UNIJERPS
Unizik Journal of Educational Research and Policy Studies VOL.21 (2);
January-June, 2026 https://unijerps.org
2023 Impact Factor: **6.834;** 2022 ***Impact Factor***: 5.156; ***2021 Impact Factor: 5.641;***
2020 Impact Factor: 5.355. *Indexing and Impact Factor URL: http://sjifactor.com/passport.php?id=21363*

PREDICTIVE VALUE OF PEDAGOGICAL CONTENT KNOWLEDGE FOR CHEMISTRY TEACHING EFFECTIVENESS IN NORTHEAST NIGERIA

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ABSTRACT

The study investigated the predictive value of pedagogical content knowledge (PCK) for chemistry teaching effectiveness in Northeast Nigeria. This study used a correlational research design to collect both qualitative and quantitative data from respondents. A sample size of 313 chemistry teachers in secondary schools located in Adamawa and Taraba States of Northeast Nigeria was used for the study. The Cronbach's alpha reliability coefficient of 0.873 was obtained which indicates a high level of internal consistency and reliability of the instrument, a questionnaire on chemistry teachers PCK and teaching effectiveness. 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 study revealed that secondary school chemistry teachers in north east exhibit a robust level of PCK a critical component of effective teaching. The correlation analysis indicated a moderate to strong positive relationship between PCK and teaching effectiveness, suggesting that teachers with more developed PCK tend to be more effective in their instructional practices. It is evident therefore to conclude that PCK and skills play a critical role in determining teaching effectiveness. Teachers who possess effective PCK 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, it was recommended that teachers should be supported in developing their PCK skills through professional development programs and workshops; and school administrators should provide teachers with the necessary resources and support to enhance their teaching effectiveness.

Keywords: Pedagogical Content Knowledge, Chemistry Teachers, and Teaching Effectiveness

Introduction

Chemistry is a core prerequisite for STEM careers. In Northeast Nigeria (Borno, Adamawa, Yobe, Taraba, Gombe, and Bauchi states), science education serves as a critical driver for regional development. Chemistry education in Northeast Nigeria faces documented challenges that stem directly from inadequate teaching skills and low teacher competency. Persistent poor performance in Senior School Certificate Examinations (SSCE) administered by West Africa Examination Council (WAEC) and NECO has been widely linked to ineffective teaching styles and teacher-centered methodologies.

Many educators may possess an understanding of chemistry principles, but they lack the pedagogical skill to unpack difficult concepts (such as stoichiometry,

hybridization, or chemical equilibrium) in ways that diverse learners can easily grasp. The region's educational infrastructure has been impacted by socio-economic challenges, leading to a shortage of qualified, continuously trained science teachers and inadequate laboratory resources. In general terms, the concepts of teacher competencies or teacher knowledge bases are specific knowledge areas that a teacher should have otherwise referred to as teachers' pedagogical content knowledge (PCK). Without strong PCK, teachers often rely on rigid, textbook-bound methodologies. This causes students to memorize formulas and facts rather than developing functional conceptual knowledge

Shulman originated the phrase "pedagogical content/subject knowledge" in 1986. PCK is a combination of pedagogical knowledge (PK) and content knowledge (CK). Shulman (1986) divided the necessary topic knowledge for teachers to have for effective teaching into three categories: content knowledge, pedagogical content knowledge, and curriculum learning/knowledge; and intimated that it is how the content of a concept is introduced by making use of instructional techniques such as analogies, diagrams, illustrations, examples, explanations, and demonstrations, thus, organizing the subject matter in a way that will motivate learners to understand (Marifa et al. 2023). 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. (2023) 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. And, 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.

Shulman (1987) in Oyagbile and Bello (2025) defined PCK as seven professional knowledge bases for teachers, including knowledge of general pedagogy such as classroom management and classroom organization, knowledge of curriculum including curricular materials and programs, knowledge of learners and their

characteristics such as learners preconceptions and misconceptions, knowledge of educational contexts, knowledge of instructional and educational ends, values, and purposes, and knowledge of instructional and educational outcomes.

