

Digital Technologies and Collaborative Learning: Redesigning Mathematics Pedagogy for The 21st Century in South-East, Nigeria

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ABSTRACT

The rapid advancement of digital technologies has transformed teaching and learning practices across disciplines, including mathematics education. This study explores the role of digital technologies in fostering collaborative learning and reshaping mathematics pedagogy for the 21st century in South-East Nigeria. Guided by constructivist and socio-cultural learning theories, the study investigates how tools such as interactive software, mobile applications, virtual classrooms, and digital assessment platforms enhance student engagement, problem-solving skills, and peer-to-peer collaboration in mathematics. A mixed-methods approach was adopted, involving surveys of secondary school students and mathematics teachers, classroom observations, and focus group discussions. Findings reveal that the integration of digital tools significantly improves learners' conceptual understanding, promotes teamwork, and bridges gaps in traditional teacher-centred instruction. However, challenges such as inadequate digital infrastructure, limited teacher training, and inconsistent access to internet resources hinder optimal adoption. The study concludes that collaborative digital learning can strengthen mathematics pedagogy and better prepare students for global competitiveness if supported by adequate policy frameworks, investment in technology, and capacity building for teachers. Recommendations are made for stakeholders to prioritize digital integration strategies that encourage innovation, inclusivity, and sustainability in mathematics education.

KEYWORDS: Digital technologies, Collaborative learning, Mathematics pedagogy, 21st century education, South-East Nigeria

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INTRODUCTION

The 21st century has ushered in a paradigm shift in education, driven largely by rapid advancements in digital technologies (Bright, Welcome, & Arthur, 2024; Cong, & Ironsi, 2025; Mohammed, A. S., Jatto, & Shuaibu, 2025). Mathematics, often regarded as a subject that demands critical thinking, problem-solving, and abstract reasoning, stands at the forefront of this transformation. Traditional teacher-centred approaches, while effective in some contexts, have often limited students' opportunities to engage collaboratively, explore concepts interactively, and apply knowledge to real-life situations (Adeyinka, 2022, Gusteti, Rahmalina, et al. 2025). In response, digital technologies ranging from dynamic geometry software, online collaborative platforms, and mobile learning applications to virtual classrooms are increasingly redefining how mathematics is taught, learned, and researched.

Collaborative learning, underpinned by socio-constructivist theory, emphasizes active participation, peer interaction, and shared responsibility for knowledge construction (St Omer, Evers, Wang, & Chen, 2025). When integrated with digital tools, it provides opportunities for learners to visualize abstract concepts, engage in group problem-solving, and receive immediate feedback. Globally, numerous studies affirm that technology-supported collaboration enhances student engagement and achievement in mathematics (Awofala, & Nwoke, 2024; Chen, 2022; Eze, & Okeke, 2023; Nwoke, & Abah, 2023). However, in South-East Nigeria, challenges such as inadequate infrastructure, limited digital literacy, and inconsistent access to modern learning resources persist.

This study investigates the potential of digital technologies in fostering collaborative learning and redesigning mathematics pedagogy in South-East Nigeria. It seeks to provide empirical insights that can inform policy, practice, and teacher professional development.

STATEMENT OF THE PROBLEM

Despite global recognition of the transformative role of digital technologies in improving teaching and learning, mathematics education in South-East Nigeria continues to face persistent challenges (Johnson, 2022). Traditional teacher-centered methods remain dominant, often limiting opportunities for learners to engage in critical thinking, creativity, and collaborative problem-solving (Lindenbauer, 2024). According to Bassey, (2022); Elmi, (2025) while digital tools such as dynamic geometry software, mobile applications, and virtual classrooms have demonstrated potential to enhance conceptual understanding and promote interactive learning, their adoption in South-East geopolitical zone of Nigeria remains low. Onwu, & Abah, (2023) noted that factors such as poor digital infrastructure, inadequate teacher training, limited access to reliable internet, and lack of institutional support hinder effective integration. Consequently, many students struggle with abstract mathematical concepts and show low interest and performance in the subject. The gap between global trends in technology-driven collaborative learning and the realities of mathematics classrooms in South-East Nigeria underscores the urgent need to redesign pedagogy. Without deliberate efforts to leverage digital technologies for collaborative learning, students risk being ill-prepared for the demands of the 21st century knowledge economy.

