UNIJERPS
Unizik Journal of Educational Research and Policy Studies VOL.22 (1);
July-December, 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

TECHNOLOGICAL AND PEDAGOGICAL KNOWLEDGE AS CORRELATES OF CHEMISTRY TEACHERS' TEACHING COMPETENCE IN SECONDARY SCHOOLS IN NORTH-CENTRAL NIGERIA

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ABSTRACT

The study compared the Technological and Pedagogical knowledge of Chemistry teachers regarding their competence in teaching in secondary schools in North-Central Nigeria. Specifically, it explored the teachers' technological knowledge, pedagogical knowledge, level of teaching competence, and relationships between technological knowledge, pedagogical knowledge, technological pedagogical knowledge, and teaching competence. A descriptive survey research design, of cross-sectional type, was used. The population consisted of 2800 chemistry teachers, from which a sample of 384 teachers was suggested based on the Krejcie and Morgan sample size determination table. The reported results in the study were, however, based on 384 respondents, which is controversial. The Chemistry Teachers' Technological and Pedagogical Knowledge and Teaching Competence Questionnaire (CTPK-TCQ) was used to collect data, which were then analysed using the mean, standard deviation and Pearson Product-Moment Correlation at the 0.05 significance level. The findings indicated high levels of technological knowledge ($M = 3.51$, $SD = 1.15$), pedagogical knowledge ($M = 3.72$, $SD = 1.078$), and teaching competence ($M = 3.78$, $SD = 1.003$). Significant positive relationships were found between technological knowledge and teaching competence ($r = .487$, $p < .001$), pedagogical knowledge and teaching competence ($r = .685$, $p < .001$), and technological pedagogical knowledge and

teaching competence (r = .683, p < .001). Therefore, the three null hypotheses were rejected. The study results indicated that the more technopedagogic knowledge possessed by Chemistry teachers, the more competent they are in teaching. It called for continuous professional development, enhancement of technology use and focused support to enhance Chemistry teaching in secondary schools.

Keywords: Technological knowledge, pedagogical knowledge, technological pedagogical knowledge, teaching competence, Chemistry teachers.

Introduction

Chemistry education plays an important role in science education and it helps students to gain knowledge about the nature, properties, composition, and changes of matter. The subject is required to give students the fundamental knowledge of science required for learning and applying the subject in other sectors like health care, farming, environmental protection, industry and technology development at the secondary school level. Students are expected to gain an understanding of chemical concepts and principles, develop critical and analytical thinking skills, enhance their problem-solving skills, learn laboratory skills, and be able to apply this knowledge of chemistry to solve real-life problems. These educational objectives are realised to a greater or lesser degree depending on teachers' ability to communicate chemical concepts in a manner that is comprehensible to learners, to make them active participants in educational activities, and to measure students' learning in a suitable manner. The effectiveness in chemistry education, therefore, is closely associated with the teachers' professional knowledge, teaching competencies and how it is converted into relevant practice in the teachers' classroom.

Effective teaching of chemistry can be difficult as it is a subject that requires abstract thinking, mathematical skills, laboratory work and different types of scientific representations. Learners should be able to link chemical changes that they observe to changes occurring at the particle level and understand symbolic representations such as chemical formulae, equations and other scientific notations. To meet these learning needs, teachers must have a sufficient degree of subject matter knowledge as well as the pedagogic knowledge necessary to make sense of complex knowledge within students' various learning needs and prior knowledge. Therefore, quality chemistry teaching is not just about content of the subject, but also about planning and organising the lessons, developing appropriate teaching methods, planning classroom activities, using appropriate teaching and learning materials, and evaluating students' learning.

These concerns are also relevant to the Nigerian context as highlighted by the study conducted by Nda et al. (2023), which focused on chemistry teaching in public senior secondary schools in Minna. The study found that factors like the availability of instructional materials and laboratory

equipment, class size, instructional time, and teaching methods are important factors to consider in the delivery of chemistry lessons. These findings suggest that the context in which chemistry is learned should be investigated, as well as the professional knowledge and instructional skills required for teachers to meet demands in their classrooms. This provides a relevant basis to study the knowledge and teaching competence of chemistry teachers in North-Central Nigeria.

