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Diagnosing Pedagogical Content Knowledge Deficits among Chemistry Teachers to Improve STEM Education in Northeast Nigeria

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ABSTRACT

The study diagnosed pedagogical content knowledge (PCK) deficits among secondary schools' chemistry teachers to improve STEM education in Northeast Nigeria. This study used a correlational research design to collect both qualitative and quantitative data from respondents. Population of 313 chemistry teachers in secondary schools located in Adamawa and Taraba States in Northeast Nigeria was used as sample size for the study. The Cronbach's alpha reliability coefficient of 0.873 was obtained which indicated a high level of internal consistency and reliability of the instrument, Chemistry Teachers Pedagogical Content Knowledge and Teaching Effectiveness Questionnaire (CTPCKTEQ). The descriptive statistics of mean and standard deviation as well as Spearman's correlation coefficients were used to answer the research questions, while multiple regression analysis was used to test the hypotheses at a .05 significance level. The findings showed that chemistry teachers in the region demonstrate a high level of content knowledge; a strong level of pedagogical knowledge, and highly effective in their teaching roles, with consistently high mean scores. Also, there is a weak positive correlation between content knowledge and teaching effectiveness, and a moderate to strong positive correlation between pedagogical knowledge and teaching effectiveness. Hence, the study concluded that pedagogical and content knowledge and skills play a critical role in determining teaching effectiveness. Teachers who possess effective pedagogical skills, such as the ability to design engaging lessons and assess student learning, are more likely to be effective in their teaching. Therefore, teachers should be supported in developing their content knowledge and pedagogical skills through professional development programs and workshops to improve STEM education in Northeast Nigeria.

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INTRODUCTION

STEM (Science, Technology, Engineering & Mathematics) education has benefits for students, such as increasing achievement and improving attitudes, motivation, interest toward STEM disciplines, and higher-order thinking skills; and providing STEM education and applying it in learning is influenced by teacher's knowledge and attitude (Jack, 2022). Assessment is necessary for every educational activity, including in the field of STEM education and mostly subject specifics like Chemistry.

Chemistry is a vital subject in science education that studies the properties and compositions of substances as well as the changes they go through. The subject plays a critical role in scientific discoveries and inventions. Almost every scientific endeavor, whether in pure or applied fields, involves chemistry in a significant way. Chemistry, by virtue of its utility and

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relevance in material, practice, and application, meets the demands of almost all students desiring to study science-related courses at any higher institution. Chemistry teachers, like other scientific teachers, receive formal instruction in Universities' faculties and Colleges of education. Chemistry teachers get subject matter expertise throughout such training programs.

The integration of subject matter and teaching strategies is the cornerstone of effective science instruction mostly influenced by teacher's pedagogical and content knowledge which goes far beyond knowing the fundamental principles of chemistry. It encompasses an instructor's ability to utilize relevant analogies, targeted representations, and effective classroom management techniques to simplify difficult topics like stoichiometry, electrochemistry, and organic chemistry. In Nigeria, the senior secondary school chemistry curriculum is designed to equip students with the foundational skills needed for careers in science, medicine, and engineering. However, successfully delivering this curriculum demands teachers who not only understand chemistry but also know how to teach it to diverse groups of learners.

In the Northeast geopolitical zone, the educational landscape has faced significant disruptions. Despite these challenges, the demand for STEM education remains vital. Effective teaching in this region requires educators to be culturally responsive, highly adaptable, and resourceful. While various studies on PCK have been conducted in other parts of Nigeria, the specific socio-educational realities and unique resource constraints of Northeast states (such as Adamawa, Borno, Gombe, Taraba and Yobe) necessitate a highly localized evaluation of how chemistry teachers apply PCK to foster student comprehension and engagement.

The competence of chemistry teachers is critical in improving students' knowledge and academic progress. The discipline knowledge earned through formal training is referred to as subject matter/content knowledge. Content knowledge as viewed by Ozdemir and Soylu (2017), is the body of information that teachers teach to students in a given subject area such as facts, concepts, theories and principles While Bakar et al (2022) refers to content knowledge as the subject matter curriculum including key concepts, facts, and theories. The author also submitted that content knowledge is a type of technical information that is essential to the foundation of teaching as a calling and profession. Content knowledge is an essential and fundamental prerequisite for the teacher's pedagogical content knowledge. Adequate content knowledge enhances pedagogical content knowledge but a lack of subject expertise among teachers can negatively affect students learning.