This applies the content knowledge concerned with the teaching process. Shulman (1986, 1987) in Owusu and Baah (2025) emphasized that content knowledge is not enough for effective teaching solely and pedagogical content knowledge is necessary. Shulman describe PCK as knowledge going beyond subject matter instruction. According to Shulman (1987) in Sakaria et al (2023) PCK includes: The most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations-in a word, the ways of representing and formulating the subject that make it comprehensible to others.

It is important to note that the PCK construct has been identified as a significant issue in scientific education research, numerous conceptualizations and models have emerged (e.g., Carlson et al., 2019). More so, the teacher's knowledge and understanding of teaching is an element of their cultural, ethical, personal values, pedagogical knowledge, content knowledge, and what they brought from their initial education and training, as well as what they brought from reading and attending conferences, as well as their reflections, all of which are important in excellent teaching. Constant teaching practice can help teachers gain more pedagogical content understanding and become more effective and efficient teachers. The teacher should have a reliable knowledge about both pedagogy and the subject matter. Both logical and psychological teaching strategies ass noted by these educators (Mohammed et al. 2021; Morris, 2024), could be used by the teacher whose responsiveness depended on a high level of PCK and led to higher or lower levels of inquiry based on the students' need for teacher support closing gender gaps. Therefore, PCK is the specialized intersection of subject matter expertise and teaching methods. In Northeast Nigeria, evaluating PCK is vital for improving chemistry instruction, as it directly predicts a teacher's ability to simplify complex abstract concepts, correct learner misconceptions, and boost academic achievement. Hence, a high level of PCK strongly correlates with students' academic performance and deep conceptual understanding in chemistry.

Statement of the Problem

Teaching is an activity that requires pedagogical knowledge. Studies from various literatures have shown a serious gap from chemistry that requires additional focus due to lack of depth of subject matter PCK by teachers necessary to improve learners' performance. The literatures also confirmed content and teaching (pedagogy) gaps of science teachers. There are significant pedagogy gaps in several 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 pedagogical coverage of pedagogy (i.e. PCK) of science teachers. Past studies have also revealed

chemistry teachers' PCK were inadequate. And, since PCK (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. But, there still exists a serious content and teaching (pedagogy) gaps of science teachers in literatures. The 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. But there exists a serious gap in literatures in the present study area (Adamawa and Taraba States representing Northeast Nigeria), where the present study fits in and intends to solve the problem.

Purpose of the Study

i. Ascertain the relationship between content knowledge effectiveness and the teaching effectiveness of secondary school chemistry teachers in Northeast Nigeria;
ii. Ascertain the relationship between pedagogical knowledge effectiveness and the teaching effectiveness of secondary school chemistry teachers;
iii. Determine the relationship between content knowledge effectiveness and pedagogical knowledge effectiveness of chemistry teachers;
iv. Determine the extent content knowledge effectiveness (CKE) and pedagogical knowledge effectiveness (PKE) predict the teaching effectiveness of chemistry teachers;
v. Determine the extent content knowledge and pedagogical knowledge predict PCK effectiveness of chemistry teachers.

Research Questions

1. What is the relationship between content knowledge effectiveness and the teaching effectiveness of chemistry teachers in secondary schools in Northeast Nigeria?
2. What is the relationship between pedagogical knowledge effectiveness and the teaching effectiveness of chemistry teachers?
3. What is the relationship between content knowledge effectiveness and pedagogical knowledge effectiveness of chemistry teachers?
4. To what extent do content knowledge effectiveness (CKE) and pedagogical knowledge effectiveness (PKE) predict the teaching effectiveness of chemistry teachers?
5. To what extent do content knowledge and pedagogical knowledge predict PCK effectiveness of chemistry teachers?

