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Technology Integration in Elementary Mathematics Education in Northern Nigeria: A Mixed-Methods Study Protocol for Informed Educational Decision-Making

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ABSTRACT

Technology-supported instruction is increasingly incorporated into school curricula, yet evidence concerning its use in elementary mathematics education remains uneven across low-resource educational settings. This manuscript presents a mixed-methods study protocol for investigating how technology integration influences mathematics teaching, pupils' engagement, and learning outcomes in selected elementary schools in Northern Nigeria. The protocol specifies the planned sampling strategy, instrument development and validation procedures, data collection protocols, and analysis plan. The study will examine the technological resources available to schools, the ways teachers use these resources during mathematics instruction, pupils' perceptions of technology-supported learning, and the institutional and infrastructural conditions that shape implementation. A convergent mixed-methods design will be used. Quantitative data will be collected through pupil achievement tests, structured questionnaires, and school-level technology inventories, while qualitative data will be obtained through teacher interviews and classroom observations. Quantitative data will be analyzed using descriptive statistics and appropriate inferential tests, while qualitative data will be examined thematically. The protocol anticipates generating context-sensitive evidence regarding the relationship between technology use, mathematics engagement, and learning outcomes. It is also designed to identify implementation barriers, including unreliable electricity, inadequate connectivity, limited access to devices, and insufficient teacher preparation. Anticipated outputs include a validated instrument set, a context-sensitive evidence base, and recommendations intended to support evidence-informed decisions by teachers, school leaders, and education policymakers. The study will avoid treating technology as an independent solution and will instead assess its effectiveness in relation to pedagogy, teacher capacity, infrastructure, and learner context.

KEYWORDS: educational technology; elementary mathematics; digital learning; Northern Nigeria; student engagement; mixed-methods research; study protocol.

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1. Introduction

Elementary education provides the foundation for later academic participation, while mathematics develops numerical reasoning, problem-solving, logical thinking, and decision-making skills (Crosnoe & Benner, 2016; McCallen & Johnson, 2020; Skinner & Pitzer, 2012; Wang, 2017). Weaknesses acquired during the early years of schooling may affect pupils' subsequent engagement with science, technology, engineering, and mathematics-related subjects. For this reason, improving the quality of elementary mathematics instruction is an important educational priority. Among the diverse array of subjects taught during these formative years, mathematics stands out as a fundamental discipline (McDonald, 2016). It serves as the bedrock upon which essential problem-solving abilities, logical reasoning, and critical thinking skills are nurtured and cultivated

(Bishan, 2015).

The growing availability of digital devices, mathematics applications, interactive displays, offline learning resources, and online platforms has created new possibilities for mathematics teaching. As the education sector increasingly integrates technology into pedagogical practices, traditional teaching approaches have evolved to incorporate digital tools and interactive learning resources (Alemu, 2015; Sarker et al., 2019). This integration seeks to create more engaging and dynamic learning environments (Serrano et al., 2019). Technology can support visual demonstrations, immediate feedback, differentiated instruction, independent practice, and collaborative problem-solving. However, its educational value depends on how it is selected, integrated, and aligned with curricular objectives.

In Northern Nigeria, technology integration must be considered within a particular social and institutional context. Schools may differ substantially in access to electricity, internet connectivity, digital devices, teacher training, instructional materials, and technical support. Socioeconomic conditions, language diversity, class size, and variations between urban, peri-urban, and rural communities may also influence how technology is used and experienced. The importance of mathematics in the elementary curriculum makes it necessary to understand the implications of technology integration in mathematics education (Kaput et al., 2020). Digital tools may influence teaching methods, student learning experiences, and academic achievement in mathematics (Callaghan et al., 2018).

Although international research has examined technology-supported mathematics education, localized evidence from elementary schools in Northern Nigeria remains limited. Existing discussions frequently describe the potential benefits of educational technology without sufficiently examining the conditions under which those benefits occur. A context-sensitive investigation is therefore needed to distinguish between technology availability, actual classroom use, quality of pedagogical integration, pupil engagement, and measurable learning outcomes. This manuscript responds to that need by presenting a detailed study protocol.

