



Transforming pedagogical practices: The ... Yaki, A.A. Et. al., (2025)

Transforming Pedagogical Practices: The Impact of a Connected Learning for STEM Intervention on Science and Mathematics Teachers in Northern Nigeria

¹YAKI, A. A., ²ADAMU, H., ³SADIQ, O. K. & ⁴MUSTAPHA, M. T.

Corresponding Author: yaki.aa@futminna.edu.ng +2347067074366

^{1&3}Department of Science Education, Federal University of Technology, Minna, Niger State

²Department of Mathematics/Statistics, Niger State Polytechnic, Zungeru, Nigeria

⁴Ibrahim Badamosi Babangida University Lapai, Niger State, Nigeria

Abstract

The purpose of this study is to explore the impact of the Connected Learning for Capacity Building initiative on the pedagogical practices of secondary school science and mathematics teachers in Northern Nigeria. It specifically examines how participation in the programme impacted teachers' understanding and implementation of equitable, inclusive, and learner-centered instructional strategies. The study adopted a qualitative descriptive research design. Data were collected through semi-structured interviews with a purposive sample of 20 novice teachers across three phases, namely baseline, midline, and endline. The data were analyzed thematically to trace the evolution of teachers' pedagogical conceptions and practices, particularly in relation to equity and inclusion. The findings indicate a substantial transformation in teachers' pedagogical orientations and classroom practices. Participants demonstrated an expanded understanding of equity and inclusion, moving beyond academic ability to consider gender, socioeconomic background, and geographical disparities. Furthermore, teachers increasingly applied principles of Universal Design for Learning (UDL) by integrating diverse instructional strategies such as the use of local materials, multimedia resources, and collaborative learning activities to accommodate varied learner needs and contexts. This study provides empirical insights into how a connected learning framework that incorporates Open Educational Resources (OER) and a mobile-based Community of Practice (CoP) can foster pedagogical innovation in resource-limited settings. It highlights the potential of connected learning as a sustainable model for teacher professional development and as a means to promote equitable quality education in alignment with Sustainable Development Goal 4.

Keywords: teacher professional development, connected learning, equity and inclusion, Universal Design for Learning (UDL), pedagogical content knowledge, Sub-Saharan Africa, STEM education

Introduction

The world has evolved from an industrial-based economy to a knowledge-based economy, which has impacted the process of education. Specifically, STEM education has become a cornerstone of 21st-century learning, requiring teachers to acquire advanced pedagogical and technological competencies to deliver meaningful classroom experiences. This will raise manpower that will add value to the knowledge-based economy of the 21st-century. However, many teachers in developing contexts still rely on traditional, teacher-centered practices that limit student engagement and critical thinking. The pursuit of inclusive and equitable quality education, which forms a cornerstone of the United Nations Sustainable Development Goal 4 (SDG 4), continues to pose significant challenges across the globe (United Nations, 2015). In Northern Nigeria, this challenge is intensified by constraints such as limited resources, overcrowded classrooms, and high levels of student diversity. These factors often leave teachers insufficiently prepared to address the varied learning needs within their classrooms (Yaki et al., 2019). One of the critical barriers to achieving inclusive Science, Technology, Engineering, and Mathematics (STEM) education lies in the limited capacity of teachers to design and implement instructional practices that accommodate learners with diverse academic abilities, gender identities, socioeconomic backgrounds, and geographical contexts (Nguyen et al., 2020).



Transforming pedagogical practices: The ... Yaki, A.A. Et. al., (2025)

In response to these challenges, the Connected Learning for STEM (CL4STEM) project was developed as an innovative professional development initiative aimed at strengthening teachers' pedagogical content knowledge (PCK) and their capacity to promote higher-order thinking with inclusion and equity (HOTIE). The project is anchored in the theoretical principles of Universal Design for Learning (UDL), which advocates for the proactive creation of flexible and accessible learning environments that minimize barriers and respond to the diverse needs of all learners (Meyer et al., 2014). Within the CL4STEM framework, these principles are operationalized through the use of curated Open Educational Resources (OER) and a mobile-based Community of Practice (CoP). Together, these components foster a continuous, collaborative, and contextually relevant professional learning experience for teachers.

