

ASSESSING CHEMISTRY TEACHERS' DIGITAL COMPETENCE AND CLASSROOM INNOVATION IN OSUN STATE, NIGERIA

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ABSTRACT

This study evaluates the digital competency of chemistry teachers and their capacity to implement innovative practices in the classroom. The study adopted a descriptive survey research design. A total of 165 Chemistry teachers participated in the study. The results mirror the average level of both digital competency and classroom innovation among chemistry teachers while a strong relationship between integration of digital tools and classroom innovation was also observed. The results highlight the need to implement digital education programs for pre-service teachers in order to acquire digital literacy before starting their professional career and as well digital professional training for the in-service chemistry teachers. This calls for a conscious commitment to policies on integrating digital tools and technologies in education in Nigeria and as well in Osun State to ensure teachers are better equipped with modern digital skills and best practices in driving sustainable paradigm shifts in educational space in the country.

KEY WORDS

digital competencies; classroom innovation; chemistry teachers; digital technologies.



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AVALIAÇÃO DA COMPETÊNCIA DIGITAL E INOVAÇÃO EM SALA DE AULA DE PROFESSORES DE QUÍMICA NO ESTADO DE OSUN, NIGÉRIA

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RESUMO

O estudo avalia a competência digital de professores de Química e a sua capacidade de implementar práticas inovadoras em sala de aula. O estudo adotou uma abordagem descritiva assente em inquérito por questionário. Um total de 165 professores de química participaram do estudo. Os resultados refletem o nível médio tanto de competência digital quanto de inovação em sala de aula entre os professores de Química, tendo-se observado também uma forte relação entre a integração de ferramentas digitais e a inovação em sala de aula. Os resultados destacam a necessidade de implementar programas de educação digital para professores em formação, a fim de que adquiram alfabetização digital antes de iniciarem sua carreira profissional, bem como formação profissional digital para professores de química em exercício. Isso exige um compromisso consciente das políticas de integração de ferramentas e tecnologias digitais na educação na Nigéria e no Estado de Osun, para garantir que os professores estejam mais bem apetrechados de habilidades digitais modernas e de melhores práticas para impulsionar mudanças paradigmáticas sustentáveis no cenário educacional do país.

PALAVRAS - CHAVE

competências digitais; inovação em sala de aula; professores de química; tecnologias digitais.



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**EVALUACIÓN DE LA COMPETENCIA DIGITAL Y LA INNOVACIÓN EN EL
AULA DEL PROFESORADO DE QUÍMICA EN EL ESTADO DE OSUN,
NIGERIA**

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RESUMEN

El estudio evalúa la competencia digital del profesorado de Química y su capacidad para implementar prácticas innovadoras en el aula. El estudio adoptó un diseño de investigación descriptivo basado en cuestionario. Participaron 165 profesores de Química. Los resultados reflejan el nivel promedio de competencia digital e innovación en el aula entre el profesorado de Química, a la vez que se observó una fuerte relación entre la integración de herramientas digitales y la innovación en el aula. Los resultados resaltan la necesidad de implementar programas de educación digital para el profesorado en formación con el fin de que adquiera competencia digital antes de comenzar su carrera profesional, así como formación profesional digital para el profesorado de Química en activo. Esto exige un compromiso consciente con las políticas de integración de herramientas y tecnologías digitales en la educación, tanto en Nigeria como en el estado de Osun, para garantizar que el profesorado esté mejor equipado con las habilidades digitales modernas y las mejores prácticas para impulsar cambios de paradigma sostenibles en el ámbito educativo del país.

PALABRAS CLAVE

competencias digitales; innovación en el aula; profesorado de química; tecnologías digitales.



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Assessing Chemistry Teachers' Digital Competence and Classroom Innovation in Osun State, Nigeria

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INTRODUCTION

The adoption of digital technologies in education has become a worldwide priority, transforming both teaching methods and student learning experiences. Its advent has opened up new possibilities in education, making it possible for the students to learn better and help teachers to teach better while also informing everyone's decision making in education systems according to the Organization for Economic Co-operation and Development (Foster, 2023). Furthermore, the impact of COVID-19 has led most educational organisations to adopt the use of digital tools to carry out educational processes, which revealed the need for the integration of technologies in education. In Nigeria, the Federal Ministry of Education has promoted the integration of ICT (Information and communications technology) in secondary schools to facilitate the teaching and learning processes, promote problem-solving, critical thinking and innovative skills and enhance the various teaching-learning strategies required to meet the needs of the population through enacting policies which focus on key areas such as human capital development, infrastructure, research and development, awareness and communication, financing, monitoring and evaluation (Federal Ministry of Education of Nigeria, 2019). In Osun state, Nigeria, the state launched the *Teacher-shift 2025*, aimed at transforming school teachers in technical and vocational education to digital ready instructors capable of driving innovation and efficient teaching activities in classrooms (Osun State Board for Technical and Vocational Education, 2025). Within chemistry education, the use of digital technology has proven to be an effective strategy for boosting students' participation and achievement. Research has shown that interactive, technology-supported teaching approaches help address difficulties in conveying abstract concepts and compensate for limited laboratory resources (Adedeji et al., 2012; Fabeku & Enyeasi, 2024; Steffes & Duverger, 2012).

