

# ASSESSMENT OF THE IMPACT OF FLIPPED CLASSROOM MODEL IN DIGITAL EDUCATION ON SCIENCE TEACHERS' PEDAGOGICAL TRANSFORMATION AND SUSTAINABILITY IN ODeL IN KADUNA STATE

Roseline EGBUNU<sup>1</sup>, Omobolanle Arike FATUSI<sup>2</sup>, Cornelius Ekene ODOH<sup>3</sup> & Tasiu AMINU<sup>4</sup>

<sup>1</sup>National Open University of Nigeria

[regbunu@noun.edu.ng](mailto:regbunu@noun.edu.ng)

<sup>2</sup>National Open University of Nigeria

[afatusi@noun.edu.ng](mailto:afatusi@noun.edu.ng)

<sup>3</sup>National Open University of Nigeria

[codoh@noun.edu.ng](mailto:codoh@noun.edu.ng)

<sup>4</sup>Kaduna State College of Education, Gidan Waya

[mtasiu19@gmail.com](mailto:mtasiu19@gmail.com)

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## ABSTRACT

This study assessed the impact of the flipped classroom model in digital education on science teachers' pedagogical transformation and sustainability in open and distance learning (ODL) in Kaduna State, Nigeria. The study adopted a descriptive survey design, with a population of 406 science teachers drawn from the National Open University of Nigeria (NOUN), Kaduna Study Centre, Kaduna Polytechnic, and Ahmadu Bello University Distance Learning Centre. Using the Taro Yamane formula, a sample of 201 teachers was selected, and data were collected through a 15-item structured questionnaire. Out of the administered copies, 187 were validly returned and analyzed using descriptive statistics. Findings revealed that flipped digital education significantly enhanced teachers' ability to design interactive lessons, improved their teaching skills, and fostered students' engagement and motivation. However, the study identified challenges such as inadequate digital infrastructure, low digital literacy, insufficient funding, limited technical support, and irregular training opportunities. To sustain flipped digital education, strategies such as regular professional development, investment in robust digital infrastructure, institutional collaborations with technology firms, and consistent monitoring and evaluation were proposed. The study concluded that flipped digital education positively transforms science teachers' pedagogical practices and contributes to sustainable ODL delivery. It recommended continuous capacity building and policy support to address infrastructural and training gaps and ensure effective integration of digital innovations in science education.

**Keywords:** Open and distance learning, flipped digital education, science teachers, transformation, and sustainability

## Introduction

Teaching and learning have been completely transformed by digital education, especially when it comes to open and remote learning. To successfully incorporate digital resources into their teaching approaches, science instructors in particular need specific training. The creative application of technology to improve instruction and learning is known as digital education. Alenezi et al. (2023) define digital education as the innovative use of digital resources in the classroom. Digital integration, according to Demissie et al. (2022), includes multimedia information, internet-based resources, hardware, and software that are smoothly included into instructional procedures. Digital education has the potential to accelerate the achievement of Sustainable Development Goal 4 (SDG 4) for education and change the ways that universal access to education is provided, according to UNESCO (2024).

Science teachers, however, play a crucial role in shaping the minds of future scientists and innovators through the application of relevant digital educational tools. Science teachers are educators who specialize in teaching science subjects, such as physics, chemistry, biology, and mathematics. According to Ajeyalemi et al. (2021), science teachers are individuals who teach science. Science teachers in Nigeria are prepared mostly from colleges of education, institutes of education, and faculties of education from different universities. However, achieving the goals and objectives of science education requires experienced and highly scientifically literate teachers.

Science teachers require specialized training to effectively integrate digital tools into their teaching practices, particularly in open and distance learning programmes. Open and distance learning (ODL) has emerged as a key solution to making education more accessible, flexible, and inclusive. Transformation and sustainability of open and distance learning stem from its potential to break barriers related to time, space, and the pace of learning. The United Nations Educational, Scientific, and Cultural Organization UNESCO (2023) revealed that open and distance learning (ODL) can mitigate the effects of education disruption and school closures, particularly in times of crises. The National Open University of Nigeria (NOUN) has been a pioneer in transforming and sustaining open and distance learning (ODL) in Nigeria, with its Kaduna study center being a notable example.

