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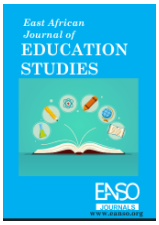

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Original Article

Chemistry Teachers' Knowledge of Teaching and Assessment of Senior High School Students

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Assessment, Chemistry, Content Knowledge, Pedagogical Knowledge, Professionally Trained Teachers.

ABSTRACT

The Ghana Education Service has employed two categories of chemistry teachers who are expected to deliver in line with a set standard of teaching and assessment. The study investigated professionally trained chemistry teachers and untrained chemistry teachers using Shulman's PCK model. The study investigated their knowledge of teaching and assessment. A multi-case study design was used to investigate multiple knowledge domains of chemistry teachers in senior high schools within the Tamale Metropolis in the Northern Region. One hundred fifty chemistry students and 12 chemistry teachers were selected through a random sampling technique, and in one of the schools, a convenient sampling technique was utilised. The study employed questionnaires, interviews, and classroom observation to solicit data from the participants. The quantitative data gathered was analysed by employing descriptive statistics and paired sample t-tests. The qualitative data was analysed by developing common themes and patterns in the respondents' responses. Comparatively, the findings revealed that the professionally trained chemistry teachers exhibited higher knowledge of teaching and assessment in chemistry than the untrained chemistry teachers. Case-by-case analysis and comparison of the findings indicated that some untrained chemistry teachers exhibited higher knowledge in teaching and assessment than some of the professionally trained chemistry teachers. It was therefore recommended that colleges of education and universities that train teachers should concentrate on the pedagogical development of chemistry teacher trainees. Content knowledge alone would not ensure professional teaching of chemistry. Ghana Education Service, in collaboration with other governmental and non-governmental agencies, should periodically organise workshops and seminars for in-service chemistry teachers' professional development to be trained in modern pedagogical trends. In-service chemistry teachers should be given opportunities for further studies to learn and discover emerging methods and strategies for teaching chemistry.

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INTRODUCTION

Chemistry is one of the elective subjects offered to general science, agricultural science, and home science students among senior high schools (SHSs) in Ghana. The knowledge of students in chemistry is considered vital and critical for their academic progression and career development. In view of this, chemistry has been listed as the major requirement for admission into tertiary institutions in Ghana for general science, agricultural science, and home science students. Teachers who teach and assess these students are considered major contributors to the knowledge transmission and knowledge application of concepts in chemistry.

Chemistry teachers need to keep an up-to-date deeper knowledge and skills of what they teach and how they teach those concepts to chemistry students in senior high schools. Chemistry teachers must take responsibility for improving teaching and assessment through appropriate professional training and professional development (Standard for Teachers' Professional Development Implementation Guidance for School Leaders, STPDIG, 2016). According to Agbidye & Ukor (2015), the quality and professional competence of chemistry teachers is a function of the quality of education in Ghana and the world at large. It is therefore recommended that chemistry teachers exhibit good and appropriate knowledge and understanding of the subject matter that they teach for the enhancement of teaching, learning and assessment of chemistry in senior high schools (Mpinge & Onyango, 2023a). Professional training and professional development programmes for chemistry teachers should be geared towards equipping the teachers with appropriate assessment tools that would assess the various learning domains and faculties of senior high school chemistry students (Etulle et al., 2023; Peretz et al., 2023).

In Ghana, the senior high schools are under the Ghana Education Service (GES). This body formulated and regulates policies and programmes that facilitate and promote effectual teaching and learning in senior high schools. GES in collaboration with the Ministry of Education, appoint and engage teachers to teach in all senior high schools in Ghana. They provide the standards for the teaching profession. That is professional values and attitudes, professional knowledge, and professional practice (MoE-NTS, 2018). These professional standards are obtained through teacher professional training from teacher training institutions. The teacher training institutions train chemistry teachers, taking into consideration content knowledge, pedagogical knowledge, and contextual knowledge (Arrigo et al., 2022). The blend of these knowledge domains would provide a unique quality; thus, the pedagogical content knowledge in every chemistry teacher is needed for effectual teaching and learning (Lee Shing et al., 2013). This unique knowledge obtained through teacher education training provides chemistry teachers with the required professional knowledge, practices, attitudes, and values for

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engagement in the chemistry classroom (Fischer et al., 2012; Kuerbis et al., 1997; Rebecca, 2018).