However, the importance of integration digital tools in education is not the same as ensuring teachers' digital competence which can be said to be the effective use of digital tools for instructional purposes in education. Some studies (Ogegbo, 2023; Ogunbodede et al., 2023) reveal difficulties among teachers in the effective use of digital tools for instructional purposes. The role of teachers remains central in any digital integration in schools. They mediate students' navigation of the digital world, not just technology, but also by instilling the behaviours and values needed to use digital tools responsibly in an increasingly data-driven age (Foster, 2023). Therefore, these advancements highlight the need to evaluate the digital competence of chemistry teachers in Osun State public schools and their capacity to implement innovative practices in the classroom. The study is guided by two research questions and a hypothesis.

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RESEARCH QUESTIONS

1. What is the level of digital competence among chemistry teachers in Osun State Public Schools?
2. How do chemistry teachers integrate digital tools into teaching-learning activities for classroom innovation in Osun State Public Schools?

RESEARCH HYPOTHESIS

H₀: Teachers' digital competence does not significantly predict classroom innovation among Chemistry teachers in Osun State Public Schools.

LITERATURE REVIEW

DIGITAL COMPETENCY

Digital competence today is seen as more than just technical know-how. It involves ethical responsibility, effective teaching practices, and the ability to adapt across different fields. Because of this, it has become a core skill in both education and professional growth (Spante et al., 2018). Digital competency is now central to education theory. Both teachers and students need the skills to navigate increasingly complex, tech-driven learning environments. Revuelta-Domínguez et al. (2022) emphasized that teacher digital competence should not only be seen as technological skills but also integrate ethical, pedagogical, and interdisciplinary considerations. Continuous professional development has been identified as a vital prerequisite for educators in navigating the complexities of a rapidly transforming digital environment (Domínguez-González et al., 2025). The authors also highlight the importance of holistic frameworks that integrate technical expertise with socio-ethical awareness, ensuring that competence development remains responsive to broader educational values. In a complementary study, Díaz-Suárez et al. (2023) examine how digital platforms are reshaping teaching practices. Their findings suggest that digital competence is not a fixed attribute but evolves through active engagement with collaborative, student-centred methodologies. This perspective underscores the dynamic nature of digital literacy, positioning it as a process of ongoing adaptation rather than a static skill set. Foster (2023) affirmed that formal policy initiatives are essential for enhancing teachers' digital competencies worldwide. It documents how countries are leveraging Artificial Intelligence (AI), learning management systems, and digital assessment platforms to enhance educators' readiness for technology-rich classrooms. This policy perspective reinforces the argument that digital competence must be embedded within broader educational ecosystems, rather than treated as an isolated technical skill. Taken together, these studies signal a clear shift from narrow, tool-based understandings of digital literacy toward more comprehensive frameworks. The literature consistently calls for interdisciplinary approaches, ethical awareness, and institution-wide responsibility in cultivating digital competence. Positioned in this way, digital competency emerges as a cornerstone of effective and equitable education in the twenty-first century.



Digital Competence Areas Needed by Chemistry Teachers

Digital competence in chemistry education has been the subject of extensive global inquiry; yet, recent Nigerian scholars provide particularly valuable localized perspectives. Aliyu (2024) found that Nigerian teachers, though moderately skilled with basic digital tools, rarely employed advanced technologies such as virtual laboratories and molecular simulations, thereby, arguing that this gap underscores the urgent need for professional development programs that integrate both technical training as well as pedagogical strategies to strengthen digital competence in classrooms. Ugosor et al. (2025) examined the incorporation of AI in Nigerian chemistry education, emphasizing its ability to clarify complex concepts, improve laboratory simulations, and enable data-driven experimentation, while also cautioning that challenges such as limited accessibility, infrastructural constraints, and the risk of diminishing emphasis on hands-on laboratory skills remain pressing concerns within Nigeria's educational system.

These Nigerian perspectives complement international frameworks that provide structured guidance for digital competence development. The European DigCompEdu framework (Redecker, 2017) outlines six domains of digital competence for educators, ranging from professional engagement to digital content creation, emphasizing the importance of ethical awareness, inclusivity, and interdisciplinary collaboration. Similarly, the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2011) emphasizes the importance of cultivating comprehensive digital competence that extends beyond technical know-how while highlighting six competency framework for teachers' work; ranging from understanding ICT in education, curriculum and assessment, pedagogy, ICT, organization and administration, to professional teacher learning. Expanding on this perspective, Domínguez-González et al. (2025) emphasize that teacher education programs should integrate digital skills throughout the curriculum rather than treating them as supplementary. In the context of chemistry instruction, this requires embedding digital resources such as molecular visualization, simulation, and assessment tools into routine classroom practice.