NOUN's ODL model has enabled students to access quality education remotely, leveraging technology to bridge geographical and time barriers. The university's instructional delivery system combines printed materials, audio-video content, and online resources, providing students with flexible learning options. For example, the sustainability of ODL in Kaduna is further enhanced by NOUN's commitment to developing institutional and professional capacity. The Regional Training and Research Institute for Distance and Open Learning (RETRIDOL), supported by the Commonwealth of Learning, offers postgraduate programs in ODL, equipping professionals with the necessary skills to manage and deliver ODL programs effectively. This initiative has contributed significantly to promoting ODL in Nigeria and ensuring its sustainability.

Meanwhile, the transformation and sustainability of open and distance learning (ODL) have been significantly influenced by technological advancements and innovative pedagogies, and teachers' professional development. In terms of pedagogical practices, science teachers require

technological proficiency to effectively integrate digital tools into their teaching practices. This necessitates interaction between how a subject is taught (pedagogy), substantive understanding of what is being taught, and the tools used (technology) in order to be effective (Samson et al., 2021). Also, Ogegbo (2023) averred that teachers, including science teachers, are expected to be technologically savvy in order to meet the demands and expectations of modern students in a digitized and changing society. Additionally, technological pedagogical content knowledge is essential for the online teaching success of science teachers. This involves the integration of technology, pedagogy, and content knowledge.

Flipped digital education is one of the numerous types of digital education for science teachers. Flipped digital education is a pedagogical approach that reverses the traditional lecture-homework format. In Flipped digital education, students engage with instructional content at home while the class time is used for interactive, collaborative, and hands-on activities. Flipped digital education allows teachers to create high-quality content, such as video lectures, podcasts, or online resources, for students to access at home, freeing up class time for more interactive and engaging activities (UNESCO, 2023).

Science teachers must consistently integrate this digital technology into their teaching practices (Oyekunle et al, 2024; Yildiz, 2022; Greenhow et al., 2022). This is because integration of digital technology such as flipped digital education is pivotal for effective transformation and sustainability of open and distance learning, Also, the flipped digital education enables teachers to adopt innovative teaching methods, such as virtual labs, augmented reality simulations, and video demonstrations, to substitute or augment traditional hands-on training (Yildiz, 2022; Greenhow, et al., 2022). Digital education allows for personalized learning approaches, enabling science teachers to cater to individual students' needs and preferences

Furthermore, the transformation and sustainability of open and distance learning lie in science teachers' professional development. Professional competence requires having qualified knowledge and being able to keep up with changes in science and technological developments. Changes in science and technology have significantly impacted teacher professionalism in carrying out teaching and learning. The digital era has been used to manage educational institutions for both teaching and administrative activities. Digital transformation has influenced pedagogy and the method of instructional delivery (Zain, 2021). Teacher capacity development programs are very important in improving the quality of instruction, particularly when using and creating Open Education Resources (OERs) for teaching and learning. Teachers who participate in open and distance learning must undergo training to gain the skills necessary to adapt to rapidly changing technologies and teaching practices (Mirete et al., 2020). Research shows that schools with consistent digital training initiatives see greater teacher readiness for digital integration compared to those without such opportunities (Baser et al., 2021; Pareigis et al., 2024). Professional development programs enhance science teachers' ability to create a transformative and sustainable open and distance learning.

However, there are challenges associated with digital education, affecting the transformation and sustainability of open and distance learning. These barriers include low digital

literacy, even among science teachers, insufficient evaluation of teachers' and students' digital competencies, and outdated curricula that fail to adapt to new tools (Nwachukwu et al., 2020). Inadequate infrastructure, including internet connectivity and digital devices, can hinder the effective implementation of digital education in open and distance learning (Irele, 2022). Limited access to digital resources and tools can exacerbate existing inequalities in education. These issues contribute to what Bonilla-Molina (2020) calls a "Global Pedagogical Blackout," characterized by inadequate investment in digital technologies and a reduced emphasis on pedagogical innovation.