Pedagogical knowledge refers to the knowledge about teaching and learning that is not topic specific such as knowledge of learning theory, classroom management and students' motivation (Auerbach & Andrew, 2018). Pedagogical knowledge enables teachers to incorporate and apply students' prior knowledge for successful subject learning during the educational process. A teacher's pedagogical knowledge allows him or her to design, implements, and assess the educational process while transforming the subject matter into a format that will improve students' learning. Pedagogical knowledge comprises "deep knowledge" of the process and practice of teaching and learning approaches. And, from all the indicators, pedagogical knowledge includes the sum total of educational purposes, values, and instructional goals. This includes lesson design and creation, implementation, student learning capacity, and classroom management by the teacher. Hence, Konig et al (2014) in Auerbach & Andrew, (2018) defined pedagogical knowledge as the knowledge of theories of learning, general principles and approaches to instruction and assessment, lesson structure, classroom organization and management, students' motivation and other knowledge of learners.

Pedagogical content knowledge (PCK) is a combination of pedagogical, and content knowledge. Pedagogical content knowledge (PCK), proposed by Shulman (1986), intimated that it is how the content of a concept is introduced by making use of instructional techniques such as

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analogies, diagrams, illustrations, examples, explanations, and demonstrations, thus, organizing the subject matter in a way that will motivate learners to understand (Marifa et al. 2023a). These analogies, diagrams, illustrations, examples etc. when used effectively can promote students' understanding and improve academic achievement in the classroom. Shulman also added that PCK instills various knowledge domains, subject matter, instructional techniques, teaching and learning materials, students' needs, and evaluation methodologies, among other things, to help learners comprehend certain ideas. The PCK according to Marifa et al. (2023b) a concept in teacher education requires additional focus and attention by pre-tertiary teachers to improve teaching and learning and learners' performance.

The PCK includes teacher knowledge of the curriculum and curriculum materials, classroom management knowledge, as well as knowledge of students and their characteristics. According to Morris (2024), the teachers view learning as an active process on the part of the learner may utilize their pedagogical reasoning to make the needed instructional adjustments. Consequently, as viewed by the author centering instruction on student learning rather than teaching methods requires a teacher to attain a high degree of professional knowledge and skills; which at the personal level of PCK, teachers must be able to respond to the needs of individual students and make adjustments to instruction.

Considering Shulman's pioneering work as noted by Morris (2024), most scholars in science education today regard well-developed PCK as essential for teachers to effectively promote student content understanding. Reynolds and Park (2021), Mohammed et al. (2021) demonstrate that teachers with strong pedagogical knowledge tend to exhibit more effective teaching practices and promote better student learning outcomes. To Adamu and Achufusi-Aka (2020) the observed level of pedagogical knowledge among chemistry teachers in this study suggests that they are well-prepared to design and deliver instruction that facilitates student understanding and engagement with chemistry concepts.

Teaching is a complex activity that necessitates extensive knowledge on every aspect of the teacher with instructional quality and PCK skills gaps in literatures. The literatures from previous research shows gap in the subject area (chemistry) that requires additional focus due to lack of depth of subject matter (content knowledge) and PCK by teachers necessary to improve learners' performance. The literatures also confirmed content and teaching (pedagogy) gaps of science teachers.

The study by Das and Mahapatra (2020) revealed that there are significant content and teaching (pedagogy) gaps in the respective units and sub-units of the chemistry curriculum. Past studies have also revealed pedagogical gaps in aspects of customized staff development on teaching and learning in teacher education, particularly the content and pedagogical coverage of pedagogy (i.e. PCK) of science teachers. It was also attested by Marifa (2023a) that the chemistry teachers' PCK were inadequate. And, since PCK (both content and pedagogical knowledge) is a vital a concept in teacher education; it requires additional focus and attention by teachers to improve teaching and learning (classroom practice) and learners' performance.

