questionnaire on Factors Contributing to Teachers' Difficulties in Organic Chemistry" [QFCTDOC] was adopted from Adu-Gyamfi and Asaki (2023) to help collect data on the factors accounting to the difficulties of teachers. The questionnaire was made up of 63 items requiring the teacher's demographic data and their level of agreement with the kind of training received from high school to tertiary and their continuous engagement with other professional bodies for their knowledge updates. Aside from the demographic data, the 57 items were five-point Likert scale questions. An excerpt of the questionnaire is shown in **Figure 2**.

From the exploratory factor analysis done by Adu-Gyamfi and Asaki (2023), four factors evolved from the 57 items. The first factor (Tertiary exposure) contained 11 items, factor two (professional collaborative learning) contained five items, factor three (professional competence) contained five items, and factor four (pre-tertiary exposure) had five items. **Table 2** presents the internal coefficient of reliability of the four factors.

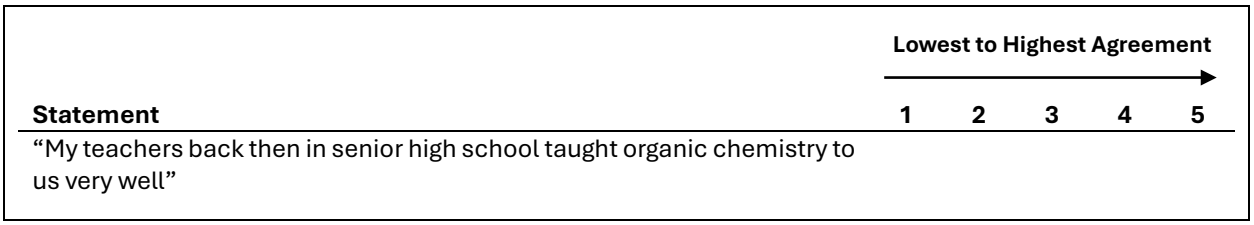

Figure 2. An excerpt from the questionnaire (Source: Adapted from Adu-Gyamfi and Asaki, 2023, p. 67)

Table 2. Internal reliability coefficient of the four factors

Factor	Cronbach's alpha
Tertiary exposure	.93
Professional collaborative learning	.85
Professional competence	.77
Pre-tertiary exposure	.88

Source: Adu-Gyamfi and Asaki (2023, p. 55)

Data Collection Procedure

As part of the data collection process, the first author visited the teachers in their schools to seek their consent and to also establish rapport with the participants. Through this visit, participants indicated their time of availability for the study. Having sought their concern, Asaki visited the teachers again for the completion of the test and questionnaire. To ensure independence of observation, Asaki stayed for respondents to complete the test and questionnaire on the same day in his presence. The test lasted for one hour and the questionnaire lasted for 45 minutes maximum. In all, 28 days were used to collect the data that is from 15th February to 15th March.

Data Processing and Analysis

Asaki did the initial analysis while Adu-Gyamfi reviewed the analysed data then the two researchers had a discussion to reach a consensus on the analysed data. As part of the analysis, OCTCT was scored and organised quantitatively. The data was tested for normality and other assumptions to ascertain its suitability for multiple regression. Thereafter, multiple regression was conducted using the four factors from QFCTDOC. The test of normality and other assumptions are reported as part of the results in the next section. The means and standard deviations of the teachers' responses to QFCTDOC were coded and analysed using SPSS.

RESULTS

Predictive Factor(s) of Conceptual Difficulties in Teaching Organic Chemistry in High School

The mean and standard deviations of the OCTCT were calculated as presented in **Table 3**. The results showed that the chemistry teachers had varied conceptual difficulties in organic chemistry concepts. For instance, in the introduction to the study of carbon compounds, the mean performance ranges from 0.75 to 1.30 with a corresponding standard deviation (Std.) ranging from 0.64 to 0.78. The mean scores indicate that the performance on these items is generally moderate to good, with Item 10 standing out with the highest score. The standard deviations suggest that there is some variability in the scores, with Item 8 showing the most consistency and Item 10 showing the most variability. Similar observations of moderate to good performance are observed in hydrocarbons and their derivatives as well as benzenes. This provides an indication that