Taking together, both Nigerian and international studies converge on the view that chemistry teachers require multidimensional digital competences; such as: pedagogical competence, technical competence, assessment competence, ethical and safety competence.

Classroom Innovation

Classroom innovation can be defined as the purposeful introduction and application of new pedagogical strategies, technologies, or organizational practices that enhance teaching effectiveness and student learning outcomes (Herodotou et al., 2019). It involves rethinking traditional instructional methods to foster creativity, critical thinking, and active engagement, while adapting to evolving educational contexts and societal needs.

Classroom innovation has become a major focus of current educational studies, with scholars emphasizing the integration of active pedagogies, digital technologies, and inclusive practices as pathways to improved learning outcomes. Global meta-analyses consistently demonstrate that approaches such as active learning, flipped classrooms, and inquiry-based teaching yield substantial gains when coherently embedded into curricula rather than applied in isolation (Hattie, 2023; Kukulska-Hulme et al., 2024).



Technology-enabled practices including learning analytics, extended reality, and generative AI are reshaping classroom dynamics, though researchers caution that their effectiveness hinges on clear pedagogical objectives, ethical safeguards, and reflective practice (Foster, 2023; UNESCO, 2023). Within Nigeria, recent studies provide localized perspectives on classroom innovation. Research conducted in Nigeria has demonstrated the level of digital proficiency among science and chemistry instructors. For instance, Abimbola et al. (2025) noticed that students' enthusiasm and participation in science courses was significantly influenced by teachers' ICT proficiency. In a similar vein, Nwankwo et al. (2023) found that Onitsha chemistry teachers had a fair level of ICT pedagogical competency but required more training for successful classroom integration of such technologies. Okeke (2025) noted the potential of artificial intelligence to simplify abstract concepts and enhance laboratory simulations, identified persistent challenges related to accessibility, infrastructure, and equity, underscoring the importance of contextualizing global innovations within Nigeria's educational realities.

Other Nigerian contributions extend the discussion beyond technology Abolarin et al. (2025) explored project-based learning in Lagos secondary schools, reporting that innovation embedded into everyday classroom practice improved student engagement, collaboration, and problem-solving skills. In higher education, Oghenevwede (2015) analysed blended learning adoption in Nigerian universities, concluding that institutional support, teacher training, and reliable infrastructure are critical for sustaining innovative practices in which, without these supports, digital tools risk being underutilized or misaligned with pedagogical goals.

Finally, both international and Nigerian literature converge on the view that classroom innovation is most effective when pedagogical strategies, technological tools, and institutional support are integrated into a coherent framework. In the Nigerian context, priority is placed on closing infrastructural deficits, enhancing teacher competencies, and promoting fair access to innovative practices, thereby harmonizing local educational conditions with global trends in transformation (Ogunbodede et al., 2023).

INTEGRATING DIGITAL TOOLS FOR CLASSROOM INNOVATION

GLOBAL PERSPECTIVES ON DIGITAL TOOLS AND INNOVATION

Integrating digital tools into teaching–learning activities is now central to educational innovation globally. Technology has the greatest impact when it supports clear teaching goals, rather than introduced as isolated additions. Hattie (2023) argues that approaches such as flipped learning, inquiry based teaching, and blended models produce meaningful gains when digital resources are aligned with clear instructional objectives and reinforced through sustained professional development for teachers. In a similar vein, Kukulska-Hulme et al. (2024) writing in the *Innovating Pedagogy 2024* report, highlight the transformative potential of extended reality (XR), learning analytics, and generative AI. They caution, however, that the effectiveness of these innovations depends less on their novelty and more on the presence of scaffolding, reflective practice, and ethical application.



At the policy level, international frameworks have provided structured guidance for embedding digital competence into teaching. The European DigCompEdu framework (Redecker, 2017) identifies six domains of competence, ranging from professional engagement to digital content creation, and stresses that “educators are not just role models. They are first and foremost learning facilitators, or more plainly: teachers. As professionals dedicated to teaching, they need, in addition to the general digital competences for life and work, educator-specific digital competences to be able to effectively use digital technologies for teaching” (Redecker, 2017, p. 15). UNESCO (2023) has delineated a framework for the responsible incorporation of generative AI in educational practice, stressing the imperatives of transparency, bias mitigation, and the preservation of academic integrity. Foster (2023) emphasizes how intelligent technology might help advance formative assessment, personalization, and collaborative learning, positioning digital tools as catalysts for systemic innovation rather than mere classroom enhancements.