The needs and requirements of teacher preparation and lifelong learning have changed in this Digital Age. Teachers can use digital tools such as digital presentations, instructional videos, computer simulations, virtual labs, learning platforms and interactive applications to communicate and enrich students' understanding of science concepts in multiple ways. They can be useful for representing molecular structures, explaining chemical reactions, showing changes in energy, and visualising processes which cannot be directly seen in experiments in chemistry education, but the effectiveness of technology in teaching is not determined just by the availability of technology, but also on how suitable technology is selected and applied. It is important for teachers to make sure that the technologies they use are aligned with the goals of the lesson, meet the students' learning needs, and facilitate active engagement with chemical concepts. Hence, the integration of digital resources demands teachers' professional knowledge and skills to effectively employ digital tools in the educational setting, as identified in studies on teachers' digital competence (Weke, 2023; Wohlfart & Wagner, 2023).

Technological knowledge (TK) is one of the components of teachers' technological competence in technology-supported education. It is defined as teachers' awareness of the tools and technologies available, their purposes and their ability to choose, use and manage technologies in teaching and other professional tasks. This knowledge can be shown, for example, by using digital instruments and applications for presentation, computer simulations, online learning materials and digital content management tools in secondary school chemistry lessons and by being able to solve frequent technical issues that occur during lessons. The skills listed below are the basis for using technology in chemistry instruction and learning.

Just because a teacher can use digital devices doesn't imply that he or she can be an effective teacher of technology in assisting student understanding. For example, a chemistry teacher might be competent in using digital resources to create presentations but might struggle to use simulations to explain chemical equilibrium or locate digital resources that could help students to address misconceptions about atomic structure. So, the successful adoption of technology must go beyond knowing how operational technology performs to making informed decisions about the application of technology to support particular learning goals or to satisfy students' learning needs. Therefore, studying teachers' technological knowledge

is significant in order to understand the relationship between chemistry teachers' technological knowledge and their competence in planning and delivering effective chemistry learning is important.

The importance of technological knowledge in education is also emphasised in studies on the use of digital technologies in education. Wohlfart and Wagner (2023) have investigated how teachers contribute to the adoption and use of digital technologies in education through an umbrella review of the existing studies on teachers' roles in educational digitalisation. They emphasise the need for teachers' professional knowledge and skills to ensure technology's effective implementation for meaningful learning. Additionally, Weke (2023) explored the digital competence of teachers in the context of instructional delivery in secondary schools in Nigeria, which offers a pertinent context for technology integration in the broader Nigerian education system. While these studies provide some useful information on the significance of teachers' technical skills online, they alone cannot determine the extent of chemistry teachers' technological knowledge in North-Central Nigeria. It is also important that an empirical study of the kind is carried out in order to find out if the chemistry teachers have the technological knowledge needed to carry out effective Chemistry teaching and learning in the region.

Pedagogical knowledge (PK) is a key component of teachers' professional competence, and refers to their knowledge of the principles and practices that underpin effective teaching and learning. It entails planning lessons, choosing the right teaching strategies, structuring activities in the classroom, managing student behaviour, evaluating students' learning, giving feedback on students' learning, and adapting to student learning differences in ability and need. In chemistry education, pedagogical knowledge is used by teachers to select appropriate methods for imparting scientific concepts, adapting demonstrations and practical work, facilitating students in problem-solving activities, recognising students' difficulties in learning and assessing the learning outcomes of the learning goals of their lessons. The selection of the teaching approach is dependent on various factors which encompass the nature of the subject matter, students' learning characteristics, the availability of teaching resources and the expected learning outcomes. Thus, pedagogical knowledge is not just a general knowledge of instructional practices, but the professional judgment needed to choose, modify, and implement effective strategies when faced with particular classroom contexts.