2. Problem Statement

Technology is increasingly promoted as a means of improving teaching and learning. Nevertheless, the effectiveness of technology-supported mathematics instruction in Northern Nigerian elementary schools has not been sufficiently established. Many schools may experience limited access to devices, intermittent electricity, weak connectivity, inadequate maintenance, and insufficient teacher preparation. These conditions can restrict technology use or lead to activities that are disconnected from the mathematics curriculum.

There is also a risk that policy decisions may be based on assumptions about technology rather than on evidence from local classrooms. Without reliable information about how technology is used, which tools are feasible, and how pupils respond to technology-supported instruction, schools may invest in resources that are difficult to sustain or pedagogically ineffective.

The central problem addressed by this study is the lack of localized, evidence-based knowledge about the influence of technology integration on elementary mathematics teaching, pupil engagement, and learning outcomes in Northern Nigeria. Despite the growing use of technology in education, the specific impact of digital tools on elementary mathematics learning in Northern Nigerian schools remains underexplored.

3. Aim and Objectives

Aim

The aim of this study is to examine how technology integration influences elementary mathematics teaching, pupil engagement, and learning outcomes in selected schools in Northern Nigeria.

Specific Objectives

1. Describe the availability and use of technological resources in elementary mathematics classrooms.
2. Identify technological tools that teachers and pupils perceive as useful, feasible, and contextually appropriate for elementary mathematics instruction.
3. Examine the relationship between technology-supported instruction and pupils' mathematics engagement and learning outcomes.
4. Identify challenges and opportunities that shape technology integration in elementary mathematics classrooms.

5. Generate context-sensitive recommendations for equitable and sustainable technology integration in elementary mathematics education.

4. Research Questions

i. What technological resources are available for mathematics instruction in selected elementary schools?
ii. How do teachers use technology when teaching elementary mathematics?

iii. What relationship exists between technology-supported instruction and pupils' mathematics achievement and engagement?

iv. How do pupils perceive and engage with technology-supported mathematics learning?

v. What challenges and opportunities shape the implementation of technology in elementary mathematics classrooms?

vi. What strategies could support equitable and sustainable technology integration?

5. Conceptual Framework

The study is organized around a technology–pedagogy–learning framework. Educational technology has transformed traditional classroom settings by supporting technology-driven pedagogies and smart learning environments (Kinshuk et al., 2016; Wong et al., 2015). Innovations associated with the Fourth Industrial Revolution have also prompted renewed attention to the role of digital technologies in teaching and learning (Agarwal et al., 2021; Oke & Fernandes, 2020).

The framework recognizes a shift from approaches based exclusively on physical resources and face-to-face delivery toward approaches that combine conventional pedagogy with digital tools, including interactive boards, software, and online resources (Dick et al., 2020; Savoy et al., 2017). Technology can reshape curriculum delivery, student engagement, and knowledge construction, while also changing the roles of teachers and learners (Cebrián et al., 2020; Lavicza et al., 2020).

The framework is structured around four interrelated components:

- Input variables: device availability, electricity, connectivity, teacher preparation, technical support, and school leadership.
- Process variables: frequency and quality of technology use, curriculum alignment, teacher guidance, learner interaction, and feedback.
- Outcome variables: mathematics achievement, engagement, confidence, participation, and conceptual understanding.
- Contextual variables: school location, class size, socioeconomic conditions, language, gender, and prior achievement.

This structure informs the research questions, instrument development, and analysis plan. It also ensures that technology is treated as one element within a broader pedagogical and institutional system rather than as an independent solution.

6. Literature Review

6.1 Technology in Mathematics Education

Technological interventions have expanded the range of tools available for mathematics education and may support problem-solving and critical-thinking activities (Becker et al., 2017; Mehta, n.d.). Digital resources can provide interactive experiences through which learners explore mathematical concepts in dynamic ways (Becker et al., 2018; Nilson & Goodson, 2021). Such resources may also support independent learning, exploratory activity, and collaborative problem-solving.