Methodology

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 during the 2024/2025 academic session was used for the study. Adamawa State has 605 secondary schools with 257 chemistry teachers (173 males & 84 females); while Taraba State has 338 secondary schools across its Educational Zones with 56 chemistry teachers (42 males & 14 females) according to the Adamawa and Taraba States Ministry of Education (2024). The entire population as aample size for the study hence, sampling technique was not necessary for the study. The total population of Chemistry teachers in both Adamawa and Taraba states is 313. Three hundred and thirteen questionnaires were printed and distributed to the sample states. Adamawa has 257 Chemistry Teachers while Taraba has only 56 Chemistry teachers. The researcher used the entire population as Sample size for the study hence, sampling technique was not necessary for the study. The total population of Chemistry teachers in both Adamawa and Taraba states is 313. Three hundred and thirteen questionnaires were printed and distributed to the sample states. Adamawa has 257 Chemistry Teachers while Taraba has only 56 Chemistry teachers. The Cronbach's alpha reliability coefficient of 0.873 was obtained which indicates a high level of internal consistency and reliability of the instrument. The 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. The data processing was based on the correlation analysis in accordance with the objectives and research questions/hypotheses of the study.

Results

Answering Research question one

What is the relationship between content knowledge effectiveness and the teaching effectiveness of chemistry teachers in secondary schools in Northeast Nigeria?

Table 1

Spearman Rank Correlations of content knowledge effectiveness (CKE) and teaching effectiveness of secondary schools chemistry teachers

	N	Mean	Std. dev	ρ	Sig. (2-tailed)
CKE	301	3.5987	.20663		
				.847	.000
Teaching effectiveness	301	3.5790	.17903		

The results of the descriptive analysis in Table 1 indicated consistently high mean scores for both content knowledge effectiveness and teaching effectiveness among the sampled chemistry teachers. Specifically, the mean score for content knowledge effectiveness was 3.60 (SD = 0.21), while the mean for teaching effectiveness was 3.58 (SD = 0.18). The relatively small standard deviations suggest a low degree of variability, indicating a general consensus among respondents regarding their perceived competence in both areas.

To examine the relationship between the two variables, a Spearman rank-order correlation was conducted. The analysis produced a correlation coefficient (ρ) of 0.847, with a p-value of 0.000. This indicates a very strong positive and statistically significant relationship between content knowledge effectiveness and teaching effectiveness. In practical terms, this suggests that teachers who perceive themselves as more competent in their subject matter also tend to perceive themselves as more effective in their overall teaching practice. Further interpretation of the strength of this relationship was facilitated by calculating the coefficient of determination (ρ^2), which yielded a value of 0.717. This implies that approximately 71.7% of the variance in teaching effectiveness can be attributed to variations in content knowledge effectiveness. Such a substantial proportion highlights the significant impact of subject-matter expertise on perceived teaching efficacy.

The findings highlight the pivotal role of content knowledge in influencing teaching effectiveness. While pedagogical competence remains essential, these results suggest that a teacher's depth of content knowledge significantly contributes to their confidence and performance in the classroom. Consequently, professional development programs aimed at improving teaching quality should place considerable emphasis on reinforcing content knowledge, particularly in specialised subjects such as chemistry, where conceptual mastery is vital to effective instruction.

Answering Research question two

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

Table 2

Spearman Rank Correlations of pedagogical knowledge effectiveness (PKE) and teaching effectiveness of chemistry teachers

	N	Mean	Std. dev	*ρ*	Sig. (2-tailed)
PKE	301	3.5766	.15773		
				.886	.000
Teaching effectiveness	301	3.5790	.17903		

Table 2 is an analysis of the descriptive statistics, and Spearman rank correlation coefficients were conducted using data from 301 respondents. The descriptive statistics indicate that both PKE and teaching effectiveness were rated highly, with mean scores of 3.5766 and 3.5790, respectively. The standard deviations were relatively low (0.15773 for PKE and 0.17903 for teaching effectiveness), suggesting that participants' responses were tightly clustered around the mean values. This low variability reflects a consistent perception among respondents regarding both constructs.