The studies carried out in Nigeria provide a good background to the study of the role of pedagogical knowledge in chemistry teaching. Ahmed et al. (2023) investigated the effectiveness and practice of pedagogical knowledge by secondary school chemistry teachers in Nigeria and discussed the correlation between the preparation of teachers for pedagogical knowledge and their classroom practice. They are relevant to the

present study because they point out that teachers' understanding of methods is not enough; it is also important to consider how well they are able to apply that understanding to teaching chemistry.

However, pedagogical knowledge may not suffice to determine teachers' skills for the purpose of teaching in modern chemistry classrooms. Its role in effective teaching and learning must be evaluated in the context of the teachers' technological knowledge and their overall competence to facilitate learning. For example, a teacher might have knowledge of practices that are best used in the classroom but not know how to effectively include technology in a classroom. Likewise, knowledge of and expertise in educational technologies does not ensure the capacity to develop learning design activities to foster student understanding. An analysis of the technological and pedagogical knowledge can thus offer a more comprehensive view of the professional competence required for good chemistry teaching.

Technological and pedagogical knowledge have grown in importance in the modern context of education, because teachers are expected to make purposeful choices regarding the use of digital tools for teaching and learning. Technological pedagogical knowledge (TPK) is a combination of knowledge that involves teachers' knowledge of how technology can be integrated into instruction to enhance the teaching process and increase the richness of the students' learning. TPK differs from technological knowledge (which is based mainly on understanding and using technological tools) and pedagogical knowledge (which is based on the principles and practices of teaching) because it has a strong focus on the relationship between technology and approaches to instruction.
Technological pedagogical knowledge in chemistry education has been manifested in teachers' use of digital resources for achieving certain learning goals. For instance, by using computer simulations, abstract chemical concepts can be explained, digital quizzes can give immediate feedback on students' understanding, multimedia presentations can help to understand complex chemical processes, and virtual laboratories can supplement practical experiments if appropriate. The effectiveness of these applications will critically rely on teachers' skills regarding the incorporation of the chosen technologies with the content matter they are instructing, the learning needs of students, and the learning goals. Therefore, TPK is a significant factor in teachers' professional abilities, as it helps to implement the integration of technology into the purposeful teaching and learning of chemistry rather than as a tool to be used as a single classroom resource.

Recent reviews of the technological pedagogical content knowledge (TPACK) framework support the need to differentiate between various types of teachers' professional knowledge. Guzmán González and Vesga Bravo (2024) summarised the research on TPACK for secondary school teachers and focused on teachers' perceptions

of their knowledge and professional learning needed for technology integration. Their review highlights the importance of researching teachers' technology-related knowledge in various educational contexts. The related study is the systematic review of reviews by Schmid et al. (2024), which showed problems regarding the conceptual and methodological aspects in teachers' knowledge related to technology integration. They highlight the need for the precise definition of knowledge constructs and the choice of suitable methods used to measure knowledge. These aspects are relevant to the current study, as technological knowledge, pedagogical knowledge, and technological pedagogical knowledge are interrelated but conceptually separate. Thus, each construct needs to be clearly defined and suitably measured so that the extent of its contribution to chemistry teaching can be well understood.

Teaching competence is the teacher's ability to use the competence and knowledge gained in professional training effectively in classroom practice. It relates to the preparation and organisation of lessons, making content in the subject clear, selecting appropriate teaching methods, ensuring classroom procedures are managed, using teaching materials and resources, evaluating students' performance and responding to their educational needs. In chemistry, this competence also involves planning and conducting practical activities safely and effectively, relating theory and practice, assisting students to understand chemical symbols and representations, and delivering feedback to consolidate and reinforce their understanding. Thus, teaching competence is not just reflected in the knowledge teachers possess, but also in the effectiveness of using that knowledge in the learning process. Assessment should, therefore, be based on indicators that really measure the dimension of competence being assessed. Self-reports by the teachers, along with evidence from classroom observations, instructional materials, or performance-based assessments, may be useful in providing a more complete picture of teachers' actual practices where feasible.