Many teachers are unfamiliar with digital tools; they often prefer traditional methods, feel less in control, and are hesitant to explore new instructional strategies (Waheed et al., 2020). Many science teachers also lack confidence in using digital education technological tools, as they were educated in environments without access to technology (Oyekunle et al., 2024). Constant technological advancements, however, require ongoing professional development to keep educators, including science teachers, updated (Demissie et al., 2022). Without reliable digital infrastructure, the transformation and sustainability of open and distance learning are unfeasible. It is against this background that this study assessed the impact of flipped digital education on science teachers' transformation and sustainability in open and distance learning in Kaduna, with reference to science teachers in three educational tertiary institutions offering open and distance learning in Kaduna state.

### **Statement of the Problem**

The rapid evolution of digital technology has transformed traditional pedagogical approaches, leading to innovative models such as the flipped classroom in digital education. This transformation has become particularly crucial in open and distance learning (ODL) contexts, where teaching and learning rely heavily on digital tools and platforms. In Nigeria, institutions such as the National Open University of Nigeria (NOUN) have championed the use of ODL to democratize access to education. However, despite the significant progress made, the full integration of digital innovations such as the flipped classroom model remains limited by infrastructural, pedagogical, and professional development challenges. Science teachers occupy a central position in ensuring the successful implementation of ODL because of the practical and interactive nature of science education. Effective teaching in this field requires not only mastery of scientific content but also the ability to use digital tools to design interactive lessons and engage students meaningfully. The flipped classroom model where instructional content is delivered through digital media outside the classroom while in-class sessions focus on active learning offers a viable strategy for achieving these goals. Yet, in Kaduna State, evidence suggests that science teachers face multiple constraints in adopting flipped digital education. These include inadequate digital infrastructure, limited technical support, insufficient digital literacy, poor funding, and irregular training opportunities.

Given these gaps, there is a pressing need to empirically assess how the flipped classroom model in digital education influences science teachers' pedagogical transformation and the sustainability of ODL delivery in Kaduna State. The study, therefore, examines the extent to which flipped digital education enhances teachers' instructional competence, promotes interactive

learning, and contributes to sustainable teaching practices in ODL environments. Furthermore, it identifies the challenges that hinder the effective use of flipped digital education and proposes strategic interventions such as regular professional development, infrastructural investment, institutional collaborations, and systematic evaluation frameworks.

To address these issues, the Nigerian government introduced policies like the National Digital Learning Policy, which aims to leverage digital technology to enhance teaching and learning. Yet infrastructural deficit still remains a critical challenge and teacher training. This problem thus necessitated this study on the assessment of flipped digital education on science teachers' transformation and sustainability in open and distance learning in Kaduna.

### **Objectives of the Study**

The specific objectives the study sought to achieve were to:

1. determine the impact of flipped digital education on science teachers for transformation and sustainability in open and distance learning in Kaduna.
2. examine the challenges of sustaining flipped digital education for science teachers in open and distance learning in Kaduna.
3. determine the intervention strategies for sustaining flipped digital education for science teachers in open and distance learning in Kaduna

### **Research Questions**

The following research questions were answered in the study:

1. What is the impact of flipped digital education on science teachers for transformation and sustainability in open and distance learning in Kaduna?
2. What are the challenges of sustaining flipped digital education for science teachers in open and distance learning in Kaduna?
3. What are the intervention strategies for sustaining flipped digital education for science teachers in open and distance learning in Kaduna?