Digital technology can support differentiated and inclusive mathematics teaching when its use is informed by sound pedagogy (Clark-Wilson et al., 2020). Research also indicates that technology-enhanced resources can shape learners' engagement with mathematics and facilitate the representation or visualization of concepts (Buckley et al., 2019; Ni Shé et al., 2023).

6.2 Effectiveness of Specific Tools

Research on technology-enhanced resources points to the potential of carefully designed digital learning activities to support engagement and conceptual learning; however, results depend on the instructional

context and intended learning objectives (Daniels et al., 2023; Kumar & Dawson, 2018; Ni Shé et al., 2023). Blended-learning tools and practices may offer flexible ways to combine classroom teaching with digital resources (Kumar et al., 2021).

Interactive whiteboards have also been examined as tools for mathematics instruction. Case studies and related research suggest that their contribution depends on the ways teachers use them to facilitate representation, interaction, and discussion rather than simply to display information (De Vita et al., 2018a, 2018b).

6.3 Challenges and Opportunities

Technology integration in mathematics education may be constrained by unequal access to devices and connectivity, as well as insufficient teacher preparation (Adams, 2018; Brown & Clark, 2019; Garcia, 2016; Patel & Lee, 2018). These constraints can make it difficult to provide equitable technology-supported instruction. At the same time, opportunities exist in the form of offline resources, mobile learning, low-cost devices, and teacher professional development. The extent to which these opportunities can be realized depends on local infrastructure, institutional support, and pedagogical capacity.

6.4 Summary and Gap

The literature establishes that technology can support mathematics learning when it is well integrated with pedagogy and curriculum. However, much of the evidence comes from high-resource settings, and there is limited localized evidence from elementary schools in Northern Nigeria. This protocol addresses that gap by specifying a context-sensitive, mixed-methods investigation.

7. Methodology

7.1 Research Design

The study will use a convergent mixed-methods design. Quantitative and qualitative data will be collected in parallel, analyzed separately, and then integrated during interpretation. This design is appropriate because the study seeks both to measure relationships between technology use, engagement, and achievement and to understand the contextual and pedagogical processes that shape those relationships.

7.2 Participants and Sampling

7.2.1 Setting

The study will be conducted in 12 elementary schools across three Local Government Areas (LGAs) in Katsina State, Northern Nigeria. The LGAs will be selected to represent urban, peri-urban, and rural locations. Schools will be purposively selected to include variation in electricity access, device availability, and connectivity, using a short screening checklist administered to school heads before final site selection.

7.2.2 Participant Categories and Sampling Frame

Instrument	Participants	Anticipated N	Sampling Approach
Mathematics Achievement Test (MAT)	Pupils in Primary 4–6	480 pupils (approx. 40 per school)	Stratified by grade level; whole-class administration
Pupil Engagement Questionnaire (PEQ)	Same pupils as MAT	480 pupils	Census of participating classes
Teacher Technology Integration Questionnaire (TTIQ)	Mathematics teachers	60 teachers (approx. 5 per school)	Census of mathematics teachers in participating schools
School Technology Audit (STA)	School heads / ICT coordinators	12 respondents	One per school
Classroom Observation Schedule (COS)	Mathematics lessons	48 lessons (4 per school)	Purposive; varied grade levels and lesson types
Semi-Structured Interview Guide (SSIG)	Mathematics teachers	24 teachers (2 per school)	Purposive; selected from questionnaire respondents to capture variation in technology use

7.2.3 Parents and Stakeholders

Parents and guardians will not be interviewed or surveyed. They will be involved only through informed consent procedures for their children's participation. Education officials (e.g., LGA education officers) will be consulted for permissions and contextual information, but will not be formal participants unless the need arises during the study. This is stated explicitly to avoid ambiguity.

7.2.4 Sample-Size Determination

The target of 480 pupils was determined using a conservative a priori power calculation for the quantitative strand. Assuming a small-to-moderate effect size (Cohen's *f* = 0.15) for the relationship between technology-supported instruction and mathematics achievement, α = .05, power = .80, and up to 20% attrition, a minimum of approximately 400 pupils is required for the planned inferential analyses. The target has been raised to 480 to accommodate clustering by school and to permit subgroup comparisons.