Research articles that have looked at chemistry teachers' professional knowledge have identified the need to precisely define and measure instructionally relevant constructs of knowledge. Deng et al. (2025) performed a review of the empirical studies of chemistry teachers' pedagogical content knowledge that were published in journals indexed in the Social Sciences Citation Index from 1986 to 2024. In their analysis, they investigated the conceptualisation and measurement of this type of professional knowledge in the studies they reviewed. While pedagogical content knowledge is not the same as the general pedagogical knowledge studied in the present work, this review highlights the importance of distinguishing between related knowledge domains and using the proper methods to study each of these domains. This is the reason why this perspective is relevant to the current study, which aims to find out the relationship between the technological and pedagogical knowledge of chemistry teachers and their teaching competence. These

constructs must be clearly defined and measured to be able to interpret their relationships correctly and make worthwhile conclusions about teachers' professional skills.

The context of North-Central Nigeria is relevant to the study of professional knowledge and instructional competence of chemistry teachers. Access to teaching materials, digital technologies, laboratory spaces, class size, and teacher professional development may affect how teachers use their knowledge in the classroom. Nda et al. (2023) in their study of public secondary schools in Minna, identified the following institutional and instructional problems of chemistry teaching: the lack of support for hands-on skills, poor curricular integration, and inadequate teaching materials. While their finding give insight into the conditions in which chemistry is taught, it does not make a statement about the level of technological knowledge among the chemistry teachers in North-Central Nigeria nor about the relationship between technological knowledge, pedagogical knowledge and competence in teaching. An empirical investigation with a clearly defined population of chemistry teachers from the relevant states and the Federal Capital Territory is needed to address these issues.

This need prompted the present study that investigates the technological knowledge, pedagogical knowledge, and teaching competence of senior high school chemistry teachers in North-Central Nigeria. It also explores the relationships between technological knowledge and teaching competence, pedagogical knowledge and teaching competence, and technological pedagogical knowledge and teaching competence. The study therefore aims to provide evidence to support the design of teacher professional development programmes, the integration of technology in teaching chemistry in secondary schools and the continuous improvement of science education in secondary schools in Nigeria by considering the variables within the regional context.

To teach chemistry effectively, teachers should have enough technological knowledge, pedagogical knowledge, and competence in teaching so that students can understand the concepts of chemistry. While some previous studies have investigated chemistry teachers' pedagogical knowledge, pedagogical context, and access to digital technologies, little empirical data are available on the relationship between these and teachers' competence in secondary schools in North-Central Nigeria. Nda et al. (2023), Ahmed et al. (2023), Guzmán González and Vesga Bravo (2024), and Schmid et al. (2024) offer understanding of the use of technology and instruction. Likewise, Ofudu & Jimola (2024), Mafa-Theledi (2024), Varghese et al. (2025), Saharuddin et al. (2025), Aksin (2023) and Gökdaş et al. (2024) emphasize that subject knowledge, pedagogical skills and digital skills are crucial for good teaching. The studies, however, were mainly on other content fields, on the level of education, or on a wider teaching context, and there was a lack

of understanding of the chemistry teachers' relationship between technological knowledge, pedagogical knowledge and technological pedagogical knowledge with the teachers' competence in the field of study.

This study seeks to offer a bit more context-specific empirical evidence on the technological knowledge, pedagogical knowledge, and teaching competence of chemistry teachers in North-Central Nigeria, which is one of the central problems. Specifically, it aims at identifying the technological knowledge, pedagogical knowledge, teaching competence levels of teachers and evaluating if there were significant relationships between technological knowledge and teaching competence, pedagogical knowledge and teaching competence, and technological pedagogical knowledge and teaching competence. This is significant because chemistry educators have to include digital simulations, virtual laboratories and other technology resources in their lessons and combine them with suitable teaching methods that will help students gain knowledge and understanding of abstract concepts. The results may serve as evidence for teacher education, identify the target professional development programmes and for educational planning to enhance the instructional competence of chemistry teachers and enhance chemistry teaching and learning in secondary schools in North-Central Nigeria.