STATEMENT OF THE PROBLEM

Students in Northeast Nigeria consistently record underachievement in Senior School Certificate Examinations (such as WAEC and NECO). Research indicates that this is largely driven by poor foundational teaching methods. Many chemistry educators in the region rely on rote memorization and abstract textbook lecturing rather than practical, inquiry-based STEM approaches. This teacher-centered approach fails to address students' preconceived misconceptions or connect chemistry to real-world phenomena. When teachers lack a sound grasp of PCK components such as knowledge of students' understanding, curriculum saliency, and topic-specific instructional strategies which they struggle to make the subject engaging and comprehensible.

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The problem on teacher factors that bothered on PCK such as poor content knowledge, poor instructional skills, poor assessment skills, and poor teaching methods were the most critical factors attributable to learners' poor performance. Studies also found that other factors, which appear to have bearing on PCK, which affects teaching are insufficient textual resources, inadequate pedagogical techniques and teacher competence and teacher's poor knowledge of instructional material for teaching specific science topics/chemistry concepts.

Several studies have been carried out on PCK of chemistry teachers on topics like electrochemistry, redox reactions, chemical bonding (Vladušić et al., 2020). Other studies have reported on teachers PCK in other subjects like mathematics, physics, and biology. However, few studies have been done on chemistry teachers' PCK and a serious gap exists in literature in the present study areas (Adamawa and Taraba States) in Northeast Nigeria. The efficacy of secondary school chemistry education mostly content and teaching (pedagogy) is a significant factor of students' academic achievement and future interest in the subject. However, there is growing concern in the present study areas about PCK of chemistry teachers. This study thus diagnosed pedagogical content knowledge (PCK) deficits among secondary schools' chemistry teachers to improve STEM education in Northeast Nigeria.

Purpose of the study

The primary objective of this study is to investigate the impact of Pedagogical Content Knowledge on teaching effectiveness in secondary school chemistry in Northeast Nigeria. Specifically, the study seeks to:

1. Assess the level of pedagogical and content knowledge possessed and applied by secondary school chemistry teachers;
2. Determine the extent of teaching effectiveness of chemistry teachers in secondary school in Northeast Nigeria.
3. Determine the relationship between chemistry teachers' pedagogical and content knowledge and their overall teaching effectiveness in the classroom.

Research Questions

The study was guided by these research questions

1. What is the level of content knowledge among secondary school chemistry teachers during classroom lessons?
2. What is the level of pedagogical knowledge among secondary school chemistry teachers during classroom lessons?
3. What is the extent of teaching effectiveness of secondary school chemistry teachers?
4. What is the relationship between content knowledge and teaching effectiveness?
5. What is the relationship between pedagogical knowledge and teaching effectiveness?

METHODOLOGY

This study used a correlational research design to collect both qualitative and quantitative data from respondents. The population of the study comprised of 313 chemistry teachers in secondary schools located in Adamawa and Taraba States of Northeast Nigeria during the 2024/2025 academic session. The entire population was used as Sample size for the study hence, sampling technique was not necessary for the study. The primary method of data collection was through the examination of chemistry teachers' lesson notes and classroom observation, facilitated by the use of classroom observation guides. Respondents were encouraged to freely express themselves, providing a detailed description under investigation.

Additionally, structured questionnaire was used to collect quantitative data to ascertain chemistry teachers' perception on their content knowledge, pedagogical knowledge, pedagogical content knowledge (PCK). Adamawa and Taraba

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states are in North-East geopolitical zone in Nigeria, which comprises of six states: Adamawa, Bauchi, Borno, Gombe, Taraba, and Yobe. The choice of the study area is due to the fact that the states faces unique challenges in education, such as limited access to quality education, especially for girls, and the impact of insurgency on the education sector, the states has rich cultural heritage and diverse linguistic groups, making it an interesting area for studying gender and educational institutions.

The instrument, Chemistry Teachers Pedagogical Content Knowledge and Teaching Effectiveness Questionnaire (CTPCKTEQ) was adapted (since it was slightly modified) from Asiyai (2018), and made up of five sections (Section A-E). Section A solicits for demographic teacher variables of the respondents regarding respondent's name of school, state, gender, qualification, teaching experience, school location and school type. The instruments for collection of qualitative data for the study comprised of classroom observation and lesson note checking. The instrument was validated by three experts and a Cronbach's alpha reliability coefficient of 0.873 was obtained which indicates a high level of internal consistency and reliability.