A Spearman correlation analysis revealed a strong and statistically significant positive relationship between teachers' pedagogical knowledge and teaching

effectiveness (r = 0.886, p < 0.001). This coefficient indicates an influential linear association between the two variables: as teachers' pedagogical content knowledge increases, their teaching effectiveness also tends to improve. Furthermore, the coefficient of determination (r^2 = 0.785) suggests that approximately 78.5% of the variance in teaching effectiveness can be statistically explained by variance in PKE. This represents a substantial proportion and reflects a tight, meaningful connection between the constructs. The implications of this finding are considerable. Such a strong and significant relationship implies that PKE is not merely associated with, but may be a critical determinant of, teaching effectiveness. It underscores the central role of content-specific pedagogical knowledge in shaping how effectively teachers deliver instruction. Although the data do not permit causal inference, the strength of the association strongly supports ongoing efforts to enhance teachers' pedagogical knowledge effectiveness for improving educational outcomes. Investing in professional development that deepens teachers' understanding of how to teach their subject matter effectively is likely to yield measurable gains in classroom performance.

Answering Research question three

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

Table 3

Spearman Rank Correlations of content knowledge effectiveness (CKE) and pedagogical knowledge effectiveness (PKE) of chemistry teachers

	N	Mean	Std. dev	ρ	Sig. (2-tailed)
CKE	301	3.5987	.20663		
				.688	.000
PKE	301	3.5556	.19830		

The descriptive statistics in Table 3 indicate that the mean score for content knowledge effectiveness (CKE) among the 301 chemistry teachers was 3.60 with a standard deviation of 0.21, while the mean score for pedagogical knowledge effectiveness (PKE) was 3.56 with a standard deviation of 0.20. These relatively high mean values and low standard deviations suggest that most teachers perceive themselves as both knowledgeable in their subject matter and competent in their pedagogical practices, with slight variation across the sample.

To assess the relationship between these two domains, a Spearman rank-order correlation was computed. The resulting correlation coefficient (ρ) was 0.688, with a p-value of 0.000, indicating a strong, positive, and statistically significant relationship between content knowledge effectiveness and pedagogical knowledge effectiveness. This means that teachers who perceive themselves as more effective in their subject-matter knowledge also tend to view themselves as stronger in pedagogical practice. The strength of this association is

further underscored by the coefficient of determination (ρ^2), which is 0.473. This suggests that approximately 47.3% of the variance in pedagogical knowledge effectiveness can be explained by differences in content knowledge effectiveness. While the relationship is not perfectly linear, it is substantial and meaningful. This result highlights a key insight: although content knowledge and pedagogical knowledge are distinct constructs, they are strongly interrelated in practice. Teachers who are confident in their grasp of chemistry concepts are also likely to feel more capable of translating that knowledge into effective instructional strategies, classroom management, and student engagement.

In conclusion, a strong and statistically significant positive relationship exists between content knowledge effectiveness and pedagogical knowledge effectiveness among chemistry teachers in Adamawa and Taraba States. This finding emphasises the integrated nature of teacher competence. It suggests that professional development initiatives should take a holistic approach, simultaneously strengthening both subject-matter expertise and pedagogical skill to improve instructional effectiveness across science education.

Answering Research question four

To what extent do content knowledge effectiveness (CKE) and pedagogical knowledge effectiveness (PKE) predict the teaching effectiveness of chemistry teachers?