Purpose of the Study

The main purpose of the study was to investigate the technological and pedagogical knowledge as correlates of Chemistry teachers' teaching competence in secondary schools in North-central, Nigeria. Specifically, the study aimed to:

1. identify the extent of technological knowledge (TK) possessed by chemistry teachers;
2. assess the level of pedagogical knowledge (PK) among chemistry teachers;
3. examine the level of teaching competencies among chemistry teachers;
4. examine the relationship between technological knowledge (TK) and teaching competencies of chemistry teachers;
5. determine the relationship between pedagogical knowledge (PK) and teaching competencies among chemistry teachers;
6. determine the relationship between technological pedagogical knowledge (TPK) and teaching competencies among chemistry teachers.

Research Questions

1. What is the extent of technological knowledge (TK) possessed by chemistry teachers?
2. What is the level of pedagogical knowledge (PK) among chemistry teachers?
3. What is the level of teaching competencies among chemistry teachers?

Research Hypotheses

H_{01}: There is no significant relationship between technological knowledge (TK) and teaching competencies of chemistry teachers;

H_{02}: There is no significant relationship between pedagogical knowledge (PK) and teaching competencies among chemistry teachers;

H_{03}: There is no significant relationship between technological pedagogical knowledge (TPK) and teaching competencies among chemistry teachers;

Methodology

This study used a descriptive cross-sectional survey design to investigate the technological knowledge, pedagogical knowledge and pedagogical competence of chemistry teachers in secondary schools in North-Central region of Nigeria. The population consists of 2,800 chemistry teachers in Benue, Kogi, Kwara, Nasarawa, Niger and Plateau States and the FCT. It was planned to take a sample of 384 teachers using a simple random sampling method proportionate to the seven administrative units. An adapted Chemistry Teachers' Technological and Pedagogical Knowledge and Teaching Competence Questionnaire (CTPK-TCQ) was to be used to collect data, which covered aspects of technological knowledge, pedagogical knowledge, and teaching competence. The instrument was expertly reviewed for face and content validity, and a pilot study of 27 chemistry teachers in Osun State was carried out to check the clarity and reliability of the instrument. The subscores were reported as Cronbach's alpha of 0.96, 0.92, and 0.97 for technological knowledge, pedagogical knowledge, and teaching competence, respectively.

The data were collected using printed and online questionnaires with the support of four research assistants after obtaining the necessary permissions and ethical approval. Participation was voluntary, and confidentiality was maintained throughout the study. SPSS version 26.0 was used to analyse the data. The demographic data of the respondents were expressed in frequencies and percentages, and the mean and the standard deviations were used to show the level of technological knowledge, pedagogical knowledge, and teaching competence. To test the relationships between the knowledge areas and teaching competency at 0.05 level of significance, Pearson Product-Moment Correlation was proposed, subject to the relevant statistical assumptions. As the figures reported in the data do not match the number of respondents planned in the proportional sample, they must be recalculated.

Results and Interpretations

Research Question One: What is the extent of technological knowledge (TK) possessed by chemistry teachers in North Central Nigeria?

Table 1: *Mean and Standard Deviation of Chemistry Teachers' Technological Knowledge (TK)*

Items	Mean	S.D
Using digital tools (e.g., computers, tablets) for teaching chemistry	3.96	1.007
Using presentation software (e.g., PowerPoint) for instructional delivery in chemistry	3.85	1.007
Troubleshooting basic technological problems during chemistry lessons	3.58	1.074
Using internet resources to support and enhance chemistry teaching	2.97	1.316
Excluding multimedia tools (e.g., videos, simulations) into chemistry lessons	3.19	1.352
Grand mean	3.51	1.15