The data collected were collated and analyzed with descriptive statistics of mean and standard deviation as well as Spearman's correlation coefficients were used to answer the research questions, and multiple regression analysis was used to test the study's hypotheses at a .05 significance level.

RESULTS

The data collected for the study are presented in tables and analyzed using mean and standard deviation, as well as Spearman's correlation coefficients to answer the research questions, with multiple regression analysis used to test the study's hypotheses at a .05 significance level.

Research Question One:

What is the level of content knowledge among secondary school chemistry teachers during classroom lessons?

Table 1: Classroom Observation of Content Knowledge of Chemistry Teachers during Classroom Lessons

S/N	Items on Content Knowledge	N	Mean	Std. Deviation	Remark
1	Planning a lesson in line with the topic to be taught or taught for each lesson	301	3.694	0.50951	Very Adequate
2	Knowledge of chemistry generally	301	3.448	0.53057	Adequate
3	Knowledge of the simple laws underlying each topic in chemistry	301	3.435	0.49661	Adequate
4	Knowledge of the content for each topic to be taught	301	3.637	0.48829	Very Adequate
5	Application of chemistry principles underlying specific topic to be taught	301	3.641	0.48045	Very Adequate
6	Knowledge of chemical theories	301	3.451	0.4985	Adequate
7	Knowledge of chemistry concepts for a specific topic	301	3.614	0.54558	Very Adequate
8	Knowledge of entry behaviour for each chemistry topic	301	3.485	0.50061	Adequate
9	Knowledge of content-based instructional materials for a specific topic in chemistry	301	3.614	0.4875	Very Adequate

The results in Table 1 indicate that chemistry teachers in secondary schools across Adamawa and Taraba States generally demonstrate a high level of content knowledge during classroom instruction. Across the nine assessed indicators, the mean scores ranged from 3.44 to 3.69 on a four-point scale, suggesting that most teachers' content knowledge falls within

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the "adequate" to "very adequate" range. This reflects positively on their preparedness and capability to deliver subject matter effectively.

Notably, the highest mean score was observed for the ability to plan lessons in line with the topic to be taught (M = 3.69), indicating that many teachers are intentional and aligned in their instructional planning.

Similarly, teachers showed strong performance in their application of chemistry principles, understanding of specific chemistry concepts, and use of instructional materials, areas that are crucial for effective teaching and learner engagement. Although still rated within the "adequate" range, the relatively lower mean scores on items such as knowledge of simple laws underlying each chemistry topic (M = 3.44) and knowledge of chemical theories suggest that some teachers may benefit from further strengthening of their foundational understanding in these domains. These are critical elements of content knowledge that support deeper conceptual teaching and student comprehension. The low standard deviations across all items (ranging between 0.48 and 0.55) point to a high level of consistency in the observed ratings, suggesting that these patterns are broadly representative of the teaching practices within the sample.

In summary, the results suggest that chemistry teachers in these states possess a commendable level of content knowledge, with particular strengths in planning, application, and instruction specific to individual topics. However, the data also highlight areas where additional professional development may enhance their overall effectiveness, particularly in reinforcing the theoretical and conceptual foundations of the subject.

Research question two:

What is the level of pedagogical knowledge among secondary school chemistry teachers during classroom lessons?

Table 2: Classroom Observation of Pedagogical Knowledge of Secondary Chemistry Teachers during Classroom Lessons

S/N	Items on Content Knowledge	N	Mean	Std. Deviation	Remark
1	Clarity of behavioural objective	301	3. 6731	0.47763	Very Adequate
2	Ability to start each specific lesson with a good method	301	3.6711	0.4706	Very Adequate
3	Ability to relate the topic to the students' level	301	3.7342	0.4573	Very Adequate
4	Ability to motivate students for their responses	301	3.6977	0.46003	Very Adequate
5	Teachers' use of appropriate teaching aids to enhance students' understanding	301	3.6013	0.51042	Very Adequate
6	Teacher's questioning approaches	301	3.495	0.50081	Very Adequate
7	Knowledge of when to involve students in their learning	301	3.4917	0.53923	Very Adequate
8	The teacher's knowledge of teaching methods appropriates for each topic	301	3.6412	0.48045	Very Adequate
9	Ability to make judicious use of a variety of teaching methods for different topics	301	3.4817	0.50711	Adequate
10	Teaching from simple terms to complex terms and from known to unknown	301	3.6213	0.48588	Very Adequate
11	Knowledge of how to evaluate students' learning.	301	3.5316	0.513	Very Adequate
12	Knowledge and understanding of how students learn.	301	3.3887	0.48827	Adequate