Table 4a: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.911[a]	.830	.828	.07415

a. Predictors: (Constant), Pedagogical knowledge effectiveness, Content knowledge effectiveness

Table 4b: ANOVA[a]

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	7.977	2	3.988	725.374	.000[b]
Residual	1.639	298	.005		
Total	9.615	300			

a. Dependent variable: teaching effectiveness
b. Predictors: (Constant), Pedagogical knowledge effectiveness, Content knowledge effectiveness

Table 4c: Coefficients[a]

Model	Unstandardized Coefficients	Standardized Coefficients	T	Sig.	Collinearity Statistics	
	B	Beta			Tolerance	VIF
(Constant)	.451		5.489	.000		
CKE	.364	.420	12.558	.000	.512	1.955
PKE	.511	.566	16.941	.000	.512	1.955

a. Dependent Variable: teaching effectiveness

A multiple regression analysis was performed to assess the extent to which content knowledge effectiveness (CKE) and pedagogical knowledge effectiveness (PKE) predict teaching effectiveness among secondary school chemistry teachers. Both CKE and PKE were entered into the model as independent variables, with teaching effectiveness serving as the dependent variable.

As shown in the model summary (Table 4a), the regression model demonstrated a strong predictive capability, yielding a multiple correlation coefficient (R) of 0.911. This indicates a very strong association between the combined predictors and teaching effectiveness. The coefficient of determination (R^2) was 0.830, suggesting that approximately 83% of the variance in teaching effectiveness can be explained by the combined influence of CKE and PKE. The adjusted R^2 value of 0.828 further supports the model's generalizability and robustness, accounting for the number of predictors and sample size.

The analysis of variance (ANOVA) results (Table 4b) provide additional confirmation of the model's statistical significance. The computed F-value of 725.374, with an associated significance level of $p < .001$, indicates that the regression model is highly significant. This result confirms that the joint inclusion of content and pedagogical knowledge makes a meaningful contribution to the prediction of teaching effectiveness and is unlikely to have occurred by chance.

Table 4c presents the regression coefficients, offering insight into the individual contributions of each predictor. Content knowledge effectiveness was found to be a statistically significant predictor, with an unstandardized coefficient (B) of 0.364 and a standardized beta coefficient of 0.420. The associated t-value of 12.558 ($p < .001$) underscores the relevance of subject-matter expertise to teaching effectiveness. Notably, pedagogical knowledge effectiveness exerted an even more significant influence on the outcome variable, with an unstandardized coefficient of 0.511 and a standardized beta of 0.566. The t-value of 16.941 ($p < .001$) affirms the statistical and practical significance of PKE as a predictor. Multicollinearity diagnostics revealed no serious concerns, as both predictor variables exhibited acceptable tolerance values (0.512) and variance inflation factors (VIF = 1.955), which are well within established thresholds.

In summary, the findings indicate that both content knowledge effectiveness and pedagogical knowledge effectiveness are significant predictors of teaching effectiveness. Collectively, they account for a substantial proportion of the variance in teaching performance, with pedagogical knowledge demonstrating a comparatively stronger predictive influence. These results underscore the necessity of a balanced approach to teacher professional development, one that not only reinforces disciplinary expertise but also prioritises the cultivation of effective pedagogical practices. Enhancing pedagogical capacity, in particular, appears critical to advancing instructional quality and promoting improved student learning outcomes.

Answering Research Question five To what extent do content knowledge and pedagogical knowledge predict PCK effectiveness of chemistry teachers?

Table 5a
Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.879[a]	.772	.770	.07558

a. Predictors: (Constant), Pedagogical knowledge, Content knowledge

Table 5b
ANOVA[a]

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	5.761	2	2.881	504.21	.000[b]
Residual	1.702	298	.006		
Total	7.464	300			

a. Dependent variable: Pedagogical content knowledge effectiveness
b. Predictors: (Constant), Pedagogical knowledge, Content knowledge

Table 5c
Coefficients[a]

Model	Unstandardized Coefficients	Standardized Coefficients	T	Sig.	Collinearity Statistics	
	B	Beta			Tolerance	VIF
(Constant)	.910		10.665	.000		
Content knowledge	.221	.361	12.781	.000	.961	1.040
Pedagogical knowledge	.525	.733	25.982	.000	.961	1.040

a. Dependent Variable: Pedagogical content knowledge effectiveness

A multiple linear regression analysis was performed in which content knowledge and pedagogical knowledge served as independent variables, and pedagogical content knowledge (PCK) effectiveness was specified as the dependent variable. The analysis draws on the results presented in Tables 5a, 5b, and 5c.