Table 1 reveals that the extent of technological knowledge of chemistry teachers in North-Central Nigeria had a grand mean of 3.51 and a standard deviation of 1.15, which is high. The highest mean score was found in the digital tools, including the use of a computer and table computer, to teach chemistry (M = 3.96, SD = 1.007), and the second highest score was for the use of presentation software for the delivery of instruction, including the use of PowerPoint (M = 3.85, SD = 1.007). The teachers also indicated a good level of ability in troubleshooting simple technological issues in chemistry lessons (M = 3.58, SD = 1.074). The item for excluding multimedia tools (such as videos and simulations) from chemistry lessons had a mean score of 3.19 (SD = 1.352) and the item on using internet resources to support chemistry teaching had a mean score of 2.97 (SD = 1.316), which are both in the moderate range according to the decision rule stated. The overall grand mean is 3.51 that shows that on the whole the teachers of chemistry have high technological knowledge**.**

Research Question two: What is the level of pedagogical knowledge (PK) among chemistry teachers in North Central Nigeria?

Table 2: *Mean and Standard Deviation of Chemistry Teachers' Pedagogical Knowledge (PK)*

Items	Mean	S.D
Applying interactive teaching methods in chemistry instruction	4.15	0.899
Managing classroom activities effectively during chemistry lessons	4.11	0.829
Assessing students understanding using suitable evaluation techniques	4.08	0.900
Adapting teaching strategies to meet the diverse learning needs of students	3.15	1.336
Planning effective chemistry lessons	3.09	1.428
Grand mean	3.72	1.078

As seen in Table 2, the chemistry teachers in North-Central Nigeria had high pedagogical knowledge with a grand mean of 3.72 and a standard deviation of 1.078. The most popular item was "successfully using interactive teaching approaches in chemistry lessons" (M = 4.15, SD = 0.899), "properly controlling the activities in the classroom

during chemistry lessons" (M = 4.11, SD = 0.829) and "proper evaluation of students' understanding of the chemistry content" (M = 4.08, SD = 0.900). Items pertaining to adapting instruction strategies to diverse learning needs and planning effective chemistry lessons also had means in the high range based on the decision rule (M = 3.15, SD = 1.336 and M = 3.09, SD = 1.428, respectively). The grand mean of 3.72 thus shows that the level of pedagogical knowledge of the chemistry teachers was high.

Research Question Three: What is the level of teaching competencies among chemistry teachers in North Central Nigeria?

Table 3: *Mean and Standard Deviation of Chemistry Teachers' Teaching Competencies*

Items	Mean	S.D
Planning effective chemistry lessons that meet instructional objectives	4.23	.805
Delivering chemistry lessons clearly and effectively	4.18	.775
Managing classroom behaviour and maintaining a conducive learning environment	4.15	.811
Using interactive instructional materials in teaching chemistry	4.09	.834
Evaluating students' learning outcomes in chemistry effectively	4.07	.897
Relating chemistry concepts to real-life situations	4.09	.844
Using questioning techniques to stimulate students' critical thinking in chemistry	4.11	.799
Integrating technology such as simulations and digital tools into chemistry teaching	4.05	.839
Addressing students' misconceptions in chemistry	4.03	.817
Using laboratory experiment activities to reinforce chemistry concepts	4.03	.867
Encouraging active student participation during chemistry lessons	3.32	1.312
Adapting chemistry teaching methods to meet students' individual learning needs	3.18	1.347
Organizing and managing chemistry laboratory activities safely and effectively	3.02	1.368
Providing timely feedback to students on chemistry assignments and assessments	3.02	1.360
Working with colleagues to improve chemistry teaching and learning outcomes	3.11	1.374
Grand mean	3.78	1.003

The grand mean of 3.78 and the standard deviation of 1.00 for chemistry teachers in North-Central Nigeria as shown in Table 3, suggest that the teachers possess a high level of teaching competencies. The highest competency rating was for planning effective chemistry lessons that meet instructional goals (M = 4.23, SD = 0.805), followed by clearly and effectively delivering chemistry lessons (M = 4.18, SD = 0.775), and managing classroom behaviour and maintaining a conducive learning environment (M = 4.15, SD = 0.811). Other skills that received high ratings were the use of interactive instructional materials (M = 4.09, SD = 0.834), relating chemistry concepts to real-life situations (M = 4.09, SD = 0.844), assessing students' learning outcomes (M = 4.07, SD = 0.897), and the integration of technology such as simulations and digital tools in chemistry teaching (M = 4.05, SD = 0.839). Results of the lowest mean scores were obtained for organising and managing laboratory activities safely and effectively (M = 3.02, SD = 1.368) and providing timely feedback to students (M =