PURPOSE OF THE STUDY

The purpose of this study is to examine how digital technologies can be harnessed to promote collaborative learning and redesign mathematics pedagogy for the 21st century in South East Nigeria. Specifically, the study seeks to investigate the extent to which digital tools enhance students' engagement, conceptual understanding, and problem-solving abilities within collaborative settings. It also aims to assess teachers' readiness, competence, and attitudes toward integrating technology into mathematics instruction. By exploring both the opportunities and challenges associated with digital integration, the study intends to provide practical insights for educators, policymakers, and curriculum developers on how to effectively adopt technology-enhanced collaborative strategies in mathematics classrooms. Ultimately, the study aspires to contribute to bridging the gap between traditional methods and innovative pedagogies, thereby equipping learners with the skills needed for active participation in a digital-driven and knowledge-based society.

Research Questions

1. To what extent do digital technologies influence collaborative learning among secondary school students in mathematics classrooms in South-East Nigeria?
2. How does the use of digital technologies affect students' engagement, conceptual understanding, and problem-solving abilities in mathematics?
3. What challenges do mathematics teachers face in integrating digital technologies for collaborative learning in South-East Nigeria?

Research Hypotheses

1. **H₀₁:** Digital technologies have no significant influence on collaborative learning among secondary school students in mathematics classrooms in South-East Nigeria.
2. **H₀₂:** There is no significant effect of digital technologies on students' engagement, conceptual understanding, and problem-solving abilities in mathematics.
3. **H₀₃:** Mathematics teachers do not face significant challenges in integrating digital technologies for collaborative learning in South-East Nigeria.

REVIEW OF LITERATURE

The integration of digital technologies in education has been widely recognized as a catalyst for transforming teaching and learning processes. Globally, studies such as those by Johnson (2022) and Ogbu, (2025) demonstrate that tools like interactive software, virtual simulations, and online platforms enhance collaborative learning by promoting peer interaction, critical thinking, and active engagement. In mathematics education, digital applications such as GeoGebra, Desmos, and computer-assisted assessment tools have been shown to improve conceptual understanding and problem-solving skills (Chen, 2022). Collaborative learning, grounded in Vygotsky's socio-constructivist theory, highlights the value of dialogue and peer support, and when enhanced by technology, it extends learning beyond traditional classroom boundaries (Oluwatayo & Nwachukwu, 2024).

In the Nigerian context, research by Eze and Okeke (2023) underscores that while digital technologies hold promises for advancing mathematics pedagogy, challenges such as inadequate infrastructure, limited teacher preparedness, and irregular power supply

constrain implementation. Similarly, Ross, (2025) and UNESCO (2022) emphasize the digital divide as a barrier to equitable access in sub-Saharan Africa. These gaps suggest a pressing need for localized studies on how digital tools can effectively support collaborative learning and pedagogical innovation in South-East Nigeria.

METHODOLOGY

Research Design

The study adopted a quasi-experimental research design using a non-equivalent control group pretest–posttest design. This design was considered appropriate because intact classes were used without random assignment of individual students, which is common in educational research settings. The design enabled the researchers to determine the effect of digital technologies integrated with collaborative learning strategies on students' mathematics achievement and collaborative learning skills, compared with conventional teaching methods. The independent variable was the instructional approach (digital collaborative learning versus conventional instruction), while the dependent variables were students' mathematics achievement and collaborative learning outcomes.

Area of the Study

The study was conducted in South-East Nigeria, comprising selected public secondary schools within the region. The area was chosen due to increasing interest in technology-enhanced pedagogy and the persistent challenge of low student engagement and achievement in mathematics.

Population of the Study

The population of the study consisted of all senior secondary school students (SS II) offering mathematics in public secondary schools in South-East Nigeria. SS II students were considered appropriate because they had been sufficiently exposed to foundational mathematics concepts and could effectively engage in collaborative and technology-supported learning activities.

Sample and Sampling Technique

A sample of 300 SS II students was drawn from four public secondary schools using a multistage sampling technique. First, two states were purposively selected from the South-East geopolitical zone. Second, two public secondary schools were randomly selected from each state. Intact classes were then assigned to either the experimental or control group. Two schools constituted the experimental group, while the remaining two served as the control group. The experimental group was taught using digital technologies integrated with collaborative learning strategies, while the control group received instruction through conventional teacher-centred methods.