Nigerian Perspectives on Digital Classroom Innovation

Recent Nigerian scholars provide localized insights into global trends in educational technology, highlighting both opportunities and challenges. In Ogun State, Aderonmu and Edache-Abah (2025) observed limited use of digital tools in secondary school science instruction, primarily due to infrastructural and training gaps. Achugbu and Eke (2020) also emphasized that digitization of chemistry teaching in Anambra State is constrained by the lack of digital resources and teacher readiness. Furthermore, Sam-Kayode et al. (2024) assessed science teachers in Ibadan and found moderate digital literacy, suggesting a growing awareness but inadequate support for full integration of digital tools in instruction. This limitation points to the need for professional development initiatives that emphasize subject specific digital innovations. Okeke (2025) investigated the incorporation of artificial intelligence into Nigerian chemistry education in a similar study. He maintained that AI could improve lab simulations, make abstract ideas easier to understand, and promote data-driven exploration. Nevertheless, infrastructural deficits, unequal access to digital resources, and persistent equity concerns remain significant barriers. Okeke’s work underscores the importance of situating global technological advances within Nigeria’s educational realities. Beyond chemistry education, Nigerian scholars have investigated broader pedagogical innovations. Eke (2024) assessed teacher educators’ readiness for AI adoption in Imo State, reporting generally positive attitudes but highlighting challenges such as inadequate infrastructure and insufficient training. His findings reinforce the argument that institutional support and capacity-building are essential for sustainable classroom innovation. Similarly, Abolarin et al. (2025) studied project-based learning supported by digital platforms in Lagos secondary schools. Their study showed that, when included into regular practice, digital tools can improve student involvement, teamwork, and problem-solving abilities. Complementing this, Oghenevwe (2015) examined blended learning adoption in Nigerian universities, concluding that reliable infrastructure, teacher training, and institutional backing are critical for long-term success. Without these supports, digital tools risk being underutilized or misaligned with pedagogical goals. Table 1 give the summary of the global view and Nigerian scholars perspectives on the use of education technology for classroom innovation.

Table 1
Comparative view of global and Nigerian perspectives on digital tools for classroom innovation

Competence area	Global perspectives	Nigerian perspectives
Pedagogical alignment	Emphasis on embedding digital tools into active learning, inquiry-based, and blended models (Hattie, 2023; Kukulka-Hulme et al., 2024).	Project-based learning supported by digital platforms improves engagement and problem-solving (Abolarin et al., 2025)
Technical proficiency	Use of simulations, XR, learning management systems, and AI-driven platforms to enhance subject-specific innovation (Foster, 2023; UNESCO, 2023).	Moderate ICT competence among chemistry teachers; limited use of advanced tools like virtual labs and molecular visualization (Ode et al., 2023).
Assessment innovation	Learning analytics and adaptive assessment enable real-time feedback and personalization (Foster, 2023).	Blended learning adoption highlights the need for digital assessment tools, but infrastructural gaps hinder widespread use (Oghenevwe, 2015)
Ethical and inclusive practice	UNESCO (2023) stresses transparency, bias mitigation, and accessibility in AI use; DigCompEdu emphasizes inclusivity (Redecker, 2017).	Okeke (2025) notes challenges of equity, access, and infrastructural limitations in AI adoption for Nigerian classrooms.
Professional development and sustainability	Global frameworks call for continuous teacher training and interdisciplinary collaboration (Redecker, 2017; Foster, 2023).	Nigerian cases demonstrate the critical necessity for institutional support and focused professional growth in order to maintain innovation. (Ode et al., 2023; Oghenevwe, 2015)

Theoretical Background

Rogers (2003) established the Diffusion of Innovations Theory, which describes how new concepts, methods, or technologies gradually dominate a social system. According to Rogers, diffusion is a communication process in which individuals of a social system learn about an innovation through particular channels, progressively influencing adoption decisions. Rogers explained that an innovation is any concept, method, or item that a person or group considers novel and that offers fresh approaches to issues. Hence, diffusion should be viewed not just as knowledge dissemination, but also as a force that alters societal structures and functions and creates major societal effects. According to Rogers, diffusion has four fundamental components:

- I. Innovation, as the novel concept, method, or item.
- II. Channels of communication: how information is disseminated.
- III. Time: the duration of the adoption process.
- IV. A social system, as a collection of people or groups that collaborate to achieve common objectives.



The Diffusion of Innovations Theory is used in this study to investigate how Osun State Chemistry teachers incorporate classroom innovation and digital competency. The framework highlights the roles of individual teacher qualities, institutional environment, and innovation attributes in the adoption of innovative teaching approaches and digital tools.

