

INTEREST-DRIVEN TECHNOLOGY-ENHANCED MATHEMATICS INSTRUCTION AND STUDENT OUTCOMES IN FEDERAL CAPITAL TERRITORY, ABUJA, NIGERIA

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ABSTRACT

This quasi-experimental study examined the association between a ten-week multi-component interest-driven technology-enhanced mathematics instructional programme and student motivation, engagement, and self-regulated learning (SRL) among Senior Secondary Two (SS 2) students in Bwari Area Council, Federal Capital Territory (FCT), Nigeria. Grounded in the Four-Phase Model of Interest Development (Hidi & Renninger, 2006) and Zimmerman's (2002) SRL framework, the programme embedded interactive digital boards, GeoGebra and Desmos tablet-based tools, collaborative problem-solving, open-exploration windows, and digital self-assessment portfolios within coordinate geometry and trigonometry instruction. A non-equivalent control group design compared 60 experimental and 58 control students from two purposively selected public secondary schools. Three validated instruments assessed outcomes: the Situational Interest–Motivation (SIM) Scale, the Student Behavioural Engagement Questionnaire (SBEQ), and the Motivated Strategies for Learning Questionnaire Self-Regulated Learning subscale (MSLQ-SRL). Student-level ANCOVA, with pre-test scores as covariates, indicated significantly higher adjusted post-test scores for the experimental group on motivation ($F(1, 115) = 114.36, p < .001, \text{partial } \eta^2 = .495$), overall engagement ($F(1, 115) = 96.82, p < .001, \text{partial } \eta^2 = .454$), and self-regulation ($F(1, 115) = 108.91, p < .001, \text{partial } \eta^2 = .480$). Interest-phase progression analysis indicated that 81.7% of experimental students advanced at least one interest phase compared with 15.5% of control students. Because treatment was assigned at the school level and the intervention comprised multiple components, findings are exploratory estimates and cannot be causally attributed to any single instructional element. Findings suggest that technology-enhanced mathematics instruction may support motivational and regulatory development when digital tools are organised around interest-triggering, contextual relevance, learner agency, and self-monitoring.

Keywords: interest development; GeoGebra; Desmos; student engagement; self-regulated learning; mathematics education

Introduction

Students who are interested in what they study sustain attention more effectively, process information more deeply, and persist longer in the face of difficulty than students whose engagement is interest-poor (Hidi & Renninger, 2006; Renninger & Hidi, 2022). Despite this robust evidence base, classroom instruction in many Nigerian public secondary schools continues to be structured primarily around content coverage and examination preparation, with limited deliberate design of conditions that trigger and sustain student interest (Ogundele & Adebayo, 2021). Mathematics classrooms are particularly susceptible to this pattern. The subject's abstract symbolic system frequently distances learners from personally meaningful connections, and mathematics anxiety is widely documented as a significant barrier to engagement and achievement across secondary school populations (Hembree, 1990; Middleton & Spanias, 1999). In Nigeria, West African Senior School Certificate Examination (WASSCE) Chief Examiner reports have repeatedly identified weaknesses in candidates' mathematics performance, particularly noting difficulty in interpreting geometrical representations, applying formulae appropriately, and translating word problems involving coordinate geometry and trigonometry into correct mathematical procedures (West African Examinations Council, 2023). These patterns reflect instructional weaknesses and a lack of deliberate motivational design, which together risk disengaging students from mathematics before they encounter its most demanding senior secondary content.

The integration of digital technology into classrooms creates a structural opportunity to embed interest-supportive features, including novelty, contextual relevance, challenge, and learner agency, systematically into the mathematics learning environment. Dynamic geometry environments such as GeoGebra and Desmos have been shown to support engagement with abstract mathematical content by making relationships visible, manipulable, and personally explorable (Arbain & Shukor, 2015; Bhagat et al., 2016; Zengin et al., 2012; Yohannes & Chen, 2021). However, technology does not automatically improve mathematics learning; poorly scaffolded use may increase cognitive load, encourage procedural clicking without conceptual understanding, or produce differential benefits depending on teacher readiness, infrastructure reliability, and students' prior digital familiarity (Cheung & Slavin, 2013; Li & Ma, 2010; Ruthven et al., 2008). What remains less clear is whether digital mathematics tools can be deliberately organised through an explicit interest-development sequence that moves students beyond initial novelty toward self-initiated mathematical engagement.