Table 3. Mean scores of the teachers on OCTCT

Item	M	Std.
Introduction to the study of carbon compounds		
8	0.82	0.64
10	1.30	0.78
19	0.97	0.74
32	0.75	0.69
Hydrocarbon		
13	1.04	0.66
15	0.93	0.72
16	1.16	0.77
18	0.31	0.62
20	0.78	0.91
21	0.93	0.85
28	0.61	0.64
30	0.96	0.73
Benzenes		
9	0.80	0.82
12	0.97	0.86
25	0.72	0.70
Derivatives of hydrocarbon		
11	0.86	0.78
14	0.73	0.74
17	0.49	0.69
22	0.65	0.54
23	0.41	0.55
24	0.94	0.83
26	0.65	0.83
27	1.18	0.82
29	0.87	0.81
31	0.75	0.69
Average mean	0.82	0.74

Table 4. Mean scores on the factors contributing to the conceptual difficulties

Variable		M	Std.
Independent	Tertiary exposure	3.54	1.23
	Professional collaborative learning	1.90	1.05
	Professional competence	2.13	1.23
	Pre-tertiary exposure	2.76	1.31

teachers do not have difficulties in all organic chemistry concepts. Some aspects of organic chemistry concepts are better understood by teachers. However, the overall mean value of 0.82 indicates that, on average, the performance or scores across the items are moderate and the overall standard deviation of 0.74 shows moderate variability in the scores. This suggests that the chemistry teachers in this study had some conceptual struggles in organic chemistry concepts.

Having established that teachers in this study had some conceptual difficulties in some organic chemistry concepts, attention was shifted to finding out the factors that contribute to the teachers' conceptual difficulties. The teachers' responses to QFCTDOC were rated, the mean and standard deviations of each item under each factor were computed and the average mean of each factor calculated. The mean score of participants in each of the four factors and their standard deviations are presented in **Table 4**.

Among the four factors, tertiary exposure had the highest mean score (M = 3.54; Std. = 1.23), with professional competence and pre-tertiary exposure having nearly the same mean score of (M = 2.13; Std. = 1.23) and (M = 2.76; Std. = 1.31) respectively. Professional collaborative learning had the lowest score (M = 1.90; Std. = 1.05).

Table 5. Pearson correlation matrix for conceptual difficulties and the four factors

	Conceptual difficulties	Pre-tertiary	Professional competence	Professional collaboration	Tertiary exposure
Correlation conceptual difficulties	1.00	.055	–.078	.045	.42

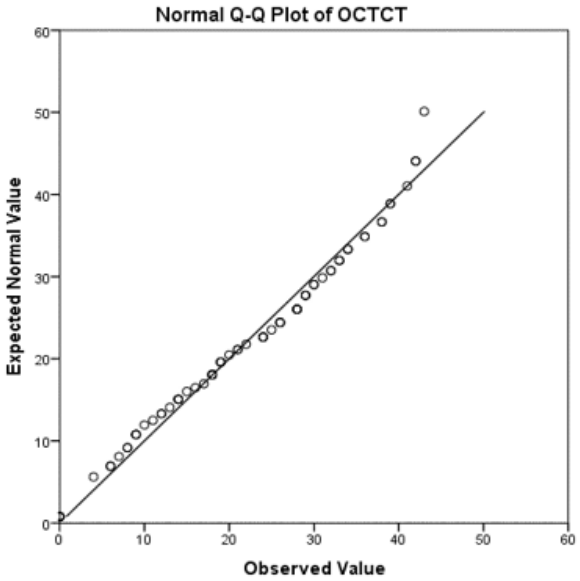

Figure 3. Normal Q-Q plot of conceptual difficulty scores from OCTCT

The results suggest that among the four factors, the teachers' tertiary exposure appeared to be the most contributing factor to the teacher's conceptual struggles in teaching with professional competence and pre-tertiary exposure contributing nearly the same to the teachers' conceptual struggles in teaching senior high school organic chemistry. However, professional collaborative learning contributed less to the teachers' conceptual difficulties.

The results in **Table 5** show the correlation test between the independent variables (tertiary exposure, professional collaborative learning, professional competence and pre-tertiary exposure) and the dependent variable (conceptual difficulties).

Of the four factors accounting for teachers' conceptual difficulties in organic chemistry, pre-tertiary exposure, professional competence, and professional collaboration correlated weakly with the scores on conceptual difficulties whereas tertiary exposure moderately correlates with the conceptual difficulty scores.