### **Theoretical Framework**

This study is anchored on Technological Pedagogical Content Knowledge (TPACK) Theory developed by Mishra and Koehler (2006). The theory provides a conceptual basis for understanding how the flipped classroom model facilitates science teachers' pedagogical transformation and sustainability within the framework of open and distance learning (ODL). The TPACK framework emphasizes the intersection of three key knowledge domains essential for effective digital pedagogy: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). The integration of these domains forms a dynamic knowledge system that allows teachers to effectively design, implement, and sustain digital-based instruction. In the context of this study, the TPACK theory explains how science teachers' ability to combine technology (flipped digital tools such as video lessons, virtual labs, and online discussion platforms), pedagogy (interactive and student-centered approaches), and content (science-specific concepts) leads to pedagogical transformation. The flipped classroom model represents an innovative pedagogical application of TPACK, where teachers shift from traditional direct instruction to active, technology-enhanced facilitation. This shift enhances teachers' digital

literacy, creativity, and capacity for differentiated instruction, key indicators of transformation and sustainability in ODL environments.

The TPACK framework aligns with the first objective of this study, which seeks to determine the impact of flipped digital education on science teachers' transformation and sustainability. It supports the idea that effective digital teaching depends not only on technological skills but on the seamless integration of pedagogy and content knowledge, fostering long-term sustainability in ODL delivery.

### **Methodology**

The study employed a descriptive survey research design. A descriptive research design is suitable for this study because it allows for the collection and analysis of data to describe the current state of digital education among science teachers. The population of the study consisted of 406 science teachers in the National Open University of Nigeria (NOUN), Kaduna Study Centre, Kaduna Polytechnic, and Ahmadu Bello University Distance Learning Centre (DLC), Kaduna. Using the Taro Yamane formula, a sample size of 201 science teachers was determined. The sample size is representative of the population, ensuring that the findings can be generalized to the larger population of science teachers in Kaduna. A fifteen (15) items closed-ended questionnaire was used to collect data from the science teachers. The questionnaire was designed to gather information on science teachers' perceptions of digital education, its impact on their teaching practices, the challenges they face in implementing it, and the intervention strategies to sustain digital education for science teachers. Content validity was used. Test-retest method of reliability was used to obtain the internal consistency. The reliability was tested in clusters, which yielded a total reliability index of 0.98, obtained using Cronbach's alpha. The collected data were analyzed using descriptive statistics, such as mean and standard deviation, to describe the current state of digital education among science teachers in Kaduna. The findings of this study will provide insights into the transformation and sustainability of digital education among science teachers in ODL in Kaduna. Out of the 201 questionnaires administered, 187 were returned valid, representing a 93% success rate. The analyses of data were carried out based on the specific objectives and research questions of the study.

Every step of this study's methodology was presented to ensure there was no unethical measure. All participating schools were properly informed of the study's purpose without withholding any information. The possibility that teachers participating in the study will miss any classes on the school timetable schedule. However, the make-up plan for such a loss following the distribution of the questionnaire was also discussed. teachers' permission to serve as research assistants was sought, and it was clearly stated that their confidentiality would be protected and they would remain anonymous. Aside from the preceding, no respondents were biologically and psychologically harmed or assaulted during the research.

**Results**

**Research Question One:** What is the impact of flipped digital education on science teachers for transformation and sustainability in open and distance learning in Kaduna?

**Table 1: Impact of flipped digital education on science teachers for transformation and sustainability in open and distance learning in Kaduna**

		n =187						
S/n	Items	SA	A	D	SD	Mean	SD	Decision
		4	3	2	1			
1.	Flipped digital education has enhanced my ability to design engaging and interactive science lessons	168	13	3	3	3.85	.50	Agreed
2.	I am confident in my ability to effectively integrate digital technologies into my science teaching	146	36	3	2	3.74	.54	Agreed
3.	My flipped digital education knowledge has improved my teaching skills.	169	11	5	2	3.86	.49	Agreed
4.	flipped digital education will continue to play a significant role in my teaching practices in the long term	164	17	3	3	3.83	.52	Agreed
5.	Digital education has increased student engagement and motivation in my science classes.	162	10	10	5	3.76	.67	Agreed
<b>Average mean</b>						<b>3.81</b>	<b>.54</b>	<b>Agreed</b>

Source: SPSS version, 23

Table 1 responses showed that flipped digital education has enhanced science teachers’ ability to design engaging and interactive science lessons. They have the ability to effectively integrate digital technologies into science teaching. Additionally, science teachers’ flipped digital education knowledge has improved their teaching skills, increased student engagement and motivation in their science classes, and flipped digital education will continue to play a significant role in science teachers’ teaching practices in the long term. These conclusions were reached because the average mean = 3.81 > 2.50, upon which decision is reached, implying that digital education has positively impacted science teachers for transformation and sustainability in open and distance learning in Kaduna responses.