Three interconnected gaps motivate this study. First, researchers have produced limited quasi-experimental evidence on interest-driven technology-enhanced instruction in Nigerian public secondary mathematics classrooms. Second, scholars have rarely tested the Four-Phase Model of Interest Development (Hidi & Renninger, 2006) as a prescriptive instructional design tool in sub-Saharan African mathematics classrooms. Third, prior Nigerian researchers on technology and engagement have seldom combined validated quantitative outcome measures with interest-phase progression tracking, leaving unanswered questions about the developmental mechanisms through which technology-enhanced mathematics instruction supports student outcomes.

The study is located in Bwari Area Council, FCT Abuja, a semi-urban context in which public secondary students are exposed to moderately modern school infrastructure within a government-funded system. Researcher visits confirmed that selected schools differed in digital infrastructure availability. SS 2 students constitute an important group for such intervention because they are already engaged with senior secondary mathematics content but are not yet under

the immediate pressure of terminal external examinations, making this a particularly suitable window for interest-support pedagogy. Findings should not be assumed to generalise beyond comparable semi-urban Nigerian public secondary mathematics classrooms.

This study contributes to the literature in three ways. First, it provides exploratory quasi-experimental evidence on the association between a multi-component interest-driven technology-enhanced instructional package and student outcomes in Nigerian public secondary mathematics classrooms. Second, it tests the Four-Phase Model as a prescriptive design framework in a sub-Saharan African mathematics education context. Third, by situating interest development within coordinate geometry and trigonometry instruction, it examines whether GeoGebra and Desmos-supported visualisation and contextual relevance framing can make symbolically abstract mathematics content more motivationally accessible to secondary students. The study did not include a mathematics achievement measure; associations between motivational gains and learning gains remain to be established in future research.

The following research questions guided the study:

1. To what extent is interest-driven technology-enhanced mathematics instruction associated with students' situational interest-motivation scores, after controlling for baseline levels?
2. To what extent is the intervention associated with students' overall engagement, after controlling for baseline scores?
3. To what extent is the intervention associated with students' cognitive engagement, after controlling for baseline scores?
4. To what extent is the intervention associated with students' agentic engagement, after controlling for baseline scores?
5. To what extent is the intervention associated with students' self-regulated learning strategies, after controlling for baseline scores?
6. Does the distribution of students across interest development phases differ significantly between the experimental and control groups at post-test?
7. Do the groups differ significantly in the proportion of students who advanced at least one interest phase from pre-test to post-test?

Theoretical Framework

The Four-Phase Model of Interest Development

Hidi and Renninger's (2006) Four-Phase Model of Interest Development provides the primary theoretical scaffold for this study. The model proposes that interest develops through a sequential, experience-dependent progression across four phases. In Phase 1 (triggered situational interest), a person's attention is captured by something novel, surprising, relevant, or challenging. This phase is typically short-lived and externally generated. In Phase 2 (maintained situational interest), the triggered response is deepened through sustained engagement with meaningful tasks, collaborative exploration, or problems that draw the learner more deeply into the content. Phase 3 (emerging individual interest) marks the transition from situationally driven to person-based engagement: the learner begins to re-engage with the topic voluntarily and develops stored knowledge and positive affect that are now intrinsically motivating. Phase 4 (well-developed individual interest) represents a stable, self-sustaining motivational orientation, characterised by deep engagement, self-generated questions, and intrinsically rewarding exploration. Given the ten-week duration of the present study, Phase 4 was interpreted only as a response pattern consistent with well-developed individual interest indicators, not as evidence of stable individual interest. Stable Phase 4 interest, as conceptualised by Hidi and Renninger (2006), implies a durable

motivational orientation confirmed across time and contexts, the establishment of which requires longitudinal follow-up extending beyond a single instructional term.