With the research question exploring the predictive factor of teacher's conceptual difficulties in teaching high school organic chemistry, standard multiple regression was performed. But prior to the performance of the multiple regression, various test on the assumptions were conducted to ascertain the suitability of the conceptual difficulty scores from OCTCT for multiple regression. Normality test was conducted to ascertain the suitability of the scores from OCTCT for regression analysis, the skewness (–.077) and Kurtosis (–.97) were found to be within the acceptable limit of ± 1. The trimmed mean (20.88) was also found to be almost the same as the actual mean (20.90) suggesting a nearly normal distribution. Besides the Kolmogorov-Smirnov statistics were found to be non-significant (sig. = .20, $\rho > 0.05$) indicating normality (Pallant, 2007). Normal Q-Q plots were seen to be reasonably straight line showing normal distribution. The results of the Q-Q plots are shown in **Figure 3**.

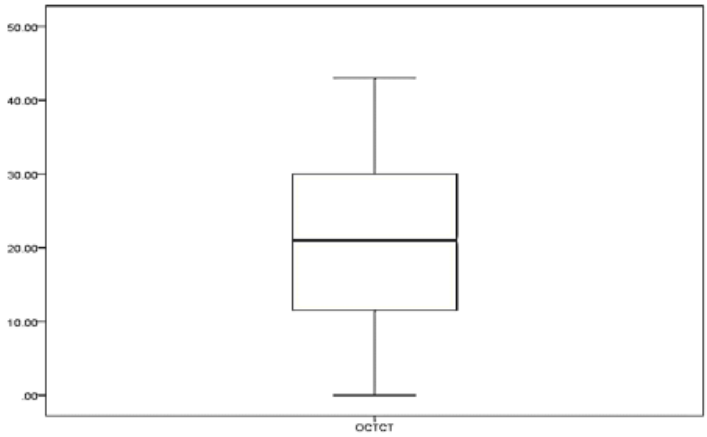

Figure 4. Box plot of the distribution of conceptual difficulty scores from OCTCT

To further determine the skewness as well as the presence of outliers, the boxplot was inspected which showed the absence of outliers. Because there were no data point outside the whiskers. Besides, the median was also found to be in the middle of the box and the whiskers are about same length signifying normal or symmetrical distribution (Mcleod, 2019). The boxplot is shown in **Figure 4**.

To further determine the presence of outliers, Mahalanobis distance was examined. To identify which cases were outliers (that is, if there was), one needed to determine the critical chi-square value by using the number of independent variables as the degrees of freedom (Pallant, 2007). Any case whose Mahalanobis distance was greater than this critical chi-square value was considered as an outlier. According to Pallant (2007), when the degrees of freedom or independent variables were 4, the critical value should be 18.47. For the four independent variables in this study, examining the data case by case, the maximum Mahalanobis distance was found to be 12.03. Thus, the data was considered not to have outliers.

Moreover, the residuals were also tested for normality to be sure they were suitable for regression analysis. The normal P-P plot and the scatter plot of the regression standardised residual of conceptual difficulty scores from OCTCT are shown in **Figure 5** and **Figure 6**.

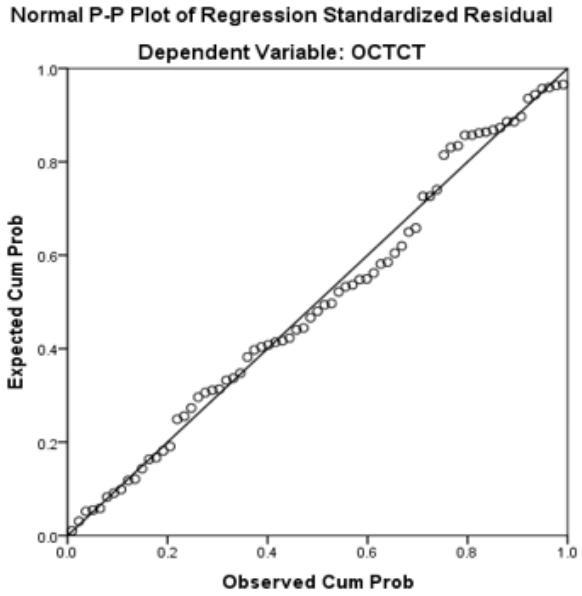

Figure 5. Normal P-P plot on regression standardised residual of conceptual difficulties from