**Research Question Two:** What are the challenges of sustaining flipped digital education for science teachers in open and distance learning in Kaduna?

**Table 2: Challenges of sustaining flipped digital education for science teachers in open and distance learning in Kaduna**

		n =187						
S/n	Items	SA	A	D	SD	Mean	SD	Decision
		4	3	2	1			
6.	Inadequate digital infrastructure is a challenge to supporting science teachers in ODL	160	6	8	13	3.67	.85	Agreed
7.	There is insufficient technical support to effectively integrate flipped digital technologies in ODL	149	7	23	8	3.59	.86	Agreed
8.	Many science teachers do not possess the necessary digital literacy skills to sustain flipped digital education in ODL.	166	8	5	8	3.78	.69	Agreed
9.	There is insufficient funding to support the sustainability of flipped digital education for science teachers in ODL	67	3	87	30	2.57	1.13	Agreed
10.	There are irregular training and development opportunities to enhance science teachers' skills in using digital technologies for ODL	162	3	19	3	3.73	.70	Agreed
<b>Average mean</b>						<b>3.67</b>	<b>.85</b>	<b>Agreed</b>

**Source:** SPSS version, 23

Table 2 responses showed that challenges of sustaining flipped digital education for science teachers in open and distance learning in Kaduna range from inadequate digital infrastructure, insufficient technical support, digital illiteracy among science teachers, insufficient funding, to irregular training and development opportunities to enhance science teachers' skills in using flipped digital technologies for ODL. These conclusions were reached because the average mean responses stood at  $3.67 > 2.50$ , upon which decision was reached.

**Research Question Three:** What are the intervention strategies for sustaining flipped digital education for science teachers in open and distance learning in Kaduna?

**Table 3: Intervention strategies for sustaining flipped digital education for science teachers in open and distance learning in Kaduna**

S/n	Items	n =187				Mean	SD	Decision
		SA 4	A 3	D 2	SD 1			
11.	Regular training and technical support for science teachers would help sustain flipped digital education in ODL	160	6	8	13	3.79	.58	Agreed
12.	Investing in robust digital infrastructure would significantly enhance the sustainability of flipped digital education for science teachers	149	7	23	8	3.75	.70	Agreed
13.	Collaborations between institutions and technology companies would provide the necessary resources and expertise to sustain flipped digital education.	166	8	5	8	3.90	.44	Agreed
14.	Offering incentives and recognition to science teachers who effectively integrate digital technologies would motivate them to sustain flipped digital education.	67	3	87	30	3.65	.76	Agreed
15.	Regular monitoring and evaluation of digital education programs would help identify areas for improvement and ensure sustainability.	162	3	19	3	3.77	.60	Agreed
<b>Average mean</b>						<b>3.77</b>	<b>.62</b>	<b>Agreed</b>

Source: SPSS version, 23

Table 3 responses showed that intervention strategies for sustaining flipped digital education for science teachers in open and distance learning in Kaduna ranges from regular training and technical

support for science teachers to, investing in robust digital infrastructure, collaborations between institutions and technology companies, offering of incentives and recognition to science teachers who effectively integrate digital technologies and regular monitoring and evaluation of digital education programs. These conclusions were reached because the average mean responses stood at  $3.77 > 2.50$ , upon which decision was reached.

