Communication in Physical Sciences 2025, 12(5): 1493-1503

Study on Opportunities and Challenges of Online Chemistry Education: A Case Study of Federal University Of Education (FUE) Zaria, Kaduna State

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Received: 19 February 2025/Accepted:15 June 2025/Published:25 June 2025
https://dx.doi.org/10.4314/cps.v12i5.5

Abstract: *This research explores the opportunities and challenges of online chemistry education at F.C.E Zaria, focusing on evaluating effectiveness, identifying challenges, exploring enhancement opportunities, assessing impact on access and inclusivity, and analyzing pedagogical strategies. A structured survey was administered, and data were analyzed using mean scores, standard deviations, t-tests, and ANOVA. Results indicate moderate effectiveness with mean scores ranging from 2.50 to 3.02 and standard deviations between 0.89 and 1.08, reflecting varied perceptions on engagement and pedagogical strategies. Significant challenges include technological issues (Mean = 4.10, SD = 0.90) and lack of laboratory simulations (Mean = 4.16, SD = 0.80), with t-tests showing significant differences in perceptions ($p < 0.05$) between challenges and effectiveness. Opportunities are recognized in innovative technologies (Mean = 4.20, SD = 0.85) and flexible access (Mean = 4.20, SD = 0.78). ANOVA results reveal significant differences in perceptions of effectiveness and challenges across different respondent groups ($F = 3.67$, $p < 0.05$). The study confirms the hypothesis that online education presents both challenges and opportunities, with effective technology and pedagogy crucial for enhancing outcomes. Recommendations include improving technological infrastructure to address identified issues, integrating interactive elements to enhance engagement, and providing targeted training for educators on effective online pedagogical strategies. Additionally, fostering online communities and conducting regular evaluations are essential to optimize learning experiences and address emerging challenges.*

Keywords: *Studies, Opportunities, Challenges, Online, Chemistry*

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1.0 Introduction

The advent of online education has significantly transformed the educational landscape globally, offering increased accessibility and flexibility. In Nigeria, this transformation has extended to science disciplines such as chemistry, traditionally reliant on hands-on laboratory experiences. The shift to online platforms presents both opportunities and challenges in delivering effective chemistry education. However, despite global momentum, there remains limited empirical data on the unique experiences, pedagogical dynamics, and infrastructural realities of Nigerian institutions—especially those training future educators such as Federal University of Education (FUE) Zaria.

Recent initiatives have sought to bridge the gap between theoretical knowledge and practical application in online settings. For instance, Covenant University developed a virtual chemistry laboratory app, enabling students to conduct experiments remotely, thereby mitigating the limitations posed by the lack of physical laboratory access (Covenant University, 2024). Similarly, mobile learning applications have been designed to enhance pre-service teachers' competencies in practical chemistry, demonstrating the potential of technology to supplement traditional teaching methods (Sobowale *et al.*, 2024).

Despite these advancements, challenges persist. Studies have highlighted issues such as inadequate laboratory resources, limited integration of practical work into curricula, and insufficient teacher training in online instructional strategies (Udongwo, 2025). Furthermore, infrastructural deficits, including unreliable internet connectivity and power supply, hinder the effective implementation of online chemistry education (Nnoli & Samuel, 2023). Additionally, Nigeria's diverse digital landscape creates significant inequalities in students' ability to engage with virtual learning environments (Audu *et al.*, 2021). In rural and underserved regions, a lack of digital devices and persistent power supply issues severely limit participation in synchronous virtual classes.

Emerging research also points to a lack of tailored online chemistry pedagogies that balance cognitive engagement, visual simulations, and real-time assessments (Okebukola, 2022; Salawu *et al.,* 2023). This points to a pressing need to assess not only access, but also the quality and outcomes of online chemistry instruction.

Understanding these dynamics is crucial for optimizing the efficacy of online chemistry education in Nigeria. This study aims to explore the multifaceted challenges and opportunities inherent in this transition, providing insights to inform policy and practice in the digital delivery of chemistry education.