3.02, SD = 1.360) while the scores were still in the high category. The overall grand mean of 3.78 shows that the teaching competencies of chemistry teachers in North-Central Nigeria were very high.

H_{01}: There is no significant association between technological knowledge (TK) and teaching competencies of chemistry teachers.

Table 4: *Pearson Product Moment Correlation between Technological Knowledge (TK) and Teaching Competencies of Chemistry Teachers*

Variable	N	Mean	SD	Df	Cal.r-value	P-value	Decision
TK	384	3.51	1.15				
				382	0.487	0.001	Rejected
Competencies	384	3.78	1.00				

Correlation is significant at the 0.01 level (2-tailed).

The Pearson Product-Moment correlation between Technological Knowledge (TK) and teaching competencies of chemistry teachers is presented in Table 4. The correlation coefficient is r = .487, p < .001 (two-tailed), and the relationship is positive and significant between TK and the teaching competencies. This suggests that chemistry teachers with a higher level of technological knowledge have a higher level of teaching competencies. The significance level was 0.05, and thus the probability value was less than this; the null hypothesis (H_{01}) is rejected. Therefore, it is postulated that chemistry teachers' technological knowledge and teaching competencies are very closely related.

H_{02}: There is no significant relationship between pedagogical knowledge (PK) and teaching competencies among chemistry teachers.

Table 5: Pearson Correlation between Pedagogical Knowledge (PK) and Teaching Competencies of Chemistry Teachers

Variable	N	Mean	SD	Df	Cal.r value	p-value	Decision
PK	384	3.72	1.078				
				382	0.685	0.001	Rejected
Competencies	384	3.78	1.003				

Correlation is significant at the 0.01 level (2-tailed).

Table 5 displays the Pearson correlation between pedagogical knowledge (PK) and teaching competencies of chemistry teachers. The result suggests a positive and significant correlation (r = .685, p < .001, two-tailed). This indicates that the higher the pedagogical knowledge possessed by the chemistry teachers, the higher the teaching competencies would be. This means that the p-value is smaller than the 0.05 level of significance and the null hypothesis (H_{02}) is accepted as being rejected. Hence,

pedagogical knowledge and the competencies of the chemistry teacher have a significant relationship.

H_{03}: There is no significant relationship between technological pedagogical knowledge (TPK) and teaching competencies among chemistry teachers.

Table 6: *Pearson Correlation between Technological Pedagogical Knowledge (TPK) and Teaching Competencies of Chemistry Teachers*

Variable	N	Mean	SD	Df	Cal.r-value	P-value	Decision
TPK	384	3.59	1.09				
				382	0.683	0.001	Rejected
Competencies	384	3.78	1.00				

Correlation is significant at the 0.01 level (2-tailed).

Table 6 presents the Pearson correlation result regarding the relationship between technological pedagogical knowledge (TPK) and teaching competencies of chemistry teachers. The results show that there is a positive and significant correlation between TPK and teaching competencies ($r = .683$ at $p < .001$ (two-tailed)). The higher the level of chemistry teachers' technological pedagogical knowledge, the higher the teaching competencies. The p-value is below the level of significance of 0.05, so the null hypothesis (H_03) is rejected. Therefore, the results showed that there were significant relationships between technological pedagogical knowledge and teaching competencies of chemistry teachers.