METHOD

Creswell (2009) emphasizes that quantitative research is a mean for testing objective theories by examining the relationship among variables. These variables in turn can be measured by the use of instruments such that the numbered data can be analysed using statistical procedures. Therefore, the research design for the study was a descriptive survey research design. The population of the study comprises all chemistry teachers in the public senior secondary schools in the three senatorial districts in Osun State, Nigeria (Osun Central, Osun East, and Osun West). A total of 165 teachers responded by completing the questionnaire sent via email and *WhatsApp*. The information was gathered with a self-developed questionnaire titled “Chemistry Teachers’ Digital Competence and Classroom Innovation Questionnaire (CTDCCIQ)”, comprised of three sections. Section A covers demographic information (presented with the results found in table 2), Section B contains 10 items related to digital competency of chemistry teachers, while section C related to information about classroom innovations (available in table 3), also containing 10 items. To ensure that the items measure the content they were intended to measure, the instrument was subjected to face and content validity. A senior colleague in the department of Science and Technology Education at the Faculty of Education, Obafemi Awolowo University, and an expert in digital technology verified the instrument before it was administered. The questionnaire was graded using a 5-point Likert system and a numerical scale ranging from 1-5 points were used, where 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree. The research questions were analysed using frequency counts, simple percentages, mean, standard deviation with composite scores used to aggregate all the items in the questions, while percentile-based classification was used to categorise the respondents’ composite scores into low, moderate and high levels and the entire data was analysed using Stata 15 software.

Table 2
Demographic information of the participants

Demographic characteristics		
	n	%
Gender		
Female	73	44.24
Male	92	55.76
Age		
20 – 39	96	58.18
40 – 49	63	38.18
50+ years	6	3.64

Demographic characteristics		
	n	%
Highest Qualification		
NCE	5	3.03
BSc/B.Ed	89	53.94
PGDE	38	23.03
MSc/M.Ed	31	18.79
PhD	2	1.21
Years of teaching experience		
0 – 5	57	34.55
6 – 10	38	23.03
11 – 15	37	22.42
16 – 20	19	11.52
21+ years	14	8.48
Typical class size for chemistry		
<20	18	10.91
20 – 35	87	52.73
36 – 50	36	21.82
>50 students	24	14.55
Senatorial district		
Osun Central	49	29.70
Osun East	61	36.97
Osun West	55	33.33

Table 3
Items measuring digital competence and classroom innovation of Chemistry Teachers

S/N	Teacher's digital competence items
1	I have formal training in educational technology or digital pedagogy.
2	I can operate basic applications (Word, PowerPoint, Excel) confidently.
3	I can use the internet to search for and evaluate teaching resources.
4	I can use chemistry-specific digital tools (e.g., PhET, simulations, Virtual labs).
5	I can set up and use a simple LMS or class/group platform (e.g., Google Classroom, WhatsApp groups).
6	I know which instructional strategies work best when using digital tools.
7	I can identify which digital resources best illustrate specific chemistry concepts.
8	I can select and adapt digital tools to teach specific chemistry topics effectively.
9	I can design assessments that use digital tools to measure chemistry understanding.
10	I reflect on my use of technology to improve teaching and learning outcomes.



Classroom Innovation items	
1	I use digital tools that make tasks easier or faster for students (e.g., automatic quizzes).
2	I redesign learning tasks with technology to promote collaboration (e.g., shared online lab reports).
3	I implement learning activities that were not possible before (e.g., virtual experiments, remote data logging).
4	I use multimedia (videos, animations) to explain challenging chemistry concepts.
5	I encourage students to create digital artefacts (e.g., presentations, simulations, models).
6	I reflect on my use of technology to improve teaching and learning outcomes.
7	I can design learning activities that combine digital tools with active learning.
8	I am motivated to integrate technology into my chemistry lessons.
9	I believe technology improves students' understanding of chemistry.
10	Integrating technology is worth the additional planning time.

Note: S/N - serial number of the item constructs.

The required procedures to determine the internal consistency of the instrument and how the items coincide or differ from the construct were conducted. The reliability analysis shows that the scale has excellent internal consistency (Cronbach's Alpha= .93). All items demonstrate acceptable to strong item-test correlations, indicating that they contribute meaningfully to the measurement of the construct. The "alpha if item deleted" statistics show no substantive improvement in the reliability from removing any item. Therefore, all items were retained for further analysis.

RESULTS

The study examined chemistry teachers' digital competency and classroom innovation. For the digital competence of Chemistry teachers, the composite scores were computed and categorized into low: 17-35, medium: 36- 44, and high level: 45 - 50 which was determined by percentile- based classification and descriptive statistics.