The Ghana Education Service, which is responsible for the appointment and engagement of teachers into senior high schools, has over the years recruited into the service professionally trained and untrained chemistry teachers. These two groups of chemistry teachers are all expected to exhibit the best standard of teaching in line with their lesson delivery in the classroom. According to Fauth et al. (2019), the chemistry teachers' competencies would include pedagogical content knowledge, self-motivation, and passion towards the teaching profession. These elements of teachers' competencies when cultivated through professional teacher training and exhibited professionally in the chemistry classroom would positively arouse chemistry students' interest towards learning. Learning outcomes in chemistry among SHS students would be enhanced.

Therefore, the study sought and investigated the pedagogical content knowledge of professionally trained and untrained chemistry teachers taking into consideration their knowledge of teaching chemistry and knowledge of assessment of chemistry concepts. Knowledge of teaching and assessment are among the knowledge domains of Shulman's PCK model for science teachers. They are vital knowledge components required by chemistry teachers for effective knowledge acquisition, knowledge application, and development of skills, attitudes and values among SHS Students (Etulle et al., 2023). The study was guided by the following objectives;

The study sought to;

- Investigate professionally trained and untrained chemistry teachers' knowledge of teaching SHS chemistry.
- Investigate professionally trained and untrained chemistry teachers' knowledge of assessing SHS chemistry students.

Professionally trained and untrained chemistry teachers are all employed to teach in Ghanaian chemistry classrooms. Would these two groups of chemistry teachers possess and exhibit the required pedagogical competencies?

REVIEW OF RELATED LITERATURE

Theoretical Review

Constructivist Theory (Bodner, 1986; Hein, 1991)

The constructivist theory has gained a stand in chemistry teaching and learning, as well as epistemology. The theory defines how learners learn and the nature of the knowledge they learn. According to Hein (1991), the constructivist theory of learning is the best approach to teaching and learning chemistry. This theory recognises the learner as an active participant in the learning process, where the teacher assumes the role of a facilitator. This theory encourages the use of student-centred activities and approaches to teaching and learning chemistry, where the learner constructs their own knowledge out of the concepts learnt.

According to Bodner (1986), teaching and learning are not synonymous. Chemistry teachers can teach and teach very well without students having to learn anything. Most cognitive development scientists have come to believe in the constructivist model of knowledge that reveals that knowledge is constructed in the minds of learners based on activity-based experiences. They looked at the professionally trained and untrained chemistry teachers' knowledge of teaching and how they enable their learners to construct understanding from the science concepts that they teach.

Experiential Learning Theory (Oxendine, Robinson, Willson, 2004)

Experiential learning involves a cyclical learning process that focuses on the learners' experiences for them to acquire knowledge. The cyclical process involves the setting of learning goals with learners, thinking and planning experiments, making observations, reflections, and reviews. When these activities are carefully incorporated into the learning process, learners are able to construct meaning from concepts. The knowledge

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constructed by each learner would be unique to them and would lead to the cognitive, emotional, and physical development aspects of their learning.

Experiential learning theory (ELT) provides a holistic learning model through learners' experiences. Learners' experiences are the main driving force towards learning since learners construct their knowledge through the transformation of their experiences. ELT confirm a common saying, "Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand".