The 60 teachers and 24 interviews were selected on the basis of information power (Malterud et al., 2016), given the study's narrow aim, the specificity of the sample, and the use of multiple qualitative data sources. The final number will be reviewed during data collection if new themes continue to emerge.

The sampling strategy is therefore sequential and purposive for the qualitative strand and stratified/census-based for the quantitative strand. The final achieved sample will be reported with a participant flow description.

7.3 Data Collection Instruments

7.3.1 Mathematics Achievement Test (MAT)

The MAT will be developed from the Nigerian Basic Education Curriculum for Primary 4–6 mathematics. Content domains will include: (a) number and numeration, (b) basic operations, (c) fractions and decimals, (d) geometry and measurement, and (e) data handling. Items will be multiple-choice (4 options) and short constructed-response, with a total of 30 items (20 multiple-choice, 10 short-response). Scoring will follow a marking guide with partial credit for constructed-response items where appropriate. The test will be blueprint-aligned to ensure content coverage and will undergo expert review by mathematics educators and measurement specialists. A pilot test (n ≈ 60) will be conducted to examine item difficulty, discrimination, and internal consistency (KR-20). Items with poor discrimination or extreme difficulty will be revised or removed. The final instrument will be administered under standardized conditions.

7.3.2 Pupil Engagement Questionnaire (PEQ)

Items will measure behavioral, emotional, and cognitive engagement in mathematics, adapted from established engagement scales and contextualized for the Northern Nigerian elementary school setting. The response format will be a 4-point Likert-type scale (e.g., *Never, Sometimes, Often, Always*) with pictorial supports for younger pupils. Subscale scores will be computed by averaging item responses. Content validity will be established through expert review; construct validity will be examined through exploratory factor analysis (EFA) on pilot data; internal consistency will be assessed using Cronbach's alpha (target α ≥ .70 per subscale).

7.3.3 Teacher Technology Integration Questionnaire (TTIQ)

This instrument will measure access, frequency of use, confidence, pedagogical practice, and perceived barriers. It will combine Likert-type items, frequency scales, and open-ended items. Scoring will follow a structured codebook. Validity will be established through expert review and pilot testing; reliability will be assessed using Cronbach's alpha for composite scales.

7.3.4 School Technology Audit (STA)

A structured checklist will be used to inventory devices, electricity, connectivity, software, maintenance, and technical support. The audit will be conducted by trained researchers using a standardized form. Inter-rater reliability will be checked on a subsample of schools (target Cohen's κ ≥ .80 for key items).

7.3.5 Classroom Observation Schedule (COS)

The COS will be a structured observation protocol recording instructional objectives, teacher guidance, pupil interaction, technology–curriculum alignment, and lesson flow. Observers will be trained, and inter-rater agreement will be established on a subsample of lessons before the main study. The schedule will include both low-inference (e.g., frequency counts of technology use) and high-inference (e.g., quality of pedagogical integration) ratings.

7.3.6 Semi-Structured Interview Guide (SSIG)

The interview guide will be developed from the conceptual framework and research questions, reviewed by experts, and pilot tested with 2–3 teachers. Interviews will be audio-recorded, transcribed, and analyzed thematically.

7.3.7 Instrument–Research Question Alignment

Research Question	Instruments
RQ1: What technological resources are available?	STA, TTIQ
RQ2: How do teachers use technology?	TTIQ, COS, SSIG
RQ3: What relationship exists between technology-supported instruction and achievement/engagement?	MAT, PEQ, TTIQ, COS
RQ4: How do pupils perceive and engage with technology-supported learning?	PEQ, COS, SSIG
RQ5: What challenges and opportunities shape implementation?	TTIQ, SSIG, COS, STA
RQ6: What strategies could support equitable and sustainable integration?	SSIG, TTIQ, STA, COS

7.4 Data Collection Procedure

Permissions will be obtained from relevant educational authorities and participating schools. Where participants are minors, parental or guardian consent and pupil assent will be obtained. Questionnaires and mathematics tests will be administered according to a standardized protocol. Classroom observations and teacher interviews will be conducted by trained researchers. Instruments will be reviewed by relevant experts and pilot tested before the main study. Data collection will proceed in three phases:

1. Preparation phase: instrument development, expert review, pilot testing, and observer training.
2. Field phase: administration of MAT and PEQ, distribution of TTIQ, conduct of STA, COS, and SSIG.
3. Data management phase: data entry, cleaning, transcription, and preparation for analysis.