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The data in Table 2 reveal that chemistry teachers in secondary schools across Adamawa and Taraba States generally demonstrate a strong level of pedagogical knowledge during classroom instruction. Most indicators of effective teaching practices received high ratings, with mean scores falling within the "very adequate" range. For instance, teachers were particularly effective in relating lessons to students' levels (Mean = 3.73), starting each lesson with an appropriate method (Mean = 3.67), and clearly stating behavioural objectives (Mean = 3.67). These suggest that teachers are confident in introducing lessons, setting clear learning goals, and engaging students in ways that are developmentally appropriate.

Other aspects of teaching, such as the use of teaching aids (Mean = 3.60), questioning techniques (Mean = 3.50), and understanding when to involve students in learning activities (Mean = 3.49), also received strong ratings, although slightly lower. These results indicate that while teachers are generally proficient in these areas, there may be opportunities to further refine their questioning strategies and timing of student engagement.

A few areas fell at the lower end of the "very adequate" or into the "adequate" range, such as the use of varied teaching methods (Mean = 3.48) and understanding how students learn (Mean = 3.39). While these still reflect satisfactory levels of competence, they suggest that some teachers may benefit from additional support or professional development to strengthen their pedagogical versatility and understanding of student learning processes. Overall, the findings paint a positive picture of chemistry teachers' pedagogical knowledge in these regions. Their teaching practices are largely effective and reflect a solid grasp of how to deliver content and manage learning. However, targeted improvements in certain pedagogical strategies could further enhance instructional quality and student outcomes.

Research question three:

What is the extent of teaching effectiveness of secondary school chemistry teachers?

Table 3: Perceptions of secondary school chemistry teachers on teaching effectiveness

S/N	Items on Content Knowledge	N	Mean	Std. Dev.	Remark
1	Careful planning of each lesson period	301	3.701	0.4658	Strongly agree
2	Ability to communicate effectively with students during lesson	301	3.7076	0.47001	Strongly agree
3	Regular attendance at class	301	3.4684	0.49983	Strongly agree
4	Listening to students' opinions	301	3.4917	0.53923	Strongly agree
5	Provision of relevant feedback to students	301	3.6412	0.48045	Strongly agree
6	Use of relevant instructional materials for topics taught	301	3.4817	0.50711	Strongly agree
7	Gets students actively engaged during instruction	301	3.6213	0.48588	Strongly agree
8	Gives assignment that is relevant to topics taught	301	3.5316	0.513	Strongly agree
9	Exhibits care and respect for students	301	3.3887	0.48827	Strongly agree
10	Clearly makes the objectives of lesson known to students	301	3.8272	0.37867	Strongly agree
11	Ability to apply variety of instructional strategies during lesson	301	3.7076	0.47705	Strongly agree
12	Ability to effectively manage the classroom	301	3.4817	0.5005	Agree
13	Motivates students in their learning	301	3.4518	0.53713	Agree

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S/N	Items on Content Knowledge	N	Mean	Std. Dev.	Remark
14	Ability to cover the curricula content outlined for each topic	301	3.701	0.45858	Strongly agree
15	Ability to differentiate learning for individual students	301	3.3422	0.47523	Agree
16	Socializes with students	301	3.701	0.4658	Strongly agree
17	Demonstrates enthusiasm for students	301	3.7076	0.47001	Strongly agree
18	Demonstrates enthusiasm for subject matter	301	3.4684	0.49983	Strongly agree

The findings from the analysis suggest that chemistry teachers in secondary schools across Adamawa and Taraba States generally perceive themselves as highly effective in their teaching roles. Responses across 18 indicators of teaching effectiveness show consistently high mean scores, ranging from 3.34 to 3.83 on a four-point scale. This indicates that, overall, teachers agree or strongly agree that they demonstrate key qualities associated with effective teaching.