The UDL framework is structured around three central principles: providing multiple means of engagement, representation, and action and expression. These principles offer a comprehensive approach to designing inclusive and responsive classroom practices (Meyer et al., 2014). Although studies in other African contexts, such as Kenya, have highlighted the benefits of UDL in addressing learner diversity (Elder et al., 2016), limited evidence exists regarding its integration within large-scale, technology-supported professional development initiatives in West Africa. This study therefore, seeks to address this gap by exploring the impact of the CL4STEM project on the pedagogical practices of science and mathematics teachers in Northern Nigeria.

Statement of the Problem

The goal of STEM education is to make learning "real" by equipping students with essential 21st-century skills, including critical thinking, problem-solving, digital literacy, and collaboration, thereby preparing them to tackle complex, real-world challenges (Partnership for 21st Century Skills, 2019). Despite this recognized importance, a persistent gap exists between the goals of STEM education and its effective implementation in classrooms. A key barrier is the varying capacity of teachers, who may lack sufficient training, resources, and support to adopt innovative, student-centred pedagogies (Darling-Hammond et al., 2017). This is particularly acute in under-resourced settings, where teachers often face isolation and limited access to professional learning communities. The Connected Learning for Teacher Capacity Building in STEM (CL4STEM) project emerges as a direct response to this challenge. CL4STEM aims to empower high school teachers and their students through engaging, interactive, and hands-on learning experiences, fostering the knowledge, skills, and values needed for success in the 21st century. Rooted in constructivist and transformative teaching principles, which emphasize that knowledge is built through experience, critical reflection, and collaboration (Mezirow, 1991; Vygotsky, 1978)

Objectives of the Study

This study explores the following research objectives in three Northern Nigerian states:

1. To explore the impact of CL4STEM capacity-building innovation on science and mathematics teachers' practices toward equity and inclusive instruction.
2. To explore science and mathematics teachers' experiences of participating in the CL4STEM project modules and community of practice toward promoting equity and inclusive instruction.

Research Question

The following research question guides the study:

1. What is the impact of the CL4STEM capacity-building innovation on science and mathematics teachers' understanding and implementation of equitable and inclusive pedagogical practices?



Transforming pedagogical practices: The ... Yaki, A.A. Et. al., (2025)

2. What are science and mathematics teachers' experiences of participating in the CL4STEM project modules toward promoting equity and inclusive instruction.

Literature Review

The importance of inclusive education is firmly established in global educational policy and research. UNESCO (2020) continues to emphasize the need for educators and policymakers to adopt inclusive instructional strategies that ensure meaningful learning opportunities for all students. Achieving this goal requires a departure from one-size-fits-all teaching approaches toward pedagogical practices that recognize and respond to learner diversity and variability (Meyer et al., 2014).

Universal Design for Learning (UDL) has emerged as a prominent framework to guide this pedagogical transformation. Drawing inspiration from the concept of universal design in architecture, UDL advocates for the intentional development of flexible learning environments that accommodate a wide range of learner needs from the outset (Meyer et al., 2014). Empirical evidence supports its effectiveness in enhancing student engagement and achievement across diverse educational settings. For example, Elder et al. (2016) reported that the implementation of UDL-based strategies in Kenyan primary schools enabled teachers to better address the varied learning needs of their students. Likewise, Yaki et al. (2019) observed that applying UDL principles within STEM instruction helped to reduce achievement disparities among students with differing academic abilities in biology classrooms.

Translating frameworks such as UDL into classroom practice, however, requires effective teacher professional development (TPD). Conventional one-off workshops have often proven insufficient in producing sustained pedagogical change (Blanton et al., 2018). Contemporary professional development models, therefore, emphasize the need for continuous support, collaboration, and contextual relevance. Communities of Practice (CoPs) provide a valuable platform for shared learning, reflection, and problem-solving among teachers, enabling them to collaboratively develop strategies for addressing learner diversity (Blanton et al., 2018). When such collaborative learning structures are integrated with accessible digital resources such as Open Educational Resources (OER) and supported through mobile technologies for scalability, as demonstrated in the CL4STEM model, they hold significant potential to transform teaching practices and advance inclusive education in resource-constrained contexts.