Conceptual Review

Content Knowledge

The content knowledge of a chemistry teacher is the in-depth knowledge that the teacher has and exhibits on the subject matter that they teach. The content knowledge enables the chemistry teacher to exhibit mastery and take control of the subject matter. It includes chemistry teachers' deep understanding of principles, theories, and laws that govern the various discoveries in the scientific community. It is the knowledge of chemistry teachers that connects the theories of scientific discoveries to the natural environment of the learners and their applications to solve real-life problems in their environment (Arrigo et al., 2022; Lee Shing et al., 2013). It is the knowledge that enables chemistry teachers to establish a meaningful conceptual relationship between the various concepts and topics contained in the chemistry curriculum. Knowing the goals aims and objectives of the chemistry curriculum and its organisation form part of the chemistry teachers' content knowledge (Arrigo et al., 2022).

Pedagogical Knowledge

Professionally trained chemistry teachers are taught professional courses such as methods of teaching, principles, and practices of teaching chemistry. These courses provide the knowledge domain needed by chemistry teachers to effectively communicate the subject matter to learners. This knowledge domain is referred to as the pedagogical knowledge of chemistry teachers. It is the knowledge of 'how to teach' and 'what to teach'. It forms the master plan of all the practices including skills, attitudes, and values of a chemistry teacher in the classroom. Pedagogical knowledge is the main framework for effective teaching and learning in the chemistry classroom. The absence of pedagogical knowledge affects the learning outcomes of chemistry students (Melo et al., 2020; Sothayapetch et al., 2021). It is, therefore, imperative for continuous training of pre-service and in-service chemistry educators to improve their knowledge of pedagogy also, teacher training institutions should consider pedagogical knowledge as a vital requirement for chemistry teacher effectiveness because it is the art and science of instruction.

Contextual Knowledge

Contextual knowledge is a required knowledge component of chemistry teachers that transcends beyond the classroom. The chemistry teachers must understand the nature of their students and their background. The organisational structures of the school, its core values and its mission statement should be understood by chemistry teachers. They are expected to act in accordance with the national policies in the Education sector, the code of conduct for Ghana Education Service staff, and the bylaws of the unit and community where the school is located. They should possess knowledge of current and new technological advancements to effectively integrate with pedagogical content knowledge. The above elements form the contextual knowledge of chemistry teachers. Those who neglect this knowledge domain would be rendered ineffective in their teaching environment. (Bayram-Jacobs et al., 2019). Chemistry teachers' contextual knowledge is an added advantage, and teachers who exhibit this knowledge domain are more successful in their classrooms (Mpinge & Onyango, 2023). Contextual knowledge is essential to the success and effectiveness of chemistry teachers, and its absence or deficiency would hinder educational development. Chemistry teachers' attempt at content integration