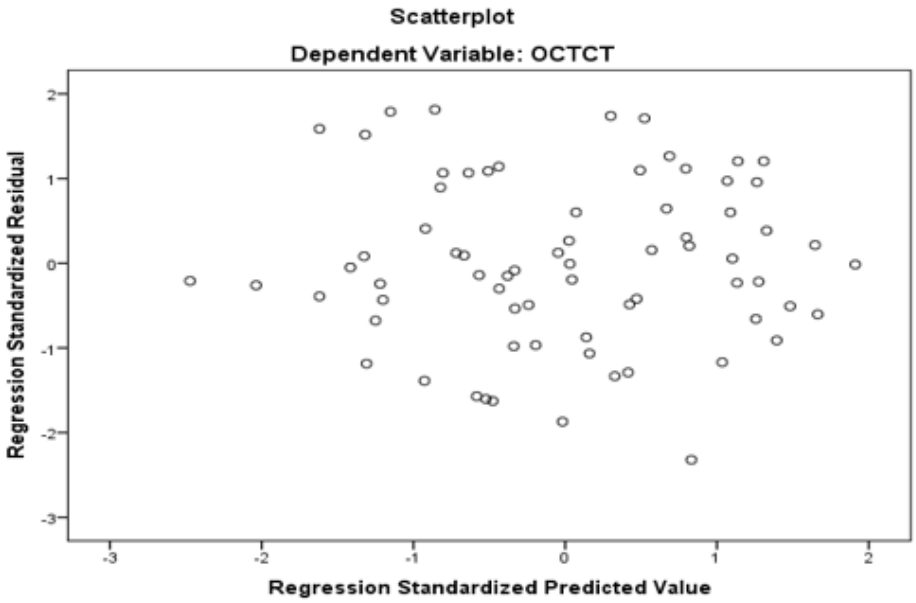

Figure 6. Scatter plots on regression standardised residual of conceptual difficulty score OCTCT

Table 6. Results on assessing multicollinearity

Conceptual difficulties	Pre-tertiary	Professional competence	Professional collaboration	Tertiary exposure
Part	–.06	–.19	–.03	.46
Tolerance	.83	.79	.83	.78
VIF	1.21	1.27	1.20	1.28

Inspecting the normal P-P plot of the regression standardised residual the point lies in a reasonably straight line suggesting no major deviation from normality.

The residual is nearly rectangularly distributed with most concentration of the scores along the center (Tabachnick & Fidell, 2019). Besides, the output from the SPSS showed there was no case with standardised residual value of above 3 or below –3 (Pallant, 2007). It was noted that in any normally distributed data, such cases if they are present, should not exceed 1.0% otherwise there should have been a cause for concern. When the Cook's distance (a measure of the influence of outliers on the model) was also examined, the maximum value was found to be .086. According to Tabachnick and Fidell (2019), if the Cook's distance was greater than 1, there was suspicion of outliers.

To further look at multicollinearity, the partial correlation, tolerance and variable inflation factor (VIF) were examined. The results of which are presented in **Table 6**.

The tolerance for pre-tertiary, .83(VIF = 1.21), professional competence, .79(VIF = 1.27), professional collaboration, .83(VIF = 1.20) and tertiary exposure are .78(VIF = 1.28) suggesting the absence of multicollinearity and a suitability for regression analysis since all the tolerance values were above .1 and the VIF values were less than 10 (Pallant, 2007; Tabachnick & Fidell, 2019).

Standard regression analysis was, then, carried out on the QFCTDOC using the four factors:

1. Pre-tertiary exposure,
2. Professional competence,
3. Professional collaboration, and
4. Tertiary exposure.

Table 7. Test of significance of regression model

R	R square	Adjusted R square	Standard error of the estimate	P
.479	.23	.18	11.12	.002

Table 8. Extract of multiple regression analysis for predictive factors of conceptual difficulties in organic chemistry

Model	Unstandardized coefficients Beta	Standardized coefficients Beta	t	p
Constant	4.45		.75	.46
pre-tertiary exposure	–.14	–.06	–.52	.61
professional competence	–.61	–.21	1.73	.09
professional collaboration	–.11	–.04	–.32	.75
Tertiary exposure	.59	.52	4.25	.00

The QFCTDOC shared approximately 18% with the conceptual difficulty scores from OCTCT (R square = .23, Adjusted R square = .18). The model reached a statistical significance ($p < .05$). The model summary is presented in **Table 7**.