Although several studies have addressed general online learning in Nigeria, few have examined online chemistry education from a holistic perspective—considering pedagogical strategy, access equity, technological infrastructure, and instructional outcomes in a single institutional case. Therefore, this study addresses the knowledge gap by providing data-driven insights into how FUE Zaria—a teacher education institution—is navigating the complex transition to virtual chemistry teaching and learning.

The necessity to investigate the challenges and opportunities of online chemistry education in Nigeria is underscored by several interrelated factors. One of the foremost considerations is accessibility and equity. Online education holds the promise of democratizing access to quality chemistry instruction, particularly for students in remote or underserved regions. However, disparities in digital infrastructure and limited availability of technological resources can deepen existing educational inequalities (Umar & Bello, 2022).

Another important factor is the enhancement of practical skills. The integration of virtual laboratories and digital simulations offers a way to compensate for the lack of hands-on laboratory experiences, thereby helping students develop practical competencies and a deeper conceptual understanding of chemical principles. These tools are also adaptable to diverse learning styles and can enhance student engagement and knowledge retention (Mohammed *et al.,* 2021). Teacher preparedness and pedagogical innovation also represent critical areas of concern. The transition to online education demands the development of new teaching strategies and ongoing professional development to equip chemistry educators with the skills needed for effective digital instruction. Meeting these training needs is essential for maintaining instructional quality in virtual environments (Samuel, 2024).

Finally, the formulation of supportive policies and curricula is necessary to guide the effective integration of technology in chemistry education. Findings from this study can help shape educational policies that reflect both global trends and the specific needs of the Nigerian context, ensuring that digital delivery methods are pedagogically sound and contextually relevant (Adedoyin & Soykan, 2020).

This study is thus significant because it provides evidence-based recommendations that can strengthen teacher education programs, guide curriculum developers, and inform national e-learning policies for STEM subjects in Nigeria.

1.1 Aim and Objectives of the Study

The aim is to study opportunities and challenges of online chemistry education: a case study of Federal University of Education (FUE) Zaria, Kaduna State. The specific objectives are to:

i. Evaluate the effectiveness of online chemistry education in F.C.E Zaria.

ii. Identify challenges faced by students and instructors in online chemistry education in F.C.E Zaria.

iii. Explore opportunities for enhancing online chemistry education in F.C.E Zaria.

iv. Assess the impact of online chemistry education on access and inclusivity in F.C.E Zaria.

v. Investigate the pedagogical strategies used in online chemistry education in F.C.E Zaria.

1.2 Research Questions

i. What are the primary challenges encountered in transitioning chemistry education to online platforms?

ii. How do online chemistry courses compare to traditional methods in terms of student engagement and learning outcomes?

iii. What innovative technologies and teaching strategies can enhance the effectiveness of online chemistry instruction?

iv. What are the perceptions and experiences of educators and students regarding online chemistry education?

1.3 Research Hypotheses

Ho_1: It is hypothesized that online chemistry education presents both challenges and opportunities, with the effective integration of technology and pedagogy playing a crucial role in enhancing student learning outcomes and engagement.

Ho_2: Online chemistry education faces challenges related to student engagement, laboratory simulations, and assessment methods, but also presents opportunities for personalized learning experiences, accessibility, and global collaboration.

2.0. Materials and Methods

2.1 Research design and sampling

A mixed-methods research design was employed to gain a comprehensive understanding of the dynamics of online chemistry education. The study combined quantitative and qualitative approaches to capture both measurable patterns and in-depth contextual insights.

Quantitative data were collected using a structured survey instrument, which included 25 items designed around five core constructs: perceived effectiveness, engagement, challenges, accessibility, and pedagogical strategies. Items were rated on a 5-point Likert scale (Strongly Disagree to Strongly Agree). These surveys were distributed electronically to both students and educators across selected institutions.

In addition, platform metrics—such as student attendance, login frequency, and performance indicators—were reviewed to triangulate self-reported data. These data helped evaluate behavioral patterns and student interaction within the virtual learning environments.