One of the most highly rated aspects was the clarity with which teachers communicate the objectives of each lesson (Mean = 3.83), reflecting a strong emphasis on helping students understand the purpose and direction of instruction. Similarly, teachers rated themselves highly in areas such as effective communication with students, careful lesson planning, covering the curriculum, and demonstrating enthusiasm for both students and the teaching process. These responses suggest that many teachers are committed, well-prepared, and actively engaged in supporting student learning.

Teachers also expressed confidence in their ability to provide feedback, keep students actively involved during lessons, and use a variety of instructional strategies to support understanding. These are encouraging signs that classrooms are dynamic and interactive learning spaces. However, a few areas received slightly lower, though still positive, ratings. These included the ability to differentiate instruction for individual learners (Mean = 3.34), consistently showing care and respect for students (Mean = 3.39), and maintaining enthusiasm for the subject matter itself (Mean = 3.47). While these scores remain within the "agree" category, they may reflect aspects of teaching where there is room for growth. In particular, responding to individual student needs and sustaining passion for the subject may benefit from further professional development or reflective practice.

Overall, the data portray chemistry teachers in these states as skilled and reflective practitioners who demonstrate many attributes of effective teaching. Their strengths lie in clarity, planning, engagement, and communication, with a few areas that could be further enhanced to enrich their classroom practice and student outcomes.

Research question four

What is the relationship between content knowledge and teaching effectiveness of chemistry teachers

Table 4: Spearman Rank Correlations of content knowledge and teaching effectiveness of chemistry teachers

	N	mean	std. dev	ρ	Sig. (2-tailed)
Content knowledge	301	3.5581	0.25795	0.186	0.001
Teaching effectiveness	301	3.579	0.17903		

Table 4 presents the results of an analysis that explored the relationship between chemistry teachers' content knowledge and their teaching effectiveness in secondary schools

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across Adamawa and Taraba States. The study drew on responses from 301 teachers and included both descriptive statistics and a Spearman rank-order correlation. Spearman correlation was chosen because it is well-suited for ordinal data, such as responses on Likert scales, which do not always meet the assumptions required for more rigid parametric tests. This method enabled an appropriate examination of the strength and direction of the relationship between the two variables.

The descriptive data show that the average rating for content knowledge was 3.56, with a standard deviation of 0.26. In contrast, the average score for teaching effectiveness was slightly higher at 3.58, with a standard deviation of 0.18. These relatively high mean scores, alongside the low variation in responses, suggest that teachers generally view themselves as competent in both their understanding of chemistry and in how they deliver that knowledge in the classroom.

The correlation analysis produced a Spearman coefficient (ρ) of 0.186 and a p-value of 0.001. Although the correlation is statistically significant, the strength of the relationship is weak. What this means in practical terms is that while there is a slight tendency for teachers with more substantial content knowledge to be more effective in their teaching, the connection is not particularly strong or predictive. In other words, knowing chemistry well doesn't automatically make someone a highly effective teacher. This result reflects a broader truth in education: teaching is a complex, multifaceted skill. Mastery of subject content is undoubtedly essential, but it's only one piece of a larger puzzle. Genuinely effective teaching also relies on a teacher's ability to engage students, manage the classroom, apply suitable instructional strategies, and respond to diverse learning needs. Therefore, these findings highlight the need for professional development programs that not only deepen subject knowledge but also build up pedagogical skills and classroom practices. A well-rounded teacher, capable of combining deep content expertise with effective teaching methods, is more likely to have a meaningful and lasting impact on student learning.

Research question five

What is the relationship between pedagogical knowledge and teaching effectiveness of secondary school chemistry teachers?