### **Discussion of Major Findings**

The study set out to assess the impact of the flipped classroom model in digital education on science teachers' pedagogical transformation and sustainability in open and distance learning (ODL) environments in Kaduna State. The major findings revealed that flipped digital education significantly enhanced science teachers' pedagogical competencies, improved student engagement, and contributed to the sustainability of ODL practices. These findings are discussed below in relation to the study's research questions and the reviewed literature.

The results indicated that the flipped digital education model enhanced science teachers' abilities to design engaging, learner-centered, and interactive lessons. Teachers also reported improved confidence in integrating digital technologies into their science instruction, suggesting a substantial shift in pedagogical orientation from traditional to technology-mediated practices. This finding aligns with Zain (2021), who emphasized that digital transformation reshapes instructional delivery and pedagogy by encouraging interactive, student-driven learning experiences. Similarly, Oyekunle, Gbenga-Julius, and Adeeko (2024) and Yildiz (2022) affirmed that continuous integration of digital technology, including flipped learning, fosters effective transformation and ensures long-term sustainability in ODL systems.

The finding that flipped digital education promotes student motivation and engagement corroborates Greenhow, Graham, and Koehler (2022), who argued that interactive and technology-supported classrooms enhance active learning and cognitive participation. In the context of Kaduna's ODL institutions, this implies that adopting flipped learning strategies not only improves teaching practices but also strengthens learner autonomy and participation, key elements of sustainable distance education.

The study further revealed persistent challenges that hinder the effective and sustainable implementation of flipped digital education among science teachers. These include inadequate digital infrastructure, insufficient technical support, low digital literacy among teachers, limited funding, and irregular professional development opportunities. These barriers mirror the observations of Nwachukwu, Johnson, and Amadi (2020), who identified limited digital competence and outdated curricula as critical impediments to educational technology integration. Likewise, Irele (2022) highlighted infrastructural deficits and poor internet access as significant constraints within Nigeria's digital education landscape.

The implication of these findings is that despite the pedagogical potential of flipped digital education, its sustainability in ODL contexts depends largely on systemic and institutional support. Without adequate infrastructure, funding, and ongoing training, the capacity of science teachers to

maintain digital transformation remains limited. The findings thus emphasize the need for holistic strategies that address both technological and human capacity factors within ODL systems.

Findings from the third research question revealed that regular professional development, robust digital infrastructure, institutional collaborations, incentive systems, and consistent monitoring are crucial for sustaining flipped digital education. This aligns with Demissie, Labiso, and Thuo (2022), who underscored the necessity of structured professional training and institutional investment in digital integration for educational transformation. The identified strategies in this study, such as partnerships between ODL institutions and technology firms, reflect UNESCO's (2024) recommendation that effective digital learning systems require continuous teacher capacity building and strong institutional frameworks.

Furthermore, the inclusion of teacher incentives and recognition programs underscores the motivational aspect of sustaining innovation in teaching practice. By rewarding effective integration of digital tools, institutions can encourage a culture of digital adaptability and lifelong learning among educators. Regular monitoring and evaluation also ensure that feedback mechanisms are embedded in ODL systems to identify gaps, improve implementation, and ensure sustainability.

## **Conclusion**

Transformation and sustainability of open and distance learning (ODL) are significantly influenced by technological advancements and innovative pedagogies. Science teachers' professional development is essential for technical knowledge about the integration of digital tools into their teaching practices. However, drawing from the findings of the study, it was concluded that flipped digital education has a positive impact on science teachers for transformation and sustainability in open and distance learning in Kaduna. Challenges of inadequate digital infrastructure, digital illiteracy among science teachers, and insufficient funding are obvious. Investment in robust digital infrastructure is essential for effective science teachers' transformation and sustainability of open and distance learning.

## **Recommendations**

The following recommendations were proposed:

1. ODL institutions should organise regular training and technical support for science teachers to help sustain flipped digital education in ODL
2. ODL authorities and the government should invest in robust digital infrastructure to enhance the sustainability of flipped digital education for science teachers
3. There should be collaborations between institutions and technology companies to provide the necessary resources and expertise to sustain flipped digital education in ODL

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