Research Methodology

This study adopted a qualitative research design to obtain a rich and detailed understanding of the changes in teachers' pedagogical perceptions and practices over time. A descriptive longitudinal approach was employed, with data collected through semi-structured interviews at three key stages of the intervention: baseline (pre-intervention), midline (during intervention), and endline (post-intervention). This design allowed for an in-depth exploration of how teachers' pedagogical conceptions evolved as they engaged with the connected learning initiative.

Participants and Sampling

The study was conducted across three states in Northern Nigeria, namely Niger, Kaduna, and Kano. The target population comprised secondary school science and mathematics teachers. Using purposive sampling, 20 teachers specializing in Biology, Chemistry, Physics, and Mathematics were selected from a larger intervention cohort of 80 participants. The selection criteria included: (1) being a novice teacher with limited prior professional development experience, and (2) possessing a functional Android smartphone to enable participation in the mobile-based components of the



Transforming pedagogical practices: The ... Yaki, A.A. Et. al., (2025)

program. This ensured that participants were both representative of early-career teachers and equipped to engage with the digital learning environment.

The CL4STEM Intervention

The Connected Learning for STEM (CL4STEM) intervention was designed as a sustained capacity-building program aimed at enhancing teachers' pedagogical content knowledge and their ability to apply inclusive and equitable instructional practices. Participants engaged with specially curated Open Educational Resources (OER) structured around the principles of Universal Design for Learning (UDL). In addition, a mobile-based Community of Practice (CoP) was established using the Telegram application to facilitate ongoing interaction among teachers and expert educators. Through this platform, participants shared lesson plans, teaching videos, and reflective experiences, thereby promoting collaborative learning, peer support, and contextualized professional growth.

Data Collection

Qualitative data were gathered through semi-structured interviews and classroom observations conducted at the baseline, midline, and endline stages of the intervention. The interview protocols were developed based on constructs of subject matter knowledge, pedagogical content knowledge, and inclusive instructional planning. Supplementary data were obtained from teacher educators' module reports to triangulate findings. Classroom observations were conducted using a non-participant observation approach, with detailed field notes recorded throughout the process (Maxwell, 2013). Transcripts were anonymized and labeled using teacher identification codes (e.g., 3101, 3103, 3104). Observational data captured classroom dynamics, including indicators such as students' engagement in collaborative learning activities and teachers' use of inclusive instructional strategies.

Data Analysis

Thematic analysis was employed to examine the qualitative data following Braun and Clarke's (2006) six-step framework: familiarization with the data, generating initial codes, identifying themes, reviewing themes, defining and naming themes, and producing the final analysis. The data were organized around two overarching research questions, from which four major themes emerged: (1) Understanding of Equity and Inclusion, (2) Planning for Equitable and Inclusive Instruction, (3) Teacher Inclusive Practices, and (4) Teachers' Experiences and Perceived Impact. Changes in the frequency of thematic codes were tracked across phases to identify patterns of growth (for example, understanding of inclusion increased from 15% at baseline to 50% at endline based on participant responses).

Discussion

The analysis identified two central themes illustrating the transformative impact of the CL4STEM project on teachers' pedagogical approaches.

Evolving Conceptions of Equity and Inclusion

At the baseline, teachers' understanding of learner diversity was largely monolithic, centring almost exclusively on academic ability, often described in binary terms of "slow" versus "fast" learners.

- i. Baseline Exemplar:** "In the class we have students with different learning ability, we have students with slow learning ability, and students with fast learning ability" (Teacher 3101, Mathematics, Male).