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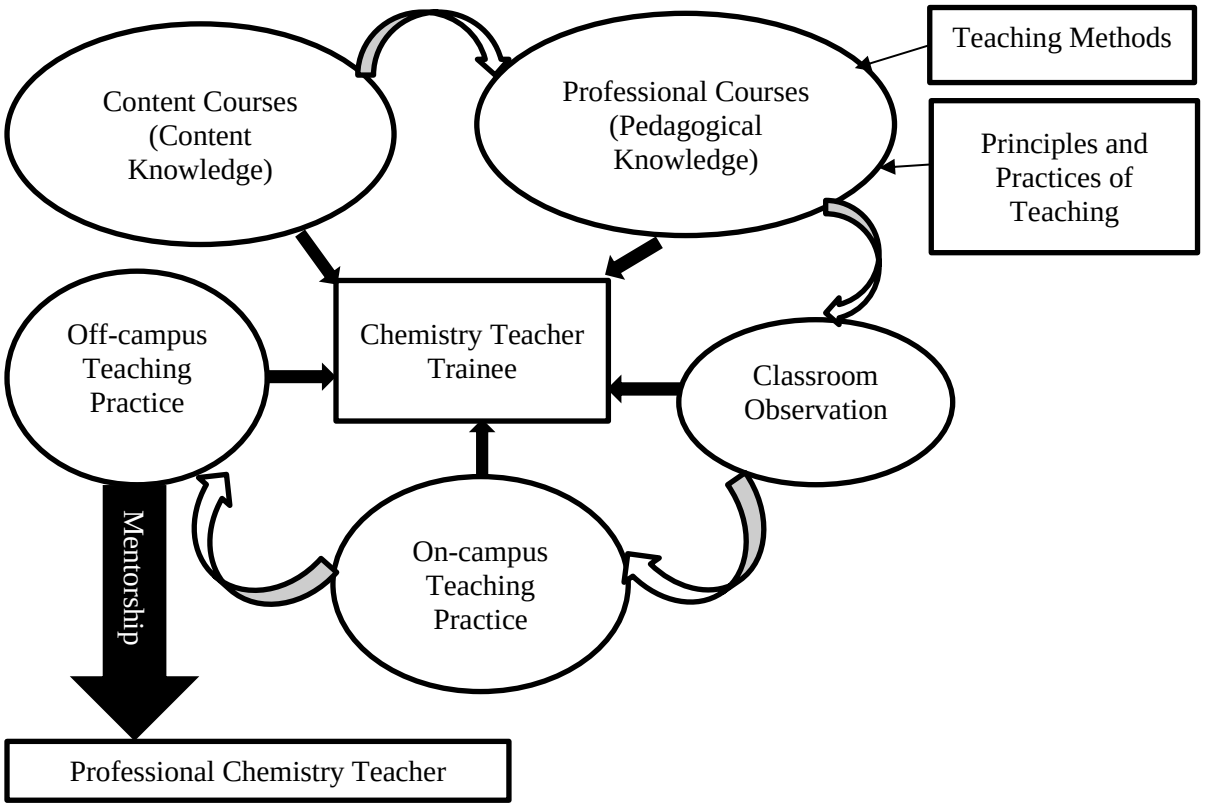
to draw accurate and reliable information for their learners to appreciate and apply would appear distorted for their learners.

Types of Assessments in Chemistry

Assessment involves the use of multiple methods and tools to examine, evaluate, and make judgments on the knowledge, skills, values, and attitudes acquired by learners in a programme of study. It includes continuous systematic documentation of empirical evidence of learning in the various knowledge domains of the learners. Assessment in chemistry aims to provide feedback to chemistry students and improve students' intended learning outcomes. Therefore, the knowledge of assessment, the tools and the methods are a vital requirement of chemistry teachers. The tools and methods used by chemistry teachers for assessment have a great impact on chemistry students' learning (Etulle et al., 2023; Peretz et al., 2023). It is imperative that chemistry teachers adopt, adapt, and construct effective assessment practices that would evaluate chemistry students' understanding and application of knowledge, skills, attitudes, and values to promote quality in education. The assessment tools should consider the practical nature of chemistry and should enable their students to recognise the link between theories and practices in their environment (Etulle et al., 2023; Ngaji & Amba, 2021; Peretz et al., 2023).

Figure 1: Professional Chemistry Teacher Training Model.



Empirical Review

Teachers' PCK is an interconnection of several knowledge components, and it is interesting to note that every teacher's PCK develops in personal and distinct ways depending on the subject matter they are teaching (Melo et al., 2020). PCK is a professional knowledge of teachers. It establishes a connection between teaching and learning processes, which are philosophically dependent (Abukari et al., 2022). In *Figure 1*, during chemistry teacher training, the pre-service teachers took several content courses to build their content knowledge of the subject matter and professional courses in methodologies and pedagogies to build their pedagogical knowledge. The pre-service teachers were also

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given opportunities to experience real classroom teaching during their training through school observation, on-campus teaching practice, and off-campus teaching practice. School observation gave the pre-service teachers the opportunity to observe experienced teachers teach and help them gain an understanding of some complex issues concerning classroom management and control. Also, both the on-campus and off-campus gave the chemistry teacher trainees opportunities to teach their peers and pupils/students in real classrooms under strict monitoring and assessment of the trainees' developed and developing competencies by tutors/lecturers and experienced science and chemistry teachers in the schools where the trainees embarked on the off-campus teaching practice. These activities formed the chemistry teacher preparation and training programme that trains chemistry teachers for the pre-tertiary level of Ghana's education system. It is therefore expected of science teacher trainees who have gone through teacher education training and preparation to have gained a deeper understanding of content and pedagogy and should be able to integrate content and pedagogy and transform it into pedagogical content knowledge in all the models of teaching learnt to promote effective teaching and learning in their classrooms.

