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Mobile Digital Laboratories for Inclusive Science Learning: Bridging the Rural–Urban Divide in Ogbadibo LGA of Benue State, Nigeria

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Abstract

Access to quality science learning resources remains a persistent challenge in rural Nigerian schools, where limited laboratory infrastructure restricts students' ability to engage in hands-on experimentation and inquiry-based learning. This study examined the effectiveness of mobile digital laboratories as tools for inclusive science learning in bridging the rural–urban divide in the Ogbadibo Local Government Area of Benue State, Nigeria. Using a quasi-experimental design, 400 junior secondary school students participated in the study, comprising 200 in the experimental group and 200 in the control group. The Science Learning Achievement Test (SLAT) was used to collect data before and after the intervention. Descriptive and inferential statistics were employed to analyse students' performance. Findings revealed that students exposed to mobile digital laboratory experiences achieved significantly higher mean scores than those taught using conventional methods. The results highlight the potential of mobile digital technologies to democratise science education, foster inclusion, and promote equity in learning outcomes across geographical divides. The study recommends adopting mobile digital laboratories as an innovative instructional model for improving science learning in underserved areas of Nigeria.

Keywords: Mobile digital laboratories, Inclusive science learning, Rural–urban divide, Quasi-experimental design, Ogbadibo L.G.A

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Introduction

Science education remains central to national development, particularly in a rapidly advancing technological world. In Nigeria, the quality of science learning has continued to generate concern due to unequal access to instructional resources and poor laboratory engagement, especially in rural areas (Achuonye, 2021). Despite the inclusion of science and technology education in the national curriculum, disparities persist between rural and urban schools, with rural learners frequently deprived of adequate facilities for experimentation and inquiry-based activities (Owolabi & Oginni, 2020). These inequalities contribute to a cycle of poor performance, low motivation, and diminished interest in science-related careers among rural students.

In recent years, the emergence of mobile digital laboratories (MDLs) has offered a promising solution to address such inequities. MDLs combine portable devices such as tablets, simulation kits, and mobile science apps with adaptable digital content that can transform traditional classrooms into interactive learning environments (Bello & Johnson, 2023). Unlike conventional laboratories that require fixed infrastructure and substantial funding, MDLs are flexible, cost-effective, and adaptable to diverse learning contexts. They can serve both urban and rural schools, effectively bridging physical and digital gaps in science education.

In this study, mobile digital laboratories refer to portable, technology-based science kits designed to deliver hands-on learning experiences in resource-limited schools. The concept of inclusive science learning is used to describe instructional practices that ensure equal participation and access for all students regardless of location or socioeconomic background. The rural-urban divide captures the disparity in educational opportunities between learners in rural and urban communities. The research adopts a quasi-experimental design to compare outcomes between experimental and control groups, focusing on the Ogbadibo Local Government Area (LGA) of Benue State, Nigeria.

Objectives of the study

The study was guided by the following general objectives:
1. To determine the impact of mobile digital laboratories on students' science learning achievement;
2. To compare the performance of students exposed to mobile digital laboratories with those taught using traditional classroom methods; and

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Global Journal of Modern
Research and Emerging Trends (GJMRET)
Vol. 1, Issue 7, December 2025 // ISSN: 1595-076X

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3.   To examine how the use of mobile digital laboratories promotes inclusivity in rural and urban schools within Ogbadibo LGA.

This investigation contributes to the broader discourse on technology-driven educational reform by providing empirical evidence on the role of mobile digital laboratories in advancing inclusive science education in resource-constrained environments.

Review of Related Literature

Mobile Digital Laboratories and Science Learning

The concept of mobile digital laboratories (MDLs) has evolved from the broader integration of mobile learning (m-learning) and digital technology in education. MDLs provide flexible, technology-enabled environments where learners can engage in interactive experimentation through simulations, virtual labs, and portable science kits (Abdullahi & Nwachukwu, 2022). These tools make it possible to deliver hands-on experiences without relying on fixed laboratory structures. Studies have shown that digital laboratories increase learners' motivation, conceptual understanding, and problem-solving abilities by supporting inquiry-based learning (Eze & Mba, 2021).

In rural contexts, MDLs address key challenges such as limited infrastructure, teacher training gaps, and unequal access to educational resources. They allow educators to bring laboratory experiences directly to students in remote communities, effectively bypassing structural inequalities. Research by Bello and Johnson (2023) demonstrated that students taught using mobile laboratory kits in low-resource schools outperformed their peers taught through conventional lecture-based methods.