The results from the extract multiple regression analysis are presented in **Table 8**. From **Table 8**, evaluating the four factors, revealed $\beta = –.06$ ($\rho > .05$) for pre-tertiary exposure, $\beta = –.21$ ($\rho > .05$) for professional competence, and $\beta = –.04$ ($\rho > .05$) for professional collaboration indicating that each of these three factors did not make a unique significant contribution to explain the dependent variable (conceptual difficulty score). However, evaluating tertiary exposure revealed $\beta = .52$ ($\rho < .05$) indicating that the variable made a unique and statistically significant contribution to explaining the dependent variable. Thus, the factor that predicted most the conceptual difficulties was their tertiary exposure.

DISCUSSION

The purpose of this study was to investigate the factor(s) that predict conceptual struggles in teaching high school organic chemistry. First the study found that their teachers show moderate conceptual difficulties in organic chemistry concepts. This finding appears to resonate with previous studies that had established that chemistry teachers had conceptual difficulties in organic chemistry concepts (Adu-Gyamfi & Asaki, 2022, 2023; Anim-Eduful & Adu-Gyamfi, 2021). This is because the calculated average means of OCTCT which measured the conceptual difficulties was moderate. Again, the study found that pre-tertiary exposure, professional competence, professional collaboration and tertiary exposure are factors accounting for conceptual struggles. This finding agrees with Adu-Gyamfi and Asaki (2023) However, unlike previous studies which did not focus on identifying the factor that predicted most of the difficulties, this study investigated the most predictive factor to help contribute to literature and to inform policy decision making.

The finding that tertiary exposure predicts most the teachers' conceptual struggles in teaching high school organic chemistry further adds to literature that the factors that accounts for chemistry teachers' conceptual struggles varies in terms of the level of contribution. The implication is that there is a shortfall in teachers' preparation at the tertiary level. The pre-service teacher education (tertiary exposure) offers pre-service teachers (that is, students) both pedagogy and content knowledge for teaching content areas, such as organic chemistry, in the senior high school. Effective tertiary exposure is important in providing pre-service teachers with the needed content knowledge of organic chemistry (Kalder & Lesik, 2011; Shulman, 1986) and if that factor is identified as the most shortfall in teaching organic chemistry, then chemistry educators and researchers have a lot to do. Though the study did not investigate the structure of chemistry education in teacher education institutions there is the need to start raising questions as how effective chemistry teacher education is? Now that the teachers involved in this study are practicing there is the need to provide scaffolds

through professional development programmes that give them the opportunity to upgrade their content knowledge (Bautista, 2023) but not to deal only with alternative approaches to teaching organic chemistry.

Teachers' conceptual difficulties in organic chemistry should be a worrying situation for teacher educators and other stakeholders. It is also the case that any lapses that will have occurred at the pre-tertiary level will be compensated in the tertiary. The education a pre-service teacher receives before going into the teaching profession is important because it affects teacher practice and student success (Kalder & Lesik, 2011). It is in this regard that Afangideh in Etiubon and Benson (2014) suggested that professional preparation is needed for chemistry teachers. Professional preparation should not be limited to pedagogy only, but the content knowledge in organic chemistry. That is, a teacher education institution today, after the ground-breaking paper of Shulman (1986), should be targeting knowledge of the pedagogy and content in organic chemistry. It is, also, important to stress that the number of teachers involved in this study have taught organic chemistry in the senior high school and are demonstrating difficulties in organic chemistry, then chemistry educators and researchers should be looking at a strong position on teaching topic-specific PCK to pre-service teachers for them to overcome their fears in teaching organic chemistry (Donkoh, 2017) to senior high school students.