Table 5: Spearman Rank Correlations of pedagogical knowledge and teaching effectiveness of chemistry teachers

	N	mean	std. dev	ρ	Sig. (2-tailed)
Pedagogical knowledge	301	3.5855	0.22036	0.488	0.000
Teaching effectiveness	301	3.5790	0.17903		

Table 5 presents the descriptive results, which showed that the mean score for pedagogical knowledge was 3.59 (SD = 0.22), while teaching effectiveness averaged 3.58 (SD = 0.18). These high mean values, coupled with low variability, suggest that teachers generally perceive themselves as both pedagogically competent and effective in the classroom. The Spearman correlation coefficient (ρ) was found to be 0.488, with a p-value of 0.000. This indicates a moderate to strong positive and statistically significant relationship between pedagogical knowledge and teaching effectiveness ($p < 0.001$). The corresponding coefficient of determination ($\rho^2 = 0.238$) implies that approximately 23.8% of the variation in teaching effectiveness can be explained by differences in pedagogical knowledge.

These findings underscore the pivotal role of pedagogical knowledge in determining the quality of teaching. While subject-matter expertise is essential, it is the ability to effectively plan, deliver, and adapt instruction that more directly influences how teachers perceive their effectiveness. Skills such as engaging students, managing the classroom, and responding to

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diverse learning needs appear central to this dynamic.

In conclusion, the study reveals a meaningful relationship between pedagogical knowledge and teaching effectiveness. The results suggest that professional development initiatives aimed at enhancing teaching quality should place strong emphasis not only on content mastery but also on deepening pedagogical skills that promote student engagement and learning outcomes.

DISCUSSION OF FINDINGS

The key findings are:

1. Chemistry teachers in secondary schools in Adamawa and Taraba States demonstrate a high level of content knowledge. They are particularly effective in planning lessons, applying chemistry principles, and using instructional materials.
2. Chemistry teachers in secondary schools in Adamawa and Taraba States demonstrate a strong level of pedagogical knowledge, with mean scores falling within the “very adequate” range. They are particularly effective in relating lessons to students’ levels, starting each lesson with an appropriate method, and clearly stating behavioral objectives.
3. Chemistry teachers in secondary schools in Adamawa and Taraba States perceive themselves as highly effective in their teaching roles, with consistently high mean scores. They are particularly effective in communicating lesson objectives, careful lesson planning, and demonstrating enthusiasm for both students and the teaching process.
4. There is a weak positive correlation between content knowledge and teaching effectiveness, indicating that teachers with more substantial content knowledge tend to be more effective in their teaching, but the connection is not particularly strong.
5. There is a moderate to strong positive correlation between pedagogical knowledge and teaching effectiveness, indicating that teachers with stronger pedagogical knowledge tend to be more effective in their teaching.
6. The findings of this study provide valuable insights into the teaching effectiveness of chemistry teachers in secondary schools in Adamawa and Taraba States. The discussion will focus on the key findings, implications, and recommendations for stakeholders in education.

Findings based on Content Knowledge (CK) and Teaching Effectiveness:

The study's findings indicate that secondary school chemistry teachers in Adamawa and Taraba States possess a high level of content knowledge, a crucial prerequisite for effective teaching. However, the correlation analysis reveals a weak positive relationship between content knowledge and teaching effectiveness, suggesting that while content knowledge is necessary, it may not be the sole determining factor for effective teaching. This implies that other variables, such as pedagogical knowledge and skills, could play a more significant role in influencing teaching effectiveness.

These results are consistent with prior research, including studies by O'Brien (2017), Pijeng-mosabala and Pollrick (2018), Asiyai (2020), Sewell (2023), and Keniewski and Harriot (2024). These studies found that chemistry teachers with robust content knowledge tend to exhibit a positive capacity to teach chemistry effectively. Nevertheless, the current study's findings highlight the complexity of the relationship between content knowledge and teaching effectiveness, underscoring the need to consider additional factors that contribute to effective teaching. To build upon these findings, future research could investigate the specific pedagogical knowledge and skills that are most critical for effective chemistry teaching. Additionally, exploring the interplay between content knowledge, pedagogical knowledge, and other factors such as teacher motivation, classroom environment, and student engagement could provide a more comprehensive understanding of the determinants of teaching effectiveness.

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Findings based on Pedagogical Knowledge and Teaching Effectiveness:

The study reveals that secondary school chemistry teachers in Adamawa and Taraba States exhibit a robust level of pedagogical knowledge, a critical component of effective teaching. The correlation analysis indicates a moderate to strong positive relationship between pedagogical knowledge and teaching effectiveness, suggesting that teachers with more developed pedagogical knowledge tend to be more effective in their instructional practices. This finding underscores the significance of pedagogical knowledge in determining teaching effectiveness and implies that teachers would benefit from ongoing support and professional development opportunities to further enhance their pedagogical skills.