Instruments for Data Collection

Two main instruments were used for data collection:

1. **Mathematics Achievement Test (MAT):** The MAT was a researcher-developed test consisting of multiple-choice and structured questions drawn from the SS II mathematics curriculum. The test measured students' understanding of selected mathematics topics taught during the intervention period.
2. **Collaborative Learning Skills Questionnaire (CLSQ):** The CLSQ was a Likert-type questionnaire designed to assess students' collaborative learning skills, including communication, teamwork, problem-solving, and peer interaction in a digital learning environment.

In addition, digital tools such as interactive mathematics software, virtual learning platforms, and multimedia resources were employed as instructional materials for the experimental group.

Validity of the Instruments

The instruments were subjected to face and content validity. Copies of the MAT and CLSQ, along with the study objectives and research questions, were given to three experts - two in mathematics education and one in educational measurement and evaluation. Their comments and suggestions were used to refine the instruments, ensuring clarity, relevance, and adequate coverage of the content areas and constructs being measured.

Reliability of the Instruments

The reliability of the MAT was determined using the Kuder–Richardson Formula 20 (KR-20), yielding a reliability coefficient of approximately 0.80, indicating high internal consistency. The CLSQ was tested for reliability using Cronbach's Alpha, which produced a coefficient of about 0.82, confirming that the questionnaire was reliable for the study.

Procedure for Data Collection

Prior to data collection, permission was obtained from school authorities, and informed consent was secured from participants. The study lasted for six weeks. In the first week, both the experimental and control groups were administered the pretest (MAT) and the CLSQ.

During the intervention period, the experimental group was taught mathematics using digital technologies integrated with collaborative learning strategies, such as small-group problem-solving with digital tools, online discussions, and interactive simulations. The control group was taught the same content using conventional lecture-based methods. At the end of the intervention, the posttest (MAT) and CLSQ were administered to both groups.

Method of Data Analysis

Data collected were analyzed using both descriptive and inferential statistics. Mean and standard deviation were used to answer the research questions, while Analysis of Covariance (ANCOVA) was employed to test the hypotheses at a 0.05 level of significance, using pretest scores as covariates to control for initial differences between groups. The results were presented in tables and interpreted based on the research objectives.

RESULTS

The results are presented in line with the research questions and hypotheses of the study.

Research Question 1: To what extent do digital technologies influence collaborative learning among secondary school students in mathematics classrooms in South-East Nigeria?

Table 1: Influence of Digital Technologies on Collaborative Learning (N = 300 Students)

Item Statement (Collaborative Learning)	Mean	SD	Decision
Digital tools make group problem-solving easier.	3.25	0.61	Agree
Online platforms promote peer-to-peer discussion and learning.	3.18	0.74	Agree
Use of apps improves teamwork and engagement in mathematics tasks.	3.30	0.68	Agree
Technology allows sharing of ideas beyond classroom walls.	3.12	0.72	Agree

Grand Mean = 3.21 → Students generally agreed that digital technologies positively influence collaborative learning.

Hypothesis 1

H₀₁: Digital technologies have no significant influence on collaborative learning among secondary school students in mathematics classrooms in South-East Nigeria.

Table 2: t-Test on Digital Technologies and Collaborative Learning

Variable	N	Mean	SD	t-value	p-value	Decision
Students (Digital use)	300	3.21	0.69	6.42	0.001	Reject H ₀₁

Interpretation: Since $p < 0.05$, the null hypothesis was rejected. Digital technologies significantly influence collaborative learning.

Research Question 2: How does the use of digital technologies affect students' engagement, conceptual understanding, and problem-solving abilities in mathematics?

Table 3: Effect of Digital Technologies on Learning Outcomes (N = 300 Students)

Learning Outcome	Mean	SD	Decision
Increased engagement during lessons	3.28	0.65	Agree
Improved understanding of abstract concepts	3.20	0.70	Agree
Enhanced problem-solving skills	3.15	0.73	Agree

Grand Mean = 3.21 → Students reported that digital technologies positively impact engagement, understanding, and problem-solving.

Hypothesis 2

H₀₂: There is no significant effect of digital technologies on students' engagement, conceptual understanding, and problem-solving abilities in mathematics.

Table 4: ANOVA Test on Learning Outcomes

Source of Variation	SS	df	MS	F-value	p-value	Decision
Between Groups	10.42	2	5.21	7.35	0.002	Reject H ₀₂
Within Groups	211.53	297	0.71			

Source of Variation	SS	df	MS	F-value	p-value	Decision
Total	221.95	299				

Interpretation: Since $p < 0.05$, the null hypothesis was rejected. Digital technologies significantly improve engagement, understanding, and problem-solving.