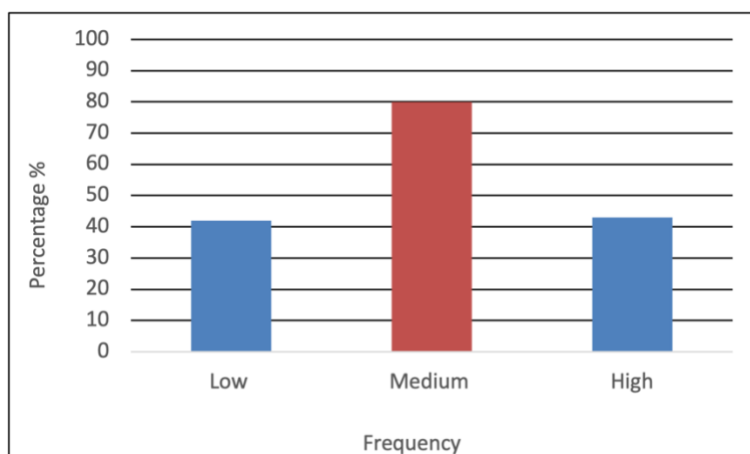
What is the level of digital competence among Chemistry teachers in Osun State Public Schools?

In determining the level of digital competence of chemistry teachers, the results analysed have a mean score of digital competencies 39.27 (SD =8.24, Variance = 68.05). The findings, as shown in Figure 1, reveals that most of the respondents 80 (48.48%) displayed medium level of digital competence, while 43 (26.06%) demonstrated high level of digital competence, and 42 (25.45%) displayed a low level of digital competency.



Thus, this suggests that most respondents have an average level of digital competency with basic knowledge in digital skills, while only few teachers show high competency in digital tools, and substantial respondents have low level of digital competency. Low and medium digital competency of teachers might indicate that teachers are struggling with the use of digital tools for pedagogical practices due to lack of digital training skills for teachers. Thus, mirroring the need for interventions for digital upskill and competence development for teachers with low and average digital competency.

Figure 1
Digital Competence of chemistry Teachers in Osun State



The study examined teachers' classroom innovation. The composite scores were computed and categorized into low: 19 -34, medium: 35- 43, and high level: 44 - 50 which was determined by percentile- based classification and descriptive statistics.

How do Chemistry teachers Integrate digital tools into teaching-learning activities for classroom innovation in Osun State Public Schools?

In determining the digital tools integration into teaching-learning activities for classroom innovation, the results reveal the mean score 37.75 (SD = 7.23, Variance = 52.39). As shown in the findings represented in Figure 2, the majority of the respondents (79, therefore, 47.88%) displayed a medium level of classroom innovation with the integration of digital tools into teaching-learning activities, while 42 (25.45%) demonstrated high level of classroom innovation with digital tools, and a similar number (44, representing 26.67%) shows low level of classroom innovation with digital tools. Thus, the findings suggest that the majority of the teachers have an average level of classroom innovation with the integration of digital tools for teaching chemistry concepts, whereas only a few are at high level of classroom innovation as well as at low level of classroom innovation. This indicates that there is inadequate classroom innovation for pedagogical practices which implies that a comparable number of teachers still adopt traditional instructional methods of teaching chemistry concepts.



Figure 2

Digital tools integration for classroom innovation of chemistry teachers

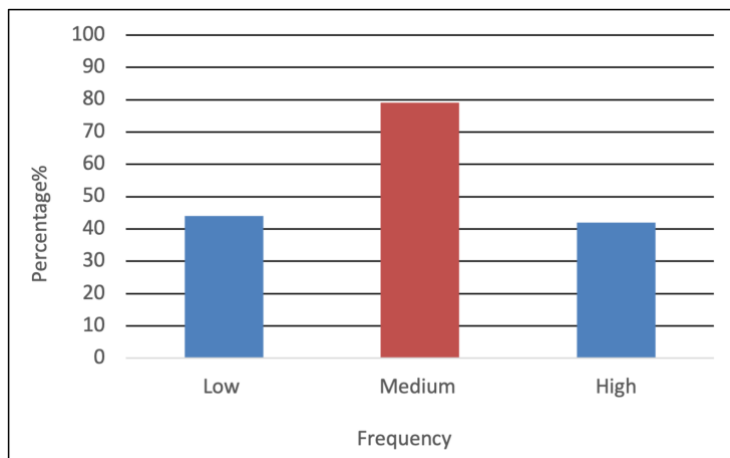


Table 4

Regression analysis of the interdependencies of the digital competence of Chemistry teachers and Classroom Innovation in Osun State Public Schools

Variable	Coef.	Std. Err.	t	P> t	95% Conf. Interval	
Digital Competence	.4974749	.0566137	8.79	0.000	.385684	.6092658
Constant	18.21432	2.271607	8.02	0.000	13.72875	22.69989

The regression analysis of the interdependencies of the digital competence of Chemistry teachers and how innovative they are in the classroom. With the p-value less than 0.05, teachers' digital competence significantly predicts classroom innovation as shown in table 4. Consequently, the null hypothesis is rejected.