A survey by Abukari et al. (2022) investigated the pedagogical content knowledge of Colleges of Education Science Tutors and how that impacts the pedagogical content knowledge development of science teacher trainees. The study was conducted on 120 science teacher trainees, and the findings revealed that 37.5% of them recorded low PCK development.

The quest for higher students' academic achievement has never been so urgent as it is now as a result of the divergent needs of our societies and the world at large (Sui et al., 2010). There is therefore the need for qualified chemistry teachers with varied domains of skills not limited to the content. They should be able to guide and assist students in their learning through learning models for holistic development.

Chemistry students' attainment of knowledge, improvement in behaviour and learning as well as knowledge application are important function that depends on chemistry teachers' competencies in their pedagogical content knowledge (Abukari et al., 2022; Adu-Yeboah & Kwaah, 2018). It is therefore, necessary that Ghana Education Service and other stakeholders in the Education sector take a keen interest in the knowledge composition of chemistry teachers that they put in the classroom. The above literature and several others have assessed science teacher trainees' PCK in Ghana with little or no available literature that sought to compare their PCK with that of untrained teachers who are equally employed by the Ghana Education Service.

Marifa et al. (2023) conducted a survey which assessed Chemistry teachers' pedagogical content knowledge in teaching hybridisation. The data from the survey revealed that chemistry teachers exhibited higher knowledge of instructional strategies for teaching chemistry and knowledge of the science curriculum. The teachers, however, scored very low marks in the assessment of their knowledge of teaching hybridisation, knowledge of assessment, and knowledge of students' understanding of science. The study revealed that the teachers had a poor PCK since their knowledge of instructional strategies and science curricula could not define them as effective chemistry teachers.

Due to the constant change in societal needs and the global need for scientific innovations, many scholars are now viewing teacher professionalism in teaching as the factor that provides professional teachers with the needed professional space and better conditions of service for teaching (Seo et al., 2017) This many believed would provide teachers with the power to responsibility in excellent educational practices.

Therefore, this study sought and provided a comparative study on the knowledge domains of professionally trained and untrained chemistry teachers employed by the Ghana Education Service.

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MATERIALS AND METHODS

Research Design

The study utilised a comparative case study design. This design was employed to provide extensive and deep knowledge of cases in sequential stages of hypotheses formulation, case selection, data collection, and comparative analysis of data within and between cases of professionally trained and untrained chemistry teachers. The design was anchored on the pragmatist philosophical foundation using a mixed research approach. This enabled the study through the comparative case study to collect quantitative and qualitative data on the knowledge domains of professionally trained and untrained chemistry teachers. It gave the study a complete view of the knowledge of chemistry teachers in the study area.

Population and Sample

The target population for the study included public science senior high schools within the Tamale Metropolis. Three schools were randomly selected for the study from a total of 11 public science senior high schools. The Geopoll statistics software calculator was used to determine the sample sizes for the study from the three selected senior high schools. The accessible population for the study included 150 chemistry students and 12 chemistry teachers, which were made up of 50 randomly selected chemistry students from each of the three schools for the study. Four (4) chemistry teachers each were also randomly and purposively (as in the case of one school) selected, taking into consideration two professionally trained and two non-professionally trained chemistry teachers for the study. A total sample size of 150 chemistry students was therefore selected from a total of 312 second-year science students and 12 chemistry teachers out of a total of 81 chemistry teachers from the three participating schools.

Research Instruments

Data collection instruments are research devices used to gather data during a research study (Canals, 2017). The researcher employed data triangulation, thus using three different data collection instruments to solicit data from respondents. Three research instruments were used: questionnaires, interviews, and classroom observation.