Preparing teachers at the tertiary level needs to be adequate and informed with the teacher being exposed to courses that put them on the right path to effective teaching (Afangideh, in Etiubon & Benson, 2014). The findings also agree with Mupa and Chinooneka (2015) that if we can get effective teachers then we need to expose them to the foundation of education, in this context the fundamental concepts of organic chemistry. Their exposure needs to be practical to avoid the case of lamentation by teachers of consequent conceptual gap. We need to be guided by Shulman (1987) assertion and expose our chemistry teachers to necessary organic concepts first. More so, we need to encourage pre-service teachers to express openly their conception of organic chemistry concepts (Valanides, 2000) if possible, give them opportunity to rediscover the concepts with similar examples (Von Aufschnaiter & Rogge, 2010).

CONCLUSION AND IMPLICATIONS

The study has shown that teachers have moderate conceptual difficulties in organic chemistry which we need to pay attention to. Contributing to these difficulties are tertiary exposure, professional collaboration and competence, and pre-tertiary exposure. The study has shown that amongst the four factors; the most predictive factor of the conceptual difficulties in teaching senior high school organic chemistry is tertiary exposure. This finding provides new insight to literature that of the many factors, tertiary exposure is the most contributor of the difficulties. It suffices then to say that much of the difficulty's teachers have from their pre-tertiary education remains unresolved and they gather little knowledge and experience in organic chemistry concepts during their tertiary education preparation. This indicates that teacher preparation in the teacher education universities is a critical issue in the effective delivery of senior high school organic chemistry to students. In this regard, future research may investigate the teacher preparation process at the tertiary level to help give fuller insight into tertiary exposure as a predictive factor for teachers' conceptual difficulties in organic chemistry

The study has added to the literature on teacher preparation about content knowledge as being critical to the component of pre-tertiary education, in particular, in the area of organic chemistry. The implication is that with the main predictive factor of teachers' conceptual difficulties being tertiary exposure, chemistry educators and researchers should design and develop alternative instructional strategies to effectively teach organic chemistry at the tertiary level. Future researchers can pay attention to how chemistry teachers are prepared at the tertiary level.

REFERENCES

Abell, S. (2007). Research on science teacher knowledge. In S. Abell, & N. Lederman (Eds.), *Handbook of research on science education* (pp. 1105–1149). Mahwah, NJ: Lawrence Erlbaum Associates.

Abell, S. K. (2008). Twenty years later: Does pedagogical content knowledge remain a useful idea? *International Journal of Science Education*, *30*(10), 1405–1416. https://doi.org/10.1080/09500690802187041

Adu-Gyamfi, K., & Anim-Eduful, B. (2022). Interaction effect of gender, across school-type on upper-secondary students' development of experimental reasoning on organic qualitative analysis. *Journal of Baltic Science Education*, *21*(3), 351–365. https://doi.org/10.33225/jbse/22.21.351

Adu-Gyamfi, K., & Asaki, I. A. (2022). Teachers' conceptual difficulties in teaching senior high school organic chemistry. *Contemporary Mathematics and Science Education*, *3*(2), Article ep22019. https://doi.org/10.30935/conmaths/12382

Adu-Gyamfi, K., & Asaki, I. A. (2023). Factors contributing to teachers' conceptual difficulties in teaching high school organic chemistry. *European Journal of Science and Mathematics Education, 11*(1), 49–67. https://doi.org/10.30935/scimath/12433

Anim-Eduful, B., & Adu-Gyamfi, K. (2021). Functional groups detection: Do chemistry teachers demonstrate conceptual difficulties in teaching?. *Global Journal of Human-Social Science*, *21*(G7), 47–60. https://doi.org/10.34257/GJHSSGVOL21IS7PG47

Anim-Eduful, B., & Adu-Gyamfi, K. (2022). Chemistry students' conceptual understanding of organic qualitative analysis. *Pedagogical Research*, *7*(4), Article em0132. https://doi.org/10.29333/pr/12307

Asare, K. B., & Nti, S. K. (2014). Teacher education in Ghana: A contemporary synopsis and matters arising. *SAGE Open*, *4*(2). https://doi.org/10.1177/2158244014529781

Bautista, M. C. (2023). *Pedagogical content knowledge change and professional development for educators: An assessment of a master's in chemistry program for high school science teachers* [Doctoral dissertation, South Dakota State University].