Table 5

Summary of regression analysis of the interdependencies of the digital competence of Chemistry teachers and Classroom Innovation among Chemistry teachers in Osun State Public Schools

Model	R ²	Adj R ²	P> F	F (1,163)	Root MSE	No. of obs
1	0.3214	0.3173	0.0000	77.21	5.9809	165

Source	SS	df	MS
Model	2762.07116	1	2762.07116
Residual	5830.74096	163	35.7714169
Total	8592.81212	164	52.3951959

The regression results indicate a strong significantly prediction of digital competence and classroom innovation. Teachers' digital competence explains approximately 32% of the variation in innovation outcomes. A 1-unit increase in digital competence is associated with a 0.5 unit increase in classroom innovation, underscoring the importance of digital investments in fostering innovative pedagogical performance in the classroom practices.

DISCUSSION

The study evaluates the digital competency of chemistry teachers in Osun State public Secondary Schools and their capacity to implement innovative practices in classroom with the integration of digital tools which can translate teaching-learning activities from traditional method, teacher-centred into 21st century model in promoting active learning, critical thinking and collaboration between teachers and students. The results from the findings reveal teachers' digital competency was widely distributed in three different levels, (low, moderate and high) and the majority of chemistry teachers were located at the significant moderate- medium level (48.48%). The majority of teachers in the medium-level suggest that teachers have basic digital competency. However, this level is inadequate to foster pedagogical practices that support innovation which can translate teaching from traditional methods to more modern methods. This is consistent with the researches of Ogegbo (2023) who assessed the proficiency level in digital competencies of secondary school teachers in Lagos, Nigeria, and Ramnarain et al., (2021) who investigated preservice science teachers' proficiency levels regarding their practical knowledge of technological pedagogical content knowledge in South African University. The two studies found out that the majority of teachers demonstrated average level of digital competency, and teachers at this average level needs to improve their knowledge of digital tools that are most effective to integrate digital technologies into pedagogical strategies and methods. Munawar and Jannah (2025) opined that teachers' digital competency must evolve beyond basic technical skills to encompass deeper pedagogical strategies that support innovation such as instructional design, technology-enhanced interaction, and assessment adaptability form, which is a triad of competencies critical for effective hybrid teaching. Dias-Trindade and Moreira (2020) corroborated that those teachers situated at this medium level need more digital competency to reach the optimal digital fluency level in order to enhance their pedagogical practices and classroom innovation. This signals the need for continuous professional development in digital tools and technologies that can make meaning in teaching-learning practices, and government investment in digital education for the pre-service and practicing teachers, to ensure teachers capability in digital fluency. Also, the slight difference between teachers with high competency level 43 (26.06%) and teachers with low competency level 42(25.45%) is noticeable in our study. This pattern may suggest a polarized distribution of teachers' digital competence, with educators tending either to possess relatively strong digital skills or to exhibit substantial deficits in digital competence. Such polarization may reflect unequal availability of digital resources across schools, differential access to digital technologies, varying levels of teacher motivation and willingness to integrate digital tools into pedagogical practice, and unequal opportunities for professional development in digital skills. ElSayary (2023) emphasizes that teachers with low digital competency need to be upskilled in line with upskill gear leading to producing a



positive attitude to digital tools and technologies which can develop digital competency in teachers for professional practices. It is only when teachers are trained and retained in the use of digital tools, that they will begin to value its use, and be competent in it. Collaboration among teachers can also enhance teachers' digital competence. The few teachers with a high level of digital competency of our study (26.06%) can engage in collaboration and digital support with other teachers to improve their digital skills, digital content creation, and digital pedagogical practices, which can address the challenges in teaching. This idea will offer two possibilities, the high skill teachers will be able to improve and sustain their digital skills and the low and average teachers will be able to improve their digital skills as well, while both categories can evenly apply digital skills necessary to integrate digital tools and technologies for pedagogical innovation which seems to be the solution for today's and the future. This doesn't only involve the teachers but also the students, and the entire educational space. Teachers' digital competency remains insignificant if it has no effect in the teaching-learning activities, or where best could teachers use the digital skills if not to improve the teaching-learning activities to achieve the desired results in the education.