The results of this study are consistent with the existing body of research that highlights the crucial role of pedagogical knowledge in teaching. The findings also align with more recent studies, including those by Reynolds and Park (2020), Mohammed et al. (2021), and Adamu and Achufusi-Aka (2020), which demonstrate that teachers with strong pedagogical knowledge tend to exhibit more effective teaching practices and promote better student learning outcomes. The observed level of pedagogical knowledge among chemistry teachers in this study suggests that they are well-prepared to design and deliver instruction that facilitates student understanding and engagement with chemistry concepts. This is particularly important in subjects like chemistry, which often require teachers to employ a range of instructional strategies to help students grasp complex concepts and principles.

Findings based on Teaching Effectiveness:

The study reveals that secondary school chemistry teachers in Adamawa and Taraba States perceive themselves as highly effective in their teaching roles, with consistently high mean scores. They are particularly effective in communicating lesson objectives, careful lesson planning, and demonstrating enthusiasm for both students and the teaching process. However, the findings also highlight areas for improvement, including: Differentiating instruction and sustaining passion for the subject matter.

These findings are consistent with previous research emphasizing the significance of teaching effectiveness in promoting student learning and achievement mostly on demographic characteristics drive learner performance (Mpiti, 2025). The high level of teaching effectiveness among chemistry teachers in this study suggests they are well-equipped to teach chemistry in a way that promotes student understanding, engagement, and academic success.

The results align with studies by Reynolds and Park (2020), Mohammed et al. (2021), and Adamu and Achufusi-Aka (2020), which demonstrate that teachers with high teaching effectiveness tend to have a positive impact on student learning outcomes. By building on these strengths and addressing areas for improvement, chemistry teachers can further enhance their instructional practices and promote student success.

Findings based on Prediction of Content Knowledge and Teaching Effectiveness:

The study reveals that there is a weak positive correlation between content knowledge and teaching effectiveness, indicating that teachers with more substantial content knowledge tend to be more effective in their teaching, but the connection is not particularly strong. The study highlights that both content knowledge effectiveness and pedagogical knowledge effectiveness are crucial predictors of teaching effectiveness among chemistry teachers. However, the findings indicate that pedagogical knowledge has a relatively stronger predictive influence on teaching effectiveness. This suggests that a teacher's ability to plan, deliver, and adapt instruction is vital to their overall teaching effectiveness.

The results imply that chemistry teachers who possess a strong foundation in chemistry concepts and principles, combined with effective pedagogical skills, are better equipped to teach chemistry in a way that promotes student learning and understanding. This finding underscores the importance of teachers having a

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deep understanding of the subject matter, as well as the skills to communicate complex concepts in a clear and engaging manner. The study's findings are supported by a growing body of research that emphasizes the significance of content knowledge and pedagogical knowledge in teaching effectiveness. Previous studies (Aydin & Turhan, 2023; Barenthien et al. 2023; Buma & Sibanda, 2022; Diwa et al. 2023; Elif & Yezdan, 2022; Hassan et al. 2022; Huaru et al. 2023; Marifa et al. 2023a&b; Morris, 2024; & Odit et al. 2023), have consistently shown that chemistry teachers with strong content knowledge and pedagogical skills tend to be more effective in teaching chemistry and promoting student learning.

CONCLUSION AND RECOMMENDATION

The study's findings suggest that pedagogical knowledge and skills play a critical role in determining teaching effectiveness. Teachers who possess effective pedagogical skills, such as the ability to design engaging lessons and assess student learning, are more likely to be effective in their teaching.

Based on the study's findings, the following recommendations are made:

1. Teachers should be supported in developing their content knowledge and pedagogical skills through professional development programs and workshops.
2. School administrators should provide teachers with the necessary resources and support to enhance their teaching effectiveness.
3. Policymakers should prioritize teacher education and professional development in their education policies to improve teachers' content and pedagogical knowledge and teaching effectiveness in STEM education in Northeast Nigeria.

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