Inclusive Education and the Rural-Urban Divide

Inclusive education emphasises providing equitable learning opportunities for all learners, including those in disadvantaged environments. The rural-urban divide in Nigeria reflects differences in resource allocation, teacher quality, and access to educational technology (Adewale, 2020). Rural students often encounter poor infrastructure, limited digital access, and fewer opportunities for collaborative learning (Nwachukwu, 2021). Integrating mobile digital laboratories provides a pathway for inclusion by ensuring that students from diverse socioeconomic and geographic backgrounds benefit equally from modern teaching tools.

In particular, the use of mobile digital labs enables participatory learning, where students interact with virtual experiments and real-time feedback. This helps learners develop scientific reasoning and cognitive engagement comparable to their urban peers (Okoro, 2022). As such, the MDL approach promotes educational equity and can reduce achievement gaps between rural and urban students.

Theoretical Framework

This study is grounded in Vygotsky's Social Constructivist Theory and Piaget's Cognitive Development Theory, both of which highlight the importance of active learning through interaction and discovery. Vygotsky (1978) proposed that learning occurs through social interaction and scaffolding, where learners internalise new knowledge with the support of peers and teachers. In the context of MDLs, technology acts as a mediating tool, facilitating collaboration and knowledge construction. Similarly, Piaget (1972) emphasised that learners build understanding through active engagement with their environment. Mobile laboratories, therefore, provide experiential learning contexts that align with cognitive development processes and enhance scientific reasoning.

Method

Research Design

The study adopted a quasi-experimental pre-test, post-test control group design to determine the effectiveness of mobile digital laboratories on students' science learning outcomes. This design enables comparison between two intact groups (experimental and control) without random assignment, making it ideal for school-based research where administrative constraints prevent full randomisation.

Population and Sample

The population comprised all Junior Secondary Two (JSS2) students in public schools across the Ogbadibo Local Government Area of Benue State, Nigeria. Using stratified random sampling, four schools were selected—two from rural areas and two from urban settings. A total of 400 students participated: 200 in the experimental group (taught with mobile digital laboratories) and 200 in the control group (taught with conventional methods). The gender distribution included 210 males and 190 females, aged between 12 and 14 years.

Instrument

Data were collected using the Science Learning Achievement Test (SLAT), developed by the researcher to assess students' understanding of selected science concepts. The instrument consisted of 40 multiple-choice items covering topics in basic chemistry, biology, and physics. It was validated by three experts in science education and educational measurement. The reliability coefficient, obtained using the Kuder-Richardson 20 (KR-20) method, was 0.86, indicating high internal consistency.

Procedure

The study lasted eight weeks. Before the intervention, both groups took a pre-test using the SLAT to determine their baseline knowledge. The experimental group was then taught selected science topics using mobile digital laboratories, which included portable sensors, tablets preloaded with simulation software, and interactive multimedia content. Lessons emphasised experimentation, observation, and data recording. The control group received instruction through traditional lecture and chalkboard methods. At the end of the intervention, both groups were given a post-test using the same SLAT instrument.

Data Analysis

Data were analysed using descriptive and inferential statistics. Mean and standard deviation scores were used to summarise students' performance, while Analysis of Covariance (ANCOVA) tested for significant differences between the two groups, controlling for pre-test scores.

Results

Table 1: Sample Demographics

Variable	Category	Frequency	Percentage (%)
Gender	Male	210	52.5
	Female	190	47.5
Location	Rural Schools / Urban Schools	200 / 200	50.0 / 50.0

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Table 2: Mean and Standard Deviation of Pre-Test and Post-Test Scores

Group	N	Pre-Test Mean	Pre-Test SD	Post-Test Mean	Post-Test SD	Mean Gain
Experimental (MDL)	200	42.15	6.28	74.60	8.32	32.45
Control (Conventional)	200	41.98	6.11	56.85	7.94	14.87