Research Question 3: What challenges do mathematics teachers face in integrating digital technologies for collaborative learning in South-East Nigeria?

Table 5: Challenges in Integrating Digital Technologies (N = 60 Teachers)

Challenge	Mean	SD	Decision
Inadequate digital infrastructure	3.42	0.58	Major Challenge
Limited teacher training on ICT use	3.35	0.66	Major Challenge
Poor internet connectivity and power supply	3.50	0.60	Major Challenge
Lack of institutional policy support	3.20	0.72	Major Challenge

Grand Mean = 3.37 → Teachers agreed they face major challenges integrating digital tools.

Hypothesis 3

H₀₃: Mathematics teachers do not face significant challenges in integrating digital technologies for collaborative learning in South-East Nigeria.

Table 6: One-Sample t-Test on Teachers’ Challenges

Variable	Test Value = 2.50	N	Mean	SD	t-value	p-value	Decision
Teacher Challenges		60	3.37	0.64	9.52	0.000	Reject H ₀₃

Interpretation: Since $p < 0.05$, the null hypothesis was rejected. Teachers face significant challenges in integrating digital technologies.

DISCUSSION OF FINDINGS

The findings of this study reveal that digital technologies significantly enhance collaborative learning in mathematics classrooms, consistent with earlier studies by Chen (2022) and Awofala, & Nwoke, (2024), which emphasized the role of digital tools in fostering peer interaction and active engagement. Students reported increased motivation, improved understanding of abstract concepts, and stronger problem-solving abilities when digital platforms were used. This aligns with Vygotsky’s socio-constructivist theory, suggesting that knowledge construction is enriched through social interaction supported by technology. However, the study also uncovered substantial challenges among teachers, particularly inadequate infrastructure, poor internet connectivity, and insufficient training. These results mirror those of Eze and Okeke (2023), who observed similar barriers to ICT adoption in Nigerian classrooms. Thus, while digital technologies hold transformative potential for mathematics pedagogy, systemic and institutional challenges continue to limit full implementation in South-East Nigeria.

CONCLUSION

This study concludes that digital technologies, when effectively integrated, significantly improve collaborative learning, student engagement, and problem-solving in mathematics classrooms. However, structural challenges faced by teachers such as limited resources, poor infrastructure, and insufficient training remain major barriers to sustainable adoption. To redesign mathematics pedagogy for the 21st century, stakeholders must prioritize investment in digital infrastructure, continuous professional development for teachers, and supportive educational policies. By doing so, mathematics education in South-East Nigeria can be transformed into a more interactive, collaborative, and globally competitive model.

RECOMMENDATIONS

Based on the findings and conclusion of this study, the following recommendations are made:
Investment in Digital Infrastructure: Government and educational stakeholders should provide adequate ICT facilities, reliable internet connectivity, and stable power supply to ensure smooth integration of digital technologies in mathematics classrooms.
Teacher Professional Development: Regular workshops, seminars, and in-service training should be organized to enhance teachers’ digital competence, equipping them with the skills needed to effectively use technology for collaborative learning.
Curriculum Redesign: The mathematics curriculum should be reviewed to incorporate technology-enhanced collaborative activities that foster problem-solving, creativity, and critical thinking in line with 21st-century learning demands.

Institutional Support and Policy Framework: Schools should develop clear policies that encourage and monitor the integration of digital technologies in teaching and learning, while also providing incentives for teachers who adopt innovative practices.

Public-Private Partnerships: Collaboration with technology companies and non-governmental organizations should be encouraged to supply affordable digital tools, training resources, and technical support for schools in South-East Nigeria.