Buczynski, S., & Hansen, C. B. (2010). Impact of professional development on teacher practice: Uncovering connections. *Teaching and Teacher Education, 26*, 599–607. https://doi.org/10.1016/j.tate.2009.09.006

Chang, R., & Goldsby, K. A. (2016). *Chemistry* (12th ed.). New York: McGraw-Hill Education.

Clayden, J., Greeves, N., & Warren, S. (2012). *Organic chemistry* (2nd ed.). Oxford: Oxford University Press. https://doi.org/10.1093/hesc/9780199270293.001.0001

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). New Delhi: SAGE Publications, Inc.

Donkoh, S. (2017). What students say about senior high school organic chemistry. *International Journal of Environmental & Science Education, 12*(10), 2139–2152.

Ellis, J. W. (1994). How are we going to teach organic if the task force has its way? Some observations of an organic professor. *Journal of Chemical Education, 71*(5), 399–403. https://doi.org/10.1021/ed071p399

Eros, J. (2011). The career cycle and the second stage of teaching: Implications for policy and professional development. *Arts Education Policy Review*, *112*(2), 65–70. https://doi.org/10.1080/10632913.2011.546683

Etiubon, R. U., & Benson, R. F. (2014) Teacher qualification and experience as determinants of quality chemistry education in Nigeria. *Journal of Education and Practice*, *5*(24), 124–131.

Gendjova, A., Markova, N., & Chakarov, K. (2022). Pedagogical content knowledge in science education: Difficulties in organic chemistry. *Pedagogy*, *94*(6), 764–778. https://doi.org/10.53656/ped2022-6.08

Gess-Newsome, J., Taylor, J. A., Carlson, J., Gardner, A. L., Wilson, C. D., & Stuhlsatz, M. A. M. (2019). Teacher pedagogical content knowledge, practice, and student achievement. *International Journal of Science Education*, *41*(7), 944–963. https://doi.org/10.1080/09500693.2016.1265158

Ghana Statistical Service. (2019). *Population distribution of the regions*. https://statsghana.gov.gh/regionalpopulation.php?population=MTQ3NzkxOTU0MS4wODQ=&&UpperEast&regid=8

Ghana Statistical Service. (2021). *Ghana 2021 population and housing census. Volume 3. General Report Highlights*. Ghana Statistical Service. https://census2021.statsghana.gov.gh/gssmain/fileUpload/reportthemelist/Volume%203%20Highlights.pdf

Inikori, G. O. (2004). *Introductory organic chemistry for tertiary institutions*. Zaria: Jodda Press.

Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning*, *7*, 75–83. https://doi.org/10.1111/j.1365-2729.1991.tb00230.x

Kalder, R. S., & Lesik, S. A. (2011). A classification of attitudes and beliefs towards mathematics for secondary mathematics pre-service teachers and elementary pre-service teachers: An exploratory study using latent class analysis. *Issues in the Undergraduate Mathematics Preparation of School Teachers, 5,* 1–19.

Kind, V. (2009). Pedagogical content knowledge in science education: Perspectives and potential for progress. *Studies in Science Education, 45*(2), 169–204. https://doi.org/10.1080/03057260903142285

Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and Psychological Measurement, 30*, 607–610. https://doi.org/10.1177/001316447003000308

Loughran, J., Berry, A., & Mulhall, P. (2012). *Understanding and developing science teachers' pedagogical content knowledge* (2nd ed.). Rotterdam: Sense Publishers. https://doi.org/10.1007/978-94-6091-821-6

Mabejane, M. R., & Ravanis, K. (2018). Linking teacher coursework training, pedagogies, methodologies and practice in schools for the undergraduate science education student teachers at the National University of Lesotho. *European Journal of Alternative Education Studies*, *3*(2) 67–87. https://doi.org/10.5281/zenodo.1442446

Mcleod, S. A. (2019). *What does a box plot tell you?* Simple Psychology. https://www.simplypsychology.org/boxplots.html

Ministry of Education [MOE]. (2018). *Education sector analysis*. Accra: Author.