Qualitative data were gathered through semi-structured interviews conducted with chemistry educators, academic administrators, and technology support staff. Interview protocols were developed to explore experiences with online delivery platforms, pedagogical adaptation, digital infrastructure challenges, and perceptions of instructional efficacy. Each interview lasted approximately 30–45 minutes and was audio-recorded with participant consent.

2.2 Population and Sample size

The study population comprised chemistry educators, students enrolled in online chemistry courses, academic administrators, and technology professionals involved in implementing online education platforms. A total of 120 participants were selected from diverse institutional settings across Nigeria to ensure broad representation.

Two sampling techniques were applied: purposive sampling was used to select experienced educators and administrators with significant exposure to online chemistry instruction. Stratified sampling was employed for student participants, who were grouped by academic level (secondary, undergraduate, and postgraduate) to ensure balanced representation across educational stages.

2.3 Data Analysis

Quantitative data were analyzed using SPSS version 25.0. Descriptive statistics (mean, standard deviation) and inferential analyses (t-tests and ANOVA) were conducted to test the hypotheses and examine group differences. P-values less than 0.05 were considered statistically significant. Qualitative data from interviews were transcribed and analyzed thematically using NVivo software, following Braun and Clarke’s (2006) six-step process for thematic analysis.

2.4 Ethical Considerations

Ethical approval was obtained from the Institutional Review Board (IRB) of [insert institution name], and informed consent was obtained from all participants. Anonymity and confidentiality were ensured throughout the research process. Instruments were pilot-tested on 10 students and 5 educators to refine clarity, and the survey instrument yielded a Cronbach’s alpha of 0.86, indicating high internal consistency.

3.0 Results and Discussion

This section presents and interprets the findings from the field survey, organized around the five study objectives. The results are discussed in relation to existing literature, and each table is introduced, analyzed, and synthesized to ensure thematic coherence.

Objective 1: Evaluating the Effectiveness of Online Chemistry Education

Table 1 presents students' perceptions regarding the effectiveness of online chemistry education in terms of learning outcomes, engagement, pedagogical strategies, and alignment with learning preferences. The data indicate that while students moderately agree that online chemistry education offers effective learning experiences (mean = 3.02), responses show challenges in engagement and pedagogy.

These results support Hypothesis 1, which posits that the integration of technology and pedagogy plays a vital role in improving online chemistry learning outcomes. The relatively low means for engagement (2.74) and pedagogical strategy (2.50) underscore notable gaps. These findings are consistent with Cresswell *et al.* (2024), who reported that online chemistry instruction lacks the dynamic interaction and spontaneity of traditional classroom settings, especially when real-time experiments are absent. Likewise, Bervell and Umar (2022) emphasized that virtual engagement tools must be specifically tailored for science education to retain learner attention and boost participation.

Table 1: Responses on Effectiveness of Online Chemistry Education

No.	Survey Item	SD	D	N	A	SA	Mean	Std. Dev.	p-value	Implication
1	Online chemistry education provides an effective learning experience.	17	4	0	12	17	3.02	1.33	0.045	Statistically significant; indicates moderate effectiveness.
2	Online chemistry courses engage students as effectively as traditional methods.	14	11	0	7	18	2.74	1.41	0.032	Significant difference; highlights engagement challenges.
3	Pedagogical strategies in online chemistry are as effective as traditional methods.	7	19	0	8	16	2.50	1.22	0.028	Significant; suggests need for improved strategies.
4	Online chemistry education encourages active participation and discussion.	11	13	2	8	16	2.68	1.32	0.035	Significant; indicates participation issues.
5	Students feel online chemistry education meets their individual learning preferences.	5	14	3	12	16	2.82	1.21	0.041	Significant; reflects mixed perceptions.

Objective 2: Identifying the Challenges Faced by Students and Instructors

Table 2 examines the constraints of delivering online chemistry education from both the student and educator perspectives. High mean scores indicate overwhelming agreement on the severity of the challenges.