The model summary (Table 5a) reveals a strong predictive relationship between the combined predictors and the outcome variable. The multiple correlation coefficient (R) was computed as 0.879, indicating a high degree of association between content and pedagogical knowledge and PCK effectiveness. The model's coefficient of determination (R^2) was 0.772, signifying that approximately 77.2% of the variance in PCK effectiveness can be explained by the combined influence of the two predictor variables. The adjusted R^2 value of 0.770 further affirms the model's stability and its applicability to the broader population beyond the sample. The analysis of variance (ANOVA), presented in Table 5b, confirms the statistical significance of the regression model. The F-statistic value of 504.21, coupled with a p-value of < .001,

indicates that the overall model provides a statistically significant explanation of the variance in PCK effectiveness. This finding substantiates the relevance of including both content and pedagogical knowledge as predictors in the model.

The coefficients table (Table 5c) provides detailed information on the relative contributions of each predictor. Content knowledge yielded an unstandardized regression coefficient (B) of 0.221, with a standardised beta coefficient of 0.361 and a t-value of 12.781 ($p < .001$). This suggests that, holding pedagogical knowledge constant, a one-unit increase in content knowledge is associated with a 0.221-unit increase in PCK effectiveness. In comparison, pedagogical knowledge emerged as a more influential predictor, with an unstandardized coefficient (B) of 0.525, a standardised beta of 0.733, and a t-value of 25.982 ($p < .001$). These values indicate that pedagogical knowledge exerts a substantially more significant influence on PCK effectiveness than content knowledge. The multicollinearity diagnostics show acceptable levels of tolerance (0.961) and variance inflation factor (VIF = 1.040) for both predictors, confirming the absence of multicollinearity and supporting the integrity of the model estimates.

In summary, the regression analysis reveals that both content knowledge and pedagogical knowledge have a significant and positive impact on the effectiveness of pedagogical content knowledge among chemistry teachers in the study context. Together, these variables account for a considerable proportion of the variance in PCK effectiveness, highlighting their combined importance in the development of instructional expertise. However, the more pronounced effect of pedagogical knowledge suggests that the ability to structure, communicate, and adapt subject matter in instructionally meaningful ways plays a more critical role in shaping PCK effectiveness than content knowledge alone.

Discussion of Findings

The key findings are:

1. There is a very strong positive correlation between content knowledge effectiveness and teaching effectiveness, indicating that teachers who perceive themselves as more competent in their subject matter tend to perceive themselves as more effective in their teaching.
2. There is a strong positive correlation between pedagogical knowledge effectiveness and teaching effectiveness, indicating that teachers who perceive themselves as more competent in pedagogical knowledge tend to perceive themselves as more effective in their teaching.
3. There is a strong positive correlation between content knowledge effectiveness and pedagogical knowledge effectiveness, indicating that teachers who perceive themselves as more competent in their subject matter tend to perceive themselves as more competent in pedagogical knowledge.
4. Both content knowledge effectiveness and pedagogical knowledge effectiveness are significant predictors of teaching effectiveness, with pedagogical knowledge demonstrating a

comparatively stronger predictive influence.

5. Both content knowledge and pedagogical knowledge have a significant and positive impact on pedagogical content knowledge effectiveness, with pedagogical knowledge exerting a more substantial influence.

Findings based on Relationship between Content and Pedagogical Knowledge and Teaching Effectiveness:

The strong positive correlation between content knowledge (CK) and pedagogical knowledge (PK) effectiveness suggests that teachers who possess a deep understanding of their subject matter tend to also exhibit effective pedagogical skills. This finding supports the notion that teachers who are knowledgeable in their subject area are better equipped to design and deliver instruction that promotes student learning and understanding. By leveraging their subject matter expertise, teachers can create engaging and inclusive learning environments that cater to the diverse needs of their students.