A set of adapted questionnaire items were administered to 150 science students and 12 chemistry teachers. This questionnaire included items on teaching methods and assessment practices. One-on-one interviews using a checklist of open-ended items were administered to 30 students randomly selected from the participating schools. The research adopted a set of observation checklists, which were used to gather data during the observation process. The checklist consisted of four answer options for each statement used to gather data on 12 science teachers. The observer ticked (✓) the most appropriate observation based on 5 points Likert scale: one (1) for poor, two (2) for satisfactory, three (3) for good, four (4) for very good and five (5) for excellent performances, and comments made on each observation.

Data Analysis

Quantitative data obtained from the questionnaires and classroom observations were analysed using Descriptive Statistics T-test Statistic all in IBM SPSS Statistics 27. Face-to-face interview data with the students were analysed qualitatively through themes and patterns of participants' responses.

RESULTS

The questionnaire for the chemistry teachers and their students was a four-point Likert scale questionnaire on the chemistry teachers' knowledge of teaching and assessment of chemistry. It was coded as strongly disagree (1), disagree (2), agree (3), and strongly agree (4). The mean (x) of the students' and the teachers' responses were determined, and to help the study decide the category of responses, the calculation below was employed. The range was determined as the difference between the highest code and the lowest code. That is 4-1 = 3. The range of chemistry teachers and the students' responses

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was determined by setting the upper and lower limits of their average response. The range was divided by the highest code, 3/4 = 0.75. The cumulative addition of 0.75 to the lowest code sets the upper and lower limit for the average response. That is 1-1.75 for those who strongly disagreed, greater than 1.75-2.50 for those who disagreed, greater than 2.50-3.25 for those who agreed, and greater than 3.25-4.00 for those who strongly agreed. *Table 1* shows the summary of the students' responses to their chemistry teachers' knowledge of teaching and assessment of chemistry.

Classroom observation was conducted using a classroom observation checklist, which contained question/statement items on chemistry teachers' knowledge of teaching and assessment. It was scored based on the teachers' performance on the chemistry teachers' knowledge of teaching and assessment of chemistry during their lesson observation. The observation was done by independent experts in the field of chemistry and science education. The scores were as follows: 1 for poor performance, 2 for satisfactory performance, 3 for good performance, 4 for very good performance, and 5 for excellent performance. The observation checklist contained ten (10) statements each on knowledge of teaching and knowledge of assessment of chemistry. *Table 2* represents the Chemistry teachers' responses to their own knowledge of teaching and assessment, whilst *Table 3* shows the Chemistry and science education experts' scores on senior high school chemistry teachers' knowledge of teaching and assessment during classroom observation.

The data in *Table 1* indicated the students' responses to a questionnaire that solicited information on their chemistry teachers' knowledge of teaching and assessment. From *Table 1*, the data on the students' responses to their chemistry teachers' knowledge of teaching and assessment indicated that they agreed that their teachers have knowledge in the areas under study. The majority of the students responded that both the professionally trained and untrained chemistry teachers had adequate knowledge of teaching and assessment.

Table 2 indicates the data on the chemistry teachers' own responses to the questionnaire that solicited information from them on their own knowledge of teaching and assessment of chemistry. *Table 2* revealed that they strongly agreed to have a deeper knowledge of teaching and assessment of chemistry. The data in *Table 2* revealed that all the chemistry teachers responded strongly that they possess knowledge of teaching chemistry and assessment of chemistry concepts. The questionnaires were administered to the chemistry teachers to assess their own performance in terms of their knowledge of teaching and assessment. This was done to ascertain the professional attitudes and values such as trustworthiness and truthfulness as part of chemistry teachers' professional ethical practice.