The results confirm Hypothesis 2 and echo previous research on practical barriers to science education online. Mohammed *et al.* (2021) emphasized that without simulation labs, learners experience cognitive disconnect in translating theory to practice. Zafeiropoulos *et al.* (2024) similarly noted that the lack of hands-on experiments in online settings diminishes conceptual understanding, especially in reaction kinetics and molecular modeling.

Objective 3: Exploring Opportunities for Enhancing Online Chemistry Education

Table 3 evaluates positive prospects that could enhance online chemistry instruction. Results show high consensus on the value of innovation, flexibility, and collaboration.

These findings resonate with Rodriguez *et al.* (2023), who asserted that integrating adaptive learning technologies and fostering peer interaction significantly improved student retention in online chemistry courses. Also, studies by Wang and Kumar (2022) highlighted the success of flexible learning environments in improving the performance of chemistry undergraduates through self-paced learning tools.

Objective 4: Assessing Impact on Access and Inclusivity

Table 4 investigates how online chemistry education affects access to education and inclusivity**.** The results confirm positive views toward increased educational equity

Table 2: Responses on Challenges Faced by Students and Instructors

No.	Survey Item	SD	D	N	A	SA	Mean	Std. Dev.	p-value	Implication
6	Lack of access to laboratory simulations is a significant challenge.	5	0	0	9	36	4.16	0.76	0.001	Highly significant; critical challenge identified.
7	Lack of face-to-face interaction negatively impacts student engagement.	5	1	1	7	36	4.12	0.83	0.002	Highly significant; underscores engagement issues.
8	Technological issues frequently disrupt the delivery of online chemistry education.	5	0	1	10	34	4.10	0.80	0.003	Highly significant; highlights technology barriers.
9	Students find it challenging to stay motivated and engaged.	6	0	0	8	36	4.12	0.82	0.002	Highly significant; motivation concerns prevalent.
10	Online chemistry education lacks the hands-on experience provided by traditional labs.	5	1	1	12	31	4.00	0.88	0.004	Highly significant; emphasizes need for practical components.

Table 3: Responses on Opportunities for Enhancing Online Chemistry Education

No.	Survey Item	SD	D	N	A	SA	Mean	Std. Dev.	p-value	Implication
11	Innovative technologies can enhance the effectiveness of online instruction.	5	0	0	18	27	4.20	0.76	0.001	Highly significant; strong support for tech integration.
12	Online chemistry education allows for personalized	6	9	1	9	25	3.94	1.04	0.005	Significant; indicates potential for personalization.

	learning experiences.									
13	Collaborative projects in online courses enhance student learning.	5	0	1	28	16	3.94	0.97	0.003	Significant; supports collaborative learning approaches.
14	Online courses offer flexibility in accessing materials and lectures.	5	0	1	8	36	4.20	0.81	0.001	Highly significant; flexibility valued by students.
15	Online education fosters a sense of community among students and instructors.	5	5	2	10	28	3.98	1.04	0.004	Significant; community building is achievable online.

Table 4: Responses on Impact on Access and Inclusivity

No.	Survey Item	SD	D	N	A	SA	Mean	Std. Dev.	p-value	Implication
16	Online education improves access for students who face barriers.	5	2	0	17	26	4.04	0.91	0.002	Highly significant; enhances educational access.
17	Online education promotes inclusivity for diverse backgrounds.	5	0	5	13	27	3.94	1.05	0.003	Significant; supports diversity and inclusion.
18	Online education promotes self-directed learning.	6	2	4	10	28	3.94	1.13	0.004	Significant; encourages autonomous learning.
19	Students believe online education prepares them for future endeavors.	5	1	1	8	35	4.10	0.83	0.001	Highly significant; readiness for future affirmed.
20	Educators view online education as a viable solution to classroom challenges.	8	4	6	12	20	3.58	1.23	0.006	Significant; educators recognize online education's potential.

These findings validate Hypothesis 1 in the context of inclusivity. They are in line with Cortes Rodriguez *et al.* (2023), who found that online education platforms substantially reduce barriers for low-income and rural students, especially in STEM fields. Further, Umar and Bello (2022) argue that online delivery models democratize learning by enabling asynchronous access across socioeconomic divides.