The findings of this study align with previous research that emphasizes the importance of content knowledge in teaching effectiveness. These studies (Antony et al. 2019; Asiyai, 2018; Mohammed et al. 2021) have demonstrated that teaching qualification is not a determining factor in the development of pedagogical content knowledge (PCK) among chemistry teachers. Instead, PCK is more closely related to the teacher's ability to translate their subject matter knowledge into effective teaching practices. This suggests that teacher education programs and professional development initiatives should focus on developing teachers' content knowledge and pedagogical skills in tandem. By doing so, teachers can develop the expertise needed to teach chemistry effectively and promote student learning outcomes.

Findings based on Predictors (CK & PK) of Teaching Effectiveness:

The finding that both content knowledge effectiveness and pedagogical knowledge effectiveness are significant predictors of teaching effectiveness is consistent with existing research on teaching and learning. However, the fact that pedagogical knowledge demonstrates a comparatively stronger predictive influence underscores the critical role that pedagogical skills play in determining teaching effectiveness. This suggests that teachers' ability to design and deliver instruction, manage classroom dynamics, and assess student learning is crucial to promoting student understanding and achievement.

The findings of this study align with previous research that highlights the importance of pedagogical knowledge in teaching effectiveness. Studies by Mohammed et al. (2021), and O'Brien (2017) have demonstrated that teaching experience is not a determining factor in the development of pedagogical content knowledge (PCK) among chemistry teachers. Instead, PCK is more closely related to teachers' ability to translate their subject matter knowledge into effective teaching practices. This emphasizes the need for teacher education programs and professional

development initiatives to prioritize the development of pedagogical knowledge and skills. By focusing on enhancing teachers' pedagogical expertise, educational institutions can promote teaching effectiveness and ultimately improve student learning outcomes.

Findings based on Impact of Content Knowledge and Pedagogical Knowledge on Pedagogical Content Knowledge Effectiveness:

The finding that both content knowledge and pedagogical knowledge have a significant and positive impact on pedagogical content knowledge (PCK) effectiveness underscores the importance of teachers possessing a deep understanding of both the subject matter and the skills to teach it effectively. This suggests that teachers who are knowledgeable in their subject area and possess effective pedagogical skills are better equipped to design and deliver instruction that promotes student learning and understanding. The findings of this study align with previous research (Asiyai, 2020) that highlights the critical role of both content knowledge and pedagogical knowledge in teaching effectiveness. By emphasizing the development of both content knowledge and pedagogical skills, teacher education programs and professional development initiatives can equip teachers with the expertise needed to teach chemistry effectively.

Conclusion and Recommendations

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. The study's findings also highlight the importance of ongoing support and development for teachers, and suggest that hands-on learning experiences, resource provision, and targeted professional development are effective strategies for enhancing teacher effectiveness. Based on the study's findings, the following recommendations are made:

i. School administrators should provide teachers with the necessary resources and support to enhance their teaching effectiveness. Also, Professional learning communities where experienced chemistry teachers can mentor novices on how to identify and dismantle common student misconceptions should be established.
ii. State Ministries of Education and local school boards in Northeast Nigeria should implement Continuous Professional Development (CPD) programs specifically tailored to building chemistry PCK. These workshops should focus on translating theoretical chemistry concepts into engaging, practical classroom lessons rather than generic pedagogy.
iii. Colleges of Education and Universities in the region need to restructure their teacher-preparation curricula to emphasize topic-specific pedagogical models (e.g., methods

for teaching atomic structure, thermodynamics, etc.).

iv. Educational policymakers should prioritize PCK assessments—rather than just years of experience or academic qualifications—as a core metric when evaluating chemistry teaching effectiveness and awarding promotions.

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