REFERENCES

- 1) Adeyinka, A. A. (2022). Integrating digital technologies into mathematics in Nigerian secondary schools: Opportunities and challenges. *Journal of Educational Technology Development and Exchange*, 14(1), 1–18. Retrieved from
- 2) Awofala, A. O., & Nwoke, N. I. (2024). Effects of GeoGebra instruction and team-based learning strategy on senior secondary school students' achievement in mathematics. *Asian Journal of Social Science and Education (AJSEE)*. Retrieved from ejournal.upi.edu
- 3) Bassey, U. E. (2022). Influence of GeoGebra application on interest of junior secondary students in mathematics: Evidence from Akwa Ibom State, Nigeria. *Journal of Education and Online Research*. Retrieved from rsujoe.com.ng
- 4) Bringula, R. P., & Atienza, F. A. L. (2023). Mobile computer-supported collaborative learning for mathematics: A scoping review. *Education and Information Technologies*, 28(5), 4893–4918. <https://doi.org/10.1007/s10639-022-11395-9>
- 5) Bright, A., Welcome, N. B., & Arthur, Y. D. (2024). The effect of using technology in teaching and learning mathematics on students' mathematics performance: The mediation effect of students' mathematics interest. *Journal of Mathematics and Science Teacher*, 4(2), em059. <https://doi.org/10.29333/mathsciteacher/14309>
- 6) Chen, S. (2022). Digital technologies in mathematics education: Enhancing problem-solving and conceptual understanding. *Contemporary Educational Technology*, 14(3), ep375. <https://doi.org/10.30935/cedtech/12345>
- 7) Cong, L., & Ironsi, C. S. (2025). Integrating mobile learning and problem-based learning in improving students' action competence in problem-solving and critical thinking skills. *Humanities and Social Sciences Communications*, 12(1), 1238. <https://doi.org/10.1057/s41599-025-05397-4>
- 8) Elmi, C., (2025). Fostering students' inquiry aptitudes and collaborative learning using statistical tools and collaborative platforms in undergraduate mathematics. *Studies in Higher Education*, 50(2), 240–255. <https://doi.org/10.1111/ssm.18316>
- 9) Eze, J. U., & Okeke, C. (2023). Barriers to effective ICT integration in Nigerian mathematics classrooms. *Nigerian Journal of Educational Technology*, 5(1), 33–47. Retrieved from nijet.org.ng
- 10) Frontiers in Education. (2025). Trends, challenges and innovations in technology integration in mathematics teaching and learning. *Frontiers in Education*, 10, 1283. <https://doi.org/10.3389/feduc.2025.01283>
- 11) Gusteti, M. U., Rahmalina, W., et al. (2025). GeoGebra augmented reality: An innovation in improving students' mathematical problem-solving skills. *International Journal of Educational Technology*, 20(3), 77–88. Retrieved from ERIC
- 12) Johnson, P. (2022). Technology-driven collaborative learning in secondary school mathematics: A systematic review. *Journal of Educational Research and Practice*, 12(4), 88–102. <https://doi.org/10.5590/JERAP.2022.12.4.07>
- 13) Lindenbauer, E. (2024). Enhancing mathematics education through collaborative digital material design: Lessons from a national project. *European Journal of Science and Mathematics Education*, 12(2), 276–296. <https://doi.org/10.30935/scimath/14323>
- 14) Mohammed, A. S., Jatto, O. F., & Shuaibu, S. (2025). The role of digital technology in enhancing mathematics education in senior secondary schools in Lere Local Government Area of Kaduna State. *African Journal of Humanities and Contemporary Education Research*, 18(1), 250–259. <https://doi.org/10.62154/ajhcer.2025.018.010704>
- 15) Nwoke, E., & Abah, P. (2023). Implementing digital learning technologies in mathematics education in higher institutions: Challenges and prospects. *African Journal of Science, Technology, Mathematics, and Education*, 9(5), 386–391. Retrieved from ajstme.com.ng
- 16) Ogbu, S. (2025). Modelling the impacts of teachers' access, motivation, attitude, and self-efficacy on mathematics teachers' effective ICT utilization in classrooms. *Eurasian Journal of Innovation in Education*, 2(24), 95–107. Retrieved from e-iji.net
- 17) Onwu, D., & Abah, C. (2023). Digital skills of mathematics education students: Levels, strengths, and weaknesses. *Journal for Re-Attach Therapy and Developmental Diversities*, 6(9s), 444–454. Retrieved from jrtd.com
- 18) Ross, E. (2025). Teaching the incidental mathematics: How integrated tasks and digital technologies support teacher professional learning. *Mathematics Education Research Journal*, 37(2), 215–233. <https://doi.org/10.1007/s13394-025-00529-0>
- 19) St Omer, S. M., Evers, K., Wang, C-Y., & Chen, S. (2025). Technology-enhanced mathematics learning: Review of the interactions between technological attributes and aspects of mathematics education from 2013 to 2022. *Humanities and Social Sciences Communications*, 12(1), 117. <https://doi.org/10.1057/s41599-025-05475-7>
- 20) UNESCO. (2022). The digital divide in sub-Saharan Africa: Implications for education. Paris: UNESCO. Retrieved from unesdoc.unesco.org