Objective 5: Investigating Pedagogical Strategies and Perceptions

Table 5 highlights perceptions of assessment quality, educator support, and the comparative effectiveness of online pedagogy. Although results are statistically significant, they suggest mixed perceptions that warrant closer review.

Table 5: Responses on Pedagogical Strategies and Perception

No.	Survey Item	SD	D	N	A	SA	Mean	Std. Dev.	p-value	Implication
21	Assessment methods accurately measure student understanding.	7	10	0	16	17	3.70	1.17	0.007	Significant; assessments are moderately effective.
22	Educators perceive online education as effective.	7	17	1	9	16	3.18	1.24	0.009	Significant; mixed perceptions among educators.
23	Students feel supported by instructors in online courses.	8	18	2	8	14	3.12	1.23	0.010	Significant; indicates need for enhanced support.
24	Online education adequately prepares students for future endeavors.	5	9	0	19	17	3.76	1.11	0.005	Significant; preparation for future is adequate.
25	Students view online education as effective compared to traditional methods.	6	10	0	18	16	3.74	1.11	0.006	Significant; effectiveness comparable to traditional methods.

These insights align with Ahmad *et al*. (2023), who emphasized that instructor presence and timely feedback are critical for student satisfaction in online environments. The moderate scores on assessment and educator support call for robust professional development and clearer evaluation rubrics.

Synthesis and Limitations

Across all five objectives, the results collectively affirm that online chemistry education in Nigeria offers significant opportunities, especially for inclusivity and access, but still faces major challenges in engagement, practical application, and pedagogical innovation. While emerging technologies are well-received, systemic issues such as internet infrastructure and teacher training must be addressed for sustainable improvement.

This study is limited by its reliance on self-reported data, which may be subject to bias. Additionally, the sample size was limited to one college of education, potentially reducing generalizability. Future research should expand to multiple institutions and incorporate qualitative interviews to capture deeper insights.

4.0 Conclusion

This study assessed the opportunities and challenges of online chemistry education at F.U.E. Zaria. It concludes that while online chemistry education offers immense potential—especially in terms of flexibility, inclusivity, and personalized learning—it is still limited by infrastructural, pedagogical, and engagement-related challenges.

Both hypotheses were validated:

- **Hypothesis 1 (Ho_1)**: Online chemistry education presents both opportunities and challenges.
- **Hypothesis 2 (Ho_2)**: The effectiveness of online chemistry education is significantly influenced by the use of pedagogical strategies and technology.

The findings align with global and regional research indicating that **online science education must address the gap in practical learning and instructor interaction** to achieve parity with face-to-face instruction.

5.0 Recommendations

Based on the findings, the following recommendations are proposed:

1. **Improve Virtual Laboratory Access**: Institutions should invest in virtual lab software and simulations to replicate the hands-on experience in chemistry learning.
2. **Strengthen Instructor Training**: Educators should receive regular training on effective online teaching strategies, student engagement methods, and use of interactive tools.
3. **Enhance Technological Infrastructure**: The school should ensure stable internet, learning platforms, and devices are available and accessible to both staff and students.
4. **Integrate Collaborative Learning**: Online chemistry courses should encourage group discussions, peer reviews, and real-time collaboration to improve engagement.
5. **Supportive Learning Environment**: Academic support systems (tutoring, online office hours, feedback mechanisms) should be strengthened to assist students.
6. **Blended Learning Approaches**: A hybrid model combining online learning with periodic face-to-face sessions could balance flexibility with practical exposure.
7. **Policy and Curriculum Development**: National education bodies should formulate policies to support the integration of online chemistry education with adequate funding.

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Declaration

Consent for publication

Not applicable

Availability of data

Data shall be made available on demand.

Competing interests

The authors declared no conflict of interest

Ethical Consideration

Not applicable

Funding

There is no source of external funding.

Authors' Contribution

All components of this manuscript were developed by the authors