Data from the midline and endline phases revealed a significant conceptual expansion. Teachers demonstrated a more nuanced understanding, identifying gender, socioeconomic status, family



Transforming pedagogical practices: The ... Yaki, A.A. Et. al., (2025)

background, and geographical location (rural vs. urban) as critical dimensions of diversity that necessitate equitable pedagogical responses.

ii. Midline/Endline Exemplars:

- a. "I realized that gender is very, very important to be considered in mathematics class." (Teacher 3101, Mathematics, Male, Midline).
- b. "Some of my students are very slow... those in the rural area face more difficulty, and students with poor backgrounds also." (Teacher 3702, Biology, Female, Midline).
- c. "The principle of universal design Learning helps me to guide students with different backgrounds." (Teacher 3305, Physics, Female, Midline).

Adoption of UDL-Aligned Instructional Practices

This broadened understanding was coupled with a marked shift in pedagogical practices, reflecting the core principles of UDL.

iii. Multiple Means of Representation: Teachers reported increasingly using varied instructional materials to enhance accessibility.

- a. **Teacher 3118 (Mathematics, Female, Endline):** "For some of the students, maths is abstract and difficult, but if you use the locally available materials and video as teaching aids... they will understand it."

iv. Multiple Means of Action & Expression (Collaborative Learning): Intentional, structured group work became a dominant strategy to engage diverse learners and leverage peer-supported learning.

- a. **Teacher 3702 (Biology, Female, Midline):** "I also group them... according to their capability... so that they'll be able to blend with each other."
- b. **Teacher 3503 (Chemistry, Male, Endline):** "Grouping students helps the low learners to learn from their peers."

Table 1: Summary of Thematic Shifts in Teacher Pedagogy

Thematic Category	Baseline Focus	Endline Focus	Illustrative Evidence
Conception of Equity	Primarily academic ability	Multifaceted (ability, gender, socioeconomic, geographical)	"students with poor background" (3702); "gender... to be considered" (3101)
Instructional Practice	Limited, ad-hoc strategies	Intentional use of UDL principles (multiple representations, collaborative learning)	"use... videos, real objects and group work" (3501); "principle of UDL" (3305, 3313)



Transforming pedagogical practices: The ... Yaki, A.A. Et. al., (2025)

Discussion

The findings of this study demonstrate a significant positive impact of the CL4STEM project on teachers' pedagogical mindsets and classroom practices. Two central themes emerged from the analysis, namely evolving conceptions of equity and inclusion, and the adoption of UDL-aligned instructional practices. These themes collectively illustrate a transformation in teachers' understanding and application of inclusive pedagogy. A major outcome of the project was the deepened understanding of equity and inclusion among participating teachers. At the baseline stage, teachers' perceptions of learner diversity were limited and primarily focused on differences in academic ability, often described in binary terms such as "slow" and "fast" learners. However, by the midline and endline stages, teachers demonstrated a broader and more nuanced understanding of learner diversity. They began to recognize gender, socioeconomic status, family background, and geographical location as important dimensions influencing learning outcomes. For example, teachers identified that students from rural areas or low-income families faced unique challenges that required equitable and differentiated instructional responses. This evolution in teachers' thinking represents a shift from a narrow academic perspective to a more holistic appreciation of learners' varied circumstances. Such change aligns with the position of UNESCO (2020), which calls for educators to acknowledge and address the full spectrum of learner diversity as a foundation for meaningful inclusion, as also supported by Nguyen et al. (2020).

This expanded conception of equity was accompanied by a notable transformation in teachers' instructional practices. Evidence from the endline phase revealed that participants actively integrated principles of Universal Design for Learning (UDL) into their classroom teaching. Teachers adopted multiple means of representation by incorporating a variety of instructional materials, including videos and locally available teaching materials or realia, to enhance content accessibility and engagement. They also applied multiple means of action and expression through structured collaborative learning activities, enabling students of varying abilities to learn together and support one another. These practices reflect the translation of theoretical understanding into concrete classroom strategies, demonstrating teachers' increasing capacity to design inclusive lessons that accommodate diverse learner needs. The adoption of these strategies aligns with UDL guidelines on engagement, representation, and action and expression (Meyer et al., 2014) and supports previous studies that have shown the effectiveness of UDL in improving teaching and learning outcomes across diverse educational contexts (Elder et al., 2016; Yaki et al., 2019).