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Table 1: Chemistry students' responses to their senior high schools' chemistry teachers' knowledge of teaching and assessment

Elements of PCK	*Professionally Trained Chem. Teachers*						*Untrained Chem. Teachers*					
	A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***	***K***	***L***
Mean scores of students on chemistry teachers' knowledge of teaching	*2.890*	*2.860*	*2.891*	*2.891*	*2.893*	*2.991*	*2.990*	*2.890*	*2.971*	*2.891*	*2.790*	*2.860*
Mean scores of students on chemistry teachers' knowledge of assessment	*2.942*	*2.842*	*2.945*	*2.942*	*2.944*	*2.952*	*2.962*	*2.942*	*2.932*	*2.934*	*2.842*	*2.942*

Source: Field Data (2022)

Table 2: Chemistry teachers' responses to their knowledge of teaching and assessment

Elements of PCK	**Professionally Trained Chem. Teachers**	**Untrained Chem. Teachers**
Knowledge of Teaching	3.4951	3.5151
Knowledge of Assessment	3.9632	3.9671

Source: Field Data (2022)

Table 3: Chemistry and science education experts' scores on senior high school chemistry teachers' knowledge of teaching and assessment during classroom observation

Elements of PCK	*Professionally Trained Chem. Teachers*						*Untrained Chem. Teachers*					
	A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***	***K***	***L***
Knowledge of Teaching	*34 (68%)*	*37 (74%)*	*26 (52%)*	*30 (60%)*	*28 (56%)*	*30 (60%)*	*22 (44%)*	*25 (50%)*	*21 (42%)*	*26 (52%)*	*22 (44%)*	*27 (54%)*
Knowledge of Assessment	*42 (84%)*	*36 (72%)*	*25 (50%)*	*29 (58%)*	*39 (78%)*	*22 (44%)*	*31 (62%)*	*28 (56%)*	*23 (46%)*	*21 (42%)*	*24 (48%)*	*20 (40%)*

Source: Field Data (2022)

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Moreover, the study utilised classroom observation to confirm the responses from the students and their teachers. *Table 3* contained data from the classroom observation that was conducted by experts in science and chemistry education who observed three different chemistry lessons of both the professionally trained and untrained chemistry teachers. Professionally trained teacher B scored higher marks (74%) in knowledge of teaching chemistry. That was followed by professionally trained teacher A with a score of 68%, and professionally trained teachers D, E, and F scored 60% and 56%, respectively. Interestingly, untrained chemistry teacher L scored higher marks (54%) in knowledge of teaching chemistry than professionally trained teacher C. A similar trend surfaced in the teachers' knowledge of assessment, where untrained chemistry teacher G exhibited higher knowledge in chemistry assessment than professionally trained chemistry teachers C and F. *Table 3* revealed the average performance of each chemistry teacher. From the data in *Table 3*, a paired sample t-test analysis was run, which determined the significant difference in the sum score for the professionally trained and untrained chemistry teachers. This is indicated in *Table 4*.

Table 4: Paired sample t-test on chemistry teachers' knowledge of teaching and assessment

Elements of PCK	Mean Difference	Std. Deviation	T	df	Sig(2-tailed)
Knowledge of Teaching	7.000	4.000	4.287	5	0.008
Knowledge of Assessment	7.667	5.086	3.692	5	0.014

Source: Field Data (2022)

The findings in *Table 4* revealed significant values (p-values) of 0.008 and 0.014. These values at a 95% confidence level are less than 0.05 alpha value. This indicated that there was a statistically significant difference between professionally trained and untrained chemistry teachers in terms of knowledge of teaching and assessment. However, the data contained in *Table 3* revealed that, by considering individual performance, some untrained chemistry teachers scored higher in knowledge of teaching as well as knowledge of assessment than some professionally trained chemistry teachers. This means that the majority of the professionally trained chemistry teachers exhibited higher knowledge in teaching and assessment than their counterparts who have not gone through professional teacher training.

The study further utilised interview guides to solicit qualitative findings from the students on what their chemistry teachers do during teaching and assessment of chemistry. Some themes and patterns were revealed in the students' face-to-face interview sessions.