Mizzi, D. (2013). The challenges faced by science teachers when teaching outside their specific science specialism. *Acta Didactica Napocensia, 6*(4), 1–6. https://files.eric.ed.gov/fulltext/EJ1053677.pdf

Mupa, P., & Chinooneka, I. T. (2015). Factors contributing to ineffective teaching and learning in primary schools: Why are schools in decadence? *Journal of Education and Practice, 6*(19), 125–132. https://files.eric.ed.gov/fulltext/EJ1079543.pdf

Nartey, E., & Hanson, R. (2021). The perceptions of senior high school students and teachers about organic chemistry: A Ghanaian perspective. *Science Education International*, *32*(4), 331–342. https://doi.org/10.33828/sei.v32.i4.8

Nbina, J. B. (2012). Analysis of poor performance of senior secondary students in chemistry in Nigeria. *African Research Review, 6*(4), 324–334. https://doi.org/10.4314/afrrev.v6i4.22

O'Dwyer, A., & Childs, P. E. (2017). Who says organic chemistry is difficult? Exploring perspectives and perceptions. *Eurasia Journal of Mathematics, Science and Technology Education, 13*(7), 3599–3620. https://doi.org/10.12973/eurasia.2017.00748a

Olaleye, B. O. (2012). *Enhancing teachers' knowledge for using multiple representations in teaching chemistry in Nigerian senior secondary schools* (Doctoral dissertation, Edith Cowan University). https://ro.ecu.edu.au/theses/494

Omwirhiren, E. M., & Ubanwa, O. A. (2016). An analysis of misconceptions in organic chemistry among selected senior secondary school students in Zaria local government area of Kaduna state, Nigeria. *International Journal of Education and Research, 4*(7), 247–266.

Pallant, J. (2007). *SPSS survival manual: A step by step guide to data analysis using SPSS for windows* (3rd ed.). Maidenhead, Berkshire: McGraw Hill Education.

Park, S., & Oliver, J. S. (2008). Revisiting the conceptualisation of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education, 38*, 261–284. https://doi.org/10.1007/s11165-007-9049-6

Sadler, P. M., & Sonnert, G. (2016). Understanding misconceptions: Teaching and learning in middle school physical science. *American Educator, 40*(1), 26–32.

Shulman, L. S. (1986) Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4–14. https://doi.org/10.3102/0013189X015002004

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1–23. https://doi.org/10.17763/haer.57.1.j463w79r56455411

Sibomana, A., Karegeya, C., & Sentongo, J. (2021). Students' conceptual understanding of organic chemistry and classroom implications in the Rwandan perspectives: A literature review. *African Journal of Educational Studies in Mathematics and Sciences*, *16*(2), 13–32. https://doi.org/10.4314/ajesms.v16i.2.2

Smith, P. S., & Banilower, E. R. (2015). Assessing pedagogical content knowledge: A new application of the uncertainty principle. In A. Berry, P. Friedrichsen, & J. Loughran (Eds.), *Re-examining pedagogical content knowledge in science education* (pp. 88–103). London: Routledge.

Solomons, T. W. G., Fryhle, C. B., & Snyder, S. A. (2016). Solomon's *organic chemistry* (12th ed.). Hoboken, NJ: Wiley.

Sukarmin, M., Suparmi, M., & Ratnasari, D. (2017). The implementation of two-tier multiple-choice (TTMC) to analyze students' conceptual understanding profile on heat and temperature. *Advances in Social Science, Education, and Humanities Research*, *158*, 179–189. https://doi.org/10.2991/ictte-17.2017.41

Supovitz, J. A., Mayer, D. P., & Kahle, J. B. (2000). Promoting inquiry-based instructional practice: The longitudinal impact of professional development in the context of systemic reform. *Educational Policy*, *14*(3), 331–356. https://doi.org/10.1177/0895904800014003001

Tabachnick, B. G., & Fidell, L. S. (2019). *Using multivariate statistics* (7th ed.). Boston: Pearson Education, Inc.

Valanides, N. (2000). Primary student teachers' understanding of the particulate nature of matter and its transformations during dissolving. *Chemistry Education: Research and Practise in Europe*, *1*(2), 249–262. https://doi.org/10.1039/A9RP90026H

Veal, W. R. (2004). Beliefs and knowledge in chemistry teacher education. *International Journal of Science Education, 26*(3), 329–351. https://doi.org/10.1080/0950069032000097389

von Aufschnaiter, C., & Rogge, C. (2010). Misconceptions or missing conceptions? *Eurasia Journal of Mathematics, Science and Technology Education,* 6(1), 3–18. https://doi.org/10.12973/ejmste/75223