Table 3: ANCOVA Summary of Post-Test Scores by Group

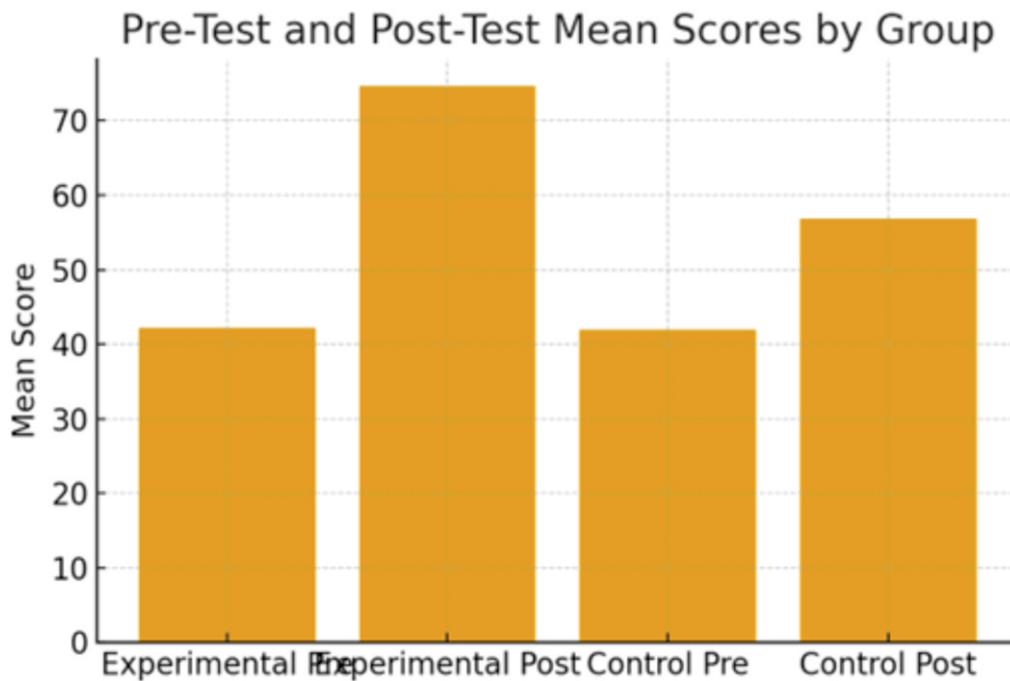| Source	Sum of Squares	df	Mean Square	F	Sig.
Pre-test (covariate)	152.48	1	152.48	3.12	0.078
Group	11245.30	1	11245.30	230.67	0.000*
Error	1936.14	397	4.88		
Total	13,333.92	399			

Figure 1: Comparison of Pre-Test and Post-Test Mean Scores

Interpretation: Figure 1 shows a clear improvement in post-test mean scores for the experimental group compared to the control group, illustrating the impact of the MDL intervention.

Discussion

The findings of this study revealed that students exposed to mobile digital laboratories performed significantly better than those taught using conventional methods. This suggests that the integration of portable digital tools enhances students' conceptual understanding, engagement, and retention. The observed improvement supports the argument that hands-on, technology-mediated instruction is essential for effective science learning in the 21st century.

These results corroborate previous studies by Bello and Johnson (2023) and Eze and Mba (2021), who found that digital laboratories and interactive technologies foster deeper understanding and motivation among learners. In this study, students in the experimental group demonstrated stronger inquiry skills and collaboration, likely because the mobile digital labs provided immediate feedback and visualisation of scientific phenomena.

Furthermore, the results highlight the inclusive potential of mobile digital laboratories. By bringing advanced learning tools to rural schools in Ogbadibo, the MDL model addressed the infrastructural limitations that often hinder equitable access to quality science education. This aligns with the global goal of achieving inclusive and equitable education (UNESCO, 2021).

Conclusion

The study concludes that mobile digital laboratories are effective tools for promoting inclusive science learning and reducing educational inequalities between rural and urban schools. Students exposed to MDL-based instruction achieved significantly higher scores and exhibited more active participation in science activities.

The mobile digital laboratory approach supports both cognitive and practical learning outcomes, offering a viable alternative for schools lacking fixed laboratory facilities. It provides experiential learning opportunities that align with constructivist theories of learning, emphasising active engagement, discovery, and collaboration.

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Global Journal of Modern
Research and Emerging Trends (GJMRET)
Vol. 1, Issue 7, December 2025 // ISSN: 1595-076X

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Recommendations

1. Integration in Curriculum: The Federal and State Ministries of Education should incorporate mobile digital laboratories into the junior secondary science curriculum as a complementary instructional model.
2. Teacher Training: Teachers should receive regular professional development on the use of mobile technologies for science instruction.
3. Government and NGO Support: Investment from public and private stakeholders is needed to scale up MDL programmes, especially in underserved rural areas.
4. Further Research: Longitudinal studies should examine the long-term impact of MDLs on students performance, motivation, and attitudes toward science.

Acknowledgement

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