> Student 1: *"My chemistry teacher always comes to class to explain the concepts to us and write or sometimes dictate notes for us to copy".*

> Student 2: *"For our two years in school now, our chemistry teacher has never taken us to the chemistry laboratory for any practical work. We do not know when we will start using the lab".*

> Student 3: *"My chemistry teacher does not always put us into groups and give us questions to discuss among ourselves and find answers to the questions. The few he did, he did border, after which we come to present our finding to the larger class".*

> Student 4: *"Our chemistry teacher gives us a lot of assignments, class exercises, and projects, which are always included in our end-of-semester grades".*

DISCUSSION

There has been an increasing demand and necessity for quality-based, high-performance-oriented, passionate, and self-motivated chemistry teachers in education that would see teaching and assessment of chemistry as an interrelationship of all the knowledge domains of their students (Barineka, 2012; James, 2018; Murekatete et al., 2022). The teaching and learning standards must be guided to ensure quality education as contained in the National Teachers' Standards, NTS (2018).

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For any country to achieve a state of teaching and learning of high-quality standards, the professional status quo of the teacher cannot be overlooked (Barineka, 2012; James, 2018; Murekatete et al., 2022; Ojelade et al., 2012; Oumaichrispine & Mairos, 2011).

The study investigated the PCK of professionally trained and untrained chemistry teachers teaching in SHSs within the Northern region. The study employed Shulman's PCK model for teaching science and laid emphasis on knowledge of teaching and assessment. The findings indicated that the professionally trained chemistry teachers exhibited higher knowledge of teaching and assessment than the untrained chemistry teachers. A case-by-case analysis of the individual performance of the professionally trained and untrained chemistry teachers revealed interesting facts. That is, some untrained chemistry teachers who have not had professional teacher training exhibited higher knowledge in teaching and assessment of chemistry than their professionally trained counterparts. This confirms the findings of Weisma (2012) that teaching is both art and science. While some were born great teachers, others could be trained to become great teachers.

The findings indicated that those professionally trained chemistry teachers who exhibited low PCK performance were a reflection of their training received during their professional teacher training. Many of the teachers have in-depth knowledge of content with little pedagogy on how the content should be communicated. This revelation resonates with the findings of Abukari et al. (2022) in their study on the pedagogical content knowledge of science tutors and its influence on their trainees. Their assessment of PCK of 120 colleges of education trainees revealed that the trainees' pedagogical unpreparedness was a reflection of how much the trainees had received from their tutors.

Furthermore, the findings of the study, as contained in *Table 3*, indicated that professionally trained teachers A, B, D, and E had consistently higher scores in both knowledge of teaching and assessment, hence higher PCK delivery. According to Marifa et al. (2023), the teachers' inability to exhibit higher knowledge performance in all the knowledge domains of Shulman's PCK model rendered them ineffective. Therefore, the finding of this study showed that the majority of the professionally trained chemistry teachers were more effective than the untrained chemistry teachers.

CONCLUSION

Ghana with its high demand for professionalism in teachers in their teaching profession, Ghana Education Service still employs both professionally trained chemistry teachers and untrained chemistry teachers in the teaching profession. Ghana Education Service expects these two groups to perform to the highest standard of teaching and learning.

The findings of this study, which resonated with the findings of other literature, revealed that pedagogical content knowledge is a requisite for effective teaching and learning. For chemistry teachers to remain relevant and effective to the emerging trends in our classrooms, they must possess and exhibit higher PCK. The evidence from this study indicated that professionally trained chemistry teachers are more effective in the classroom than untrained chemistry teachers. It is therefore, evident that professional teacher training is necessary before engaging chemistry teachers to teach.

Recommendations

The following recommendations were made considering the results of the study. These included;

- Ghana Education Service, Colleges of education and universities that train teachers in collaboration with other governmental and non-governmental agencies should concentrate on the pedagogical development of chemistry teacher trainees. Workshops and seminars should be periodically organised for in-service chemistry teachers to be trained and professionally developed in modern pedagogical trends. Content knowledge alone

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would not ensure professional teaching of chemistry.

- In-service chemistry teachers should be given opportunities for further studies to learn and discover emerging methods and strategies for teaching chemistry.

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Conflict of Interest

The authors declare that there was no conflict of interest.

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