Furthermore, the explicit mention of UDL by several teachers in their reflections suggests that they were not only applying inclusive teaching techniques but were also engaging metacognitively with the framework. This indicates a deeper level of professional growth, as teachers were able to connect practice with theory and make intentional pedagogical decisions based on inclusive principles.

The success of this pedagogical transformation can be attributed to the thoughtful design of the CL4STEM intervention. The combination of curated Open Educational Resources (OER) and a mobile-based Community of Practice (CoP) created a dynamic environment for continuous professional learning. The OER modules provided practical and contextually relevant instructional materials rooted in UDL principles, while the CoP offered opportunities for sustained collaboration, mentorship, and reflective dialogue among teachers and facilitators. This integration of structured content and ongoing peer support aligns with the findings of Blanton et al. (2018), who emphasised that effective teacher professional development should be continuous, collaborative, and contextually



Transforming pedagogical practices: The ... Yaki, A.A. Et. al., (2025)

grounded. The CL4STEM model, therefore, represents a scalable and context-sensitive approach to teacher capacity building that can effectively strengthen pedagogical competence and promote equitable, inclusive STEM education in resource-constrained settings.

Conclusion

This study concludes that the CL4STEM project effectively enhanced the capacity of science and mathematics teachers in Northern Nigeria to understand and implement equitable and inclusive pedagogical practices. The project's model, which integrates UDL-based OERs with a supportive, technology-facilitated Community of Practice, presents a viable and powerful approach to teacher professional development in resource-constrained environments.

Implications

The implications of this research are threefold: Educational policymakers in Nigeria and similar contexts should consider scaling and institutionalizing connected learning models like CL4STEM to achieve broader systemic impact on teaching quality and equity. Teacher training institutions should integrate UDL principles and community of practice models into both pre-service and in-service teacher education curricula. Future studies should employ mixed-methods or quasi-experimental designs to quantitatively measure the impact of these changed teaching practices on student learning outcomes and engagement in STEM subjects.

Acknowledgement

This work was supported by the Global Partnership for Education Knowledge and Innovation Exchange, a joint endeavor with the International Development Research Centre, Canada. The views expressed herein do not necessarily represent those of IDRC or its Board of Governors.

References

- Blanton, L. P., Pugach, M. C., & Boveda, M. (2018). Interrogating the intersections between general and special education in the history of teacher education reform. *Journal of Teacher Education*, 69(4), 354–366. <https://doi.org/10.1177/0022487118778539>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp063oa>
- Elder, B. C., Damiani, M. L., & Oswago, B. O. (2016). From attitudes to practice: Utilising inclusive teaching strategies in Kenyan primary schools. *International Journal of Inclusive Education*, 20(4), 413–434. <https://doi.org/10.1080/13603116.2015.1082648>
- Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). *Effective teacher professional development*. Learning Policy Institute.
- Meyer, A., Rose, D. H., & Gordon, D. (2014). *Universal Design for Learning: Theory and practice*. CAST Professional Publishing.
- Nguyen, T. P. L., Nguyen, T. H., & Tran, T. K. (2020). STEM education in secondary schools: Teachers' perspective towards sustainable development. *Sustainability*, 12(21), 8865. <https://doi.org/10.3390/su12218865>
- Partnership for 21st Century Skills. (2019). *Framework for 21st century learning*. http://static.battelleforkids.org/documents/p21/P21_Framework_Brief.pdf
- UNESCO. (2020). *Global Education Monitoring Report 2020: Inclusion and education: All means all*. United Nations Educational, Scientific and Cultural Organization.
- United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*. Resolution adopted by the General Assembly. A/RES/70/1.
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.



www.foefugusau.com.ng
des@fugusau.edu.ng

DOI: <https://doi.org/10.64348/zije.2025197>

Transforming pedagogical practices: The ... Yaki, A.A. Et. al., (2025)

Yaki, A. A., Saat, R. M., Sathasivam, R. V., & Hutkemri, Z. (2019). Enhancing science achievement utilising an integrated STEM approach. *Malaysian Journal of Learning and Instruction*, 16(1), 181-205. <https://doi.org/10.32890/mji2019.16.1.8>