Renninger and Hidi (2022) extended the model's educational implications, demonstrating that technology-mediated instruction affords distinctive opportunities for triggering and sustaining situational interest through multimedia novelty, adaptive challenge, and personal relevance cues. Critically, they argue that interest promotion through technology must be intentionally designed: interactive multimedia that presents content without relevance or adaptive challenge cues may merely entertain without triggering genuine situational interest or enabling its development into individual interest. This design-dependence principle guided the instructional architecture of the present study.

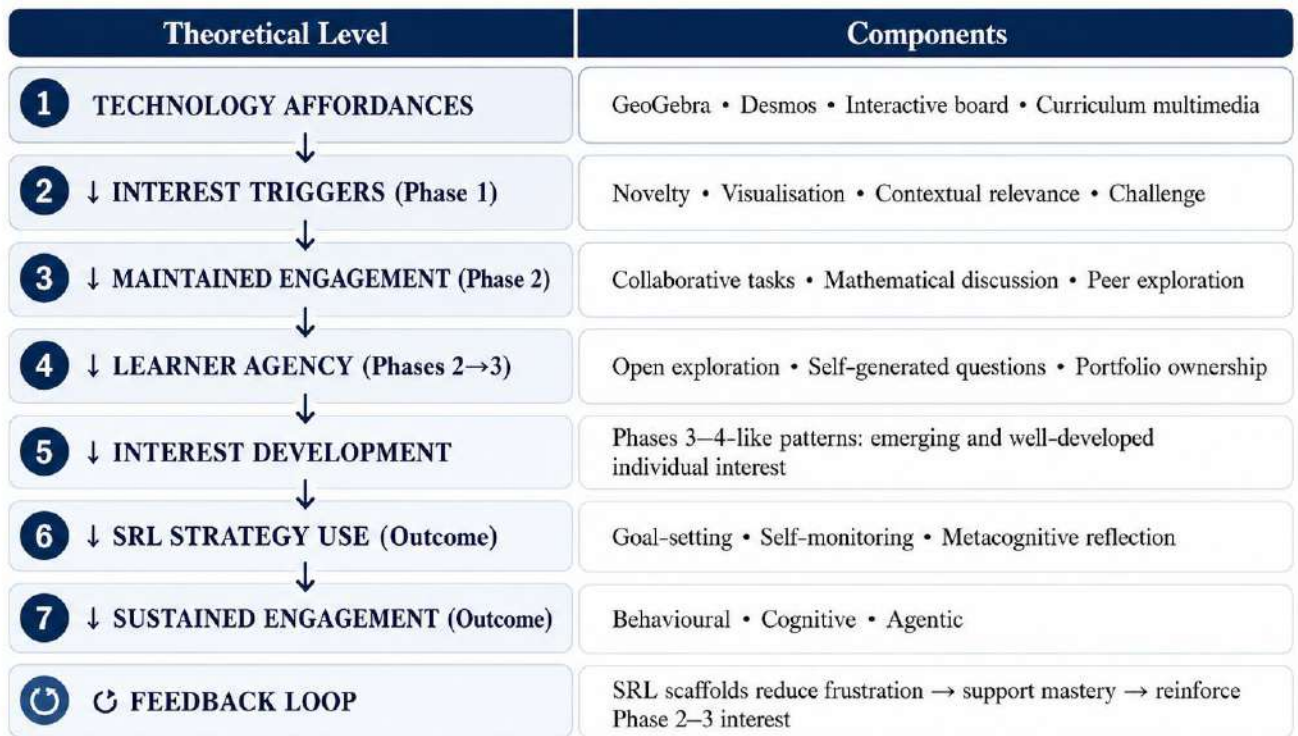
Self-Regulated Learning (SRL) Framework

Zimmerman's (2002) cyclical model of self-regulated learning identifies three recurring phases