Highlighting the results of digital tools integration for classroom innovation among chemistry teachers, the findings also reflect that the majority of teachers (47.88%) were located in the average-medium level. This indicates that most teachers have basic digital skills and demonstrate limited classroom innovation in teaching-learning activities, but still have insufficient digital proficiency to integrate advanced pedagogical practices. This is consistent with the study conducted by Kubrushko et al. (2020) who investigated teachers' readiness for innovative pedagogy activities in Russian State Agrarian University. Also, the proportion of the teachers in the low category (26.67%) suggest a lack of digital competency that supports classroom innovation signifying that those teachers still rely on traditional methods of teaching chemistry concepts. The study of Nychkalo et al. (2024) found that a wide range of digital tools and resources are used to organize the process of integration of Ukrainian children and students in Slovakia. This established that Slovak teachers are proficient in the use of digital tools and use digital tools such as Microsoft Teams, Cisco Webex Meetings, Google Classroom, and Zoom to integrate Ukrainian students into the educational environment. In a similar manner, Demissie et al. (2022) study assessed teachers' digital competencies and technology integration in teaching and learning in Wolaita Zone, Ethiopia. The results from this study show that teachers were competent in pedagogical-content knowledge domains regardless of school type. The competence of these teachers in digital tools might be due to access to digital resources in schools, government support and motivation to use digital tools in enhancing learning and digital skills development available to teachers in those countries which might be lacking in Nigeria. Foster (2023) emphasizes teachers need to be adequately prepared to integrate digital skills into teaching-learning activities since teachers are at the centre of the digital ecosystem. Digital competency level of teachers will avail them to carry out innovative pedagogical activities, and ensure their motives for professional and personal self-development, open them to a new knowledge, learn quickly and effectively, carried out research and solve educational challenges, while still allowing them to facilitate the needed knowledge to students adequately (Kubrushko et al., 2020).

Finally, the regression analysis showed a strong association between teachers' competence and classroom innovation. This aligns with Abubakar et al. (2025) who found that when digital tools are incorporated into teaching-learning activities, it enhances effective instructional delivery. Omodara and Popoola (2025) established that access to technology-equipped classrooms, and digital infrastructures and technology devices

greatly impact learning and improve students' capacity to conduct research, collaborate and interact with the academic materials. Although their study was carried out within the university settings, the results reflect the positive relationship of digital tools integration and pedagogical innovation in teaching activities regardless of the education level.

CONCLUSION AND LIMITATION

The study, which uses a quantitative methodology, investigates chemistry teachers' digital competence and how they integrate digital tools for classroom innovation. The results mirror the average level of both digital competency and classroom innovation among chemistry teachers in Nigeria. This indicates lack or insufficient digital skills to advance classroom innovation and enhance teaching-learning activities. A strong relationship between digital tools integration and classroom innovation was also observed. As indicated by the existing literature. For example, Gallego Joya et al. (2025) emphasize digital competency is an indispensable instrument for pedagogical innovation especially in chemistry subjects where digital tools such as simulation, virtual laboratories, PhET among others can help to remove abstract and ambiguity that existed. Our concern is that chemistry teachers can be equipped to carry out teaching-learning activities in conformity to the 21st century model in order to improve pedagogical practices and better facilitate students' learning. Availability of digital infrastructures and professional education in digital tools will make this achievable.

The study has been limited to chemistry teachers, in order to evaluate their digital competency and classroom innovation in public secondary schools in Osun state, due to the complexity of the subject and its abstract nature. Hence, we recommend that future studies can explore how teachers of other subjects (science and non-science subjects) are digitally competent and how they integrate digital tools to bring about classroom innovation. Further studies can also investigate digital competency and classroom innovation among public and private schools due to the capabilities of the latter to provide digital resources and support teachers to integrate them for classroom innovation.

IMPLICATION FOR THE STUDY

The findings of the study implies that classroom innovation in this digital dispensation is dependent on teachers' digital competency which as well concretize the fact that teachers are at the centre of the digital ecosystem. Hence, this suggests the need for targeted intervention programs, through digital skills development for low and average digital skilled level teachers to improve their digital skills to support classroom innovation. Also, since few teachers have high digital competency - 43 (26.06%), collaborative teaching among teachers with high competency and teachers with low and medium digital competency might enhance digital skills of teachers for classroom innovation.

It is imperative to implement digital education programs for pre-service teachers which would see them achieve digital literacy before starting their professional career and as well digital professional training for the in-service chemistry teachers, especially those in the low and medium categories while it is advisable the training doesn't focus on acquiring digital skills alone, but application of it for classroom practices.



School administrators and policy makers should ensure adequate provision of digital resources and its accessibility in schools, and as well motivate teachers to the use of digital tools for pedagogical practices to improve classroom innovation. Similarly, conscious commitment to the policies on integrating digital tools and technologies in education in Nigeria and as well in Osun State such as *Teacher-shift 2025* (Osun State Board for Technical and Vocational Education, 2025) should be properly implemented to ensure teachers are better equipped with modern digital skills and best practices in driving sustainable paradigm shifts in educational space in the country.

DISCLOSURE ON THE USE OF ARTIFICIAL INTELLIGENCE TOOLS

Consensus AI was used to pull literature review from peer-review papers.

AUTHORS CONTRIBUTION

Conceptualization: O. E. F.; Methodology: O. E. F.; Validation: O. E. F.; Formal analysis: O. E. F.; Investigation: S. C. E.; Resources: O. E. F.; Data curation: O. E. F.; Writing—original draft preparation: S. C. E.; Writing—review and editing: O. E. F. and S. C. E.; Visualization: O. E. F.; Supervision: O. E. F. and S. C. E. All authors have read and agreed to the published version of the manuscript.

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