7.5 Data Analysis

7.5.1 Quantitative Analysis

Descriptive statistics (means, standard deviations, frequencies, percentages) will be computed for all quantitative variables. Reliability will be assessed using Cronbach's alpha (and KR-20 for the achievement test). Inferential tests will include:

- Independent-samples t-tests and one-way ANOVA to compare mathematics achievement and engagement across groups (e.g., high vs. low technology use; urban vs. rural).
- Pearson or Spearman correlations to examine relationships between technology use, engagement, and achievement.
- Multiple regression to examine the contribution of technology use, teacher confidence, and school resources to achievement and engagement, controlling for pupil characteristics.
- Multilevel modeling (if clustering by school is substantial, as indicated by intraclass correlation coefficients) to account for the nested structure of pupils within schools.

Assumptions (normality, homogeneity of variance, multicollinearity) will be checked and reported. Non-parametric alternatives will be used where assumptions are violated.

7.5.2 Qualitative Analysis

Interview and observation data will be analyzed using Braun and Clarke's (2006) six-phase thematic analysis: familiarization, coding, theme development, review, definition, and reporting. Coding will be both deductive (based on the conceptual framework) and inductive (allowing new themes to emerge). Trustworthiness will be supported through triangulation, member checking, an audit trail, and reflexive journaling.

7.5.3 Integration of Strands

The study uses a convergent mixed-methods design. Integration will occur at the interpretation stage through a joint display that maps quantitative findings (e.g., achievement gains, engagement scores) against qualitative findings (e.g., teacher practices, pupil experiences). Integration will identify convergence (agreement across strands), complementarity (one strand explains or elaborates the other), and divergence (contradictions requiring further exploration). A mixed-methods matrix will be used to organize findings by research question.

7.6 Limitations

Potential limitations include self-report bias, non-random school participation, differences in teacher experience and school resources, irregular electricity or connectivity, and the difficulty of separating technology effects from novelty or additional instructional attention. The cross-sectional design will not permit causal claims. The sampling strategy, while purposive and stratified, may limit generalizability beyond the selected LGAs. These limitations will be documented and considered during interpretation.

8. Expected Outcomes

The protocol anticipates the following outputs:

i. A clearer understanding of the availability and use of technology in elementary mathematics classrooms.
ii. A validated set of instruments for measuring technology integration, pupil engagement, and mathematics achievement in low-resource settings.
iii. Context-sensitive evidence on the relationship between technology-supported instruction, pupil engagement, and learning outcomes.
iv. Identification of implementation barriers and opportunities, including infrastructural, pedagogical, and institutional factors.
v. Practical recommendations for teachers, school leaders, and policymakers on equitable and sustainable technology integration.

These outputs are intended to support evidence-informed decision-making and to contribute to the broader literature on educational technology in low-resource contexts.

9. Ethical Considerations

Ethical approval will be obtained from the relevant institutional review board. Permissions will be obtained from educational authorities and school heads. Informed consent will be obtained from teachers and from parents/guardians of participating pupils; pupil assent will also be obtained. Participation will be voluntary, and participants may withdraw at any time without penalty. Data will be anonymized, stored securely, and used only for research purposes. Where interviews are audio-recorded, separate consent for recording will be sought.

10. Conclusion

This protocol specifies a convergent mixed-methods investigation of technology integration in elementary mathematics education in Northern Nigeria. By detailing the sampling strategy, instrument development and validation procedures, data collection protocols, and analysis plan, the protocol addresses the methodological gaps identified in the review process. The study is designed to generate context-sensitive evidence that can inform pedagogical practice, school-level decision-making, and education policy in low-resource settings. It treats technology as one element within a broader system of pedagogy, teacher capacity, infrastructure, and learner context, and it avoids assuming that technology is inherently beneficial.

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