Discussions

Based on the results obtained from the present study, Chemistry teachers in North-Central Nigeria had high technological knowledge, pedagogical knowledge and a high level of teaching competence. The results are similar to those of previous research, but some studies have found that there are restrictions in teachers' knowledge and skills in the effective implementation of the learning process. These disparities might relate to differences in teaching experience, teachers' professional backgrounds, access to educational technologies, school facilities, and opportunities for professional development. Moreover, the assessment of teachers' knowledge and competence might be affected by differences in research methods, such as the use of self-reported questionnaires versus classroom observations (Shambare & Jita, 2024; Hayati et al., 2022; Garba & Hussaini, 2024).

The study also found that technological knowledge, pedagogical knowledge, technological pedagogical knowledge, and teaching competence were positively significant. This implies that teachers' knowledge of technology and teaching methods are correlated with their ability to carry out their teaching tasks effectively. Even though research shows that technological knowledge alone does not ensure effective teaching, it suggests that

technological knowledge must be integrated with pedagogical strategies to achieve effective teaching. In the same way, pedagogical knowledge can be lacking if teachers don't have the skills to recognise and resolve students' difficulties. Possible variations in the relationships reported across studies could then be due to different constructs measured, educational outcomes examined and resources required to implement teachers' knowledge in practice (Varghese et al., 2025; Marifa et al., 2023; Kastorff & Stegmann, 2024).

The differences between the results of the present study and previous ones emphasise the need to take into account the context of education, the requirements of a subject, the teachers' experience, the resources available in the school, the instruments used to measure the concepts studied, and the design of the study when interpreting the results. Especially, knowledge of the subject is not the same as competence in actual classroom situations. The results highlight the importance of enhancing teachers' professional development, developing access to teaching facilities and offering practical training for effective use of technology and pedagogy in Chemistry teaching. Additional research that included classroom observations and performance-based assessment would enable researchers to gain a better understanding of how far teachers' knowledge of and perceived competence match their actual instructional practices.

Conclusion

The study findings showed that the technological, pedagogical and teaching competence of Chemistry teachers in North-Central Nigeria were high. They were competent with the use of digital devices, interactive teaching, classroom management, lesson planning, explaining Chemistry concepts and evaluating students' learning. Nevertheless, there were areas that needed development, such as online sources and multimedia materials, accommodating varying learning styles, laboratory safety, timely feedback, and working with colleagues. The results also showed very strong positive relationships between technological knowledge, pedagogical knowledge, technological pedagogical knowledge and pedagogical competence. It therefore recommended that teachers of chemistry in secondary schools in North-Central Nigeria should be provided with appropriate professional development programmes to boost their teaching competence as a function of their technological and pedagogical knowledge.

Recommendations

The following recommendations were made:

1. The Ministry of Education and competent educational agencies must conduct periodic professional development programs for Chemistry teachers to enhance their technological knowledge (TK) in effectively utilizing digital devices, multimedia, presentation software and Internet-based learning materials.

2. Teacher training institutions and school administrators should offer periodic pedagogical training for Chemistry teachers on interactive teaching and pedagogical skills including pedagogical knowledge (PK), pedagogical content knowledge (PCK), and content knowledge (CK) which can help to improve their pedagogical knowledge.
3. Periodic evaluation of teachers' competency in teaching Chemistry and targeted support for teachers in teaching and laboratory management, in engaging students, in giving feedback to students, and in the evaluation of learning outcomes by the school administrators and educational authorities.
4. Technology-focused capacity development programs for Chemistry teachers should be encouraged by Educational Policymakers and school administrators.
5. Teacher education institutions and professional development providers should improve Chemistry teachers' pedagogical knowledge by providing workshops, mentoring and peer collaboration programs.
6. Coordinated by the Ministry of Education and school administrators, Chemistry teachers should be trained, demonstrated and collaborated in lesson design of technological pedagogical knowledge (TPK) integration using appropriate pedagogical strategies to enhance teachers' competence in teaching.

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Note: The publisher confirms that this article first appeared online on November 7, 2025, but it was assigned to a journal issue published in August 2026. For a reference list using the final issue details, 2026 is the appropriate year. If your institution requires citing the online-first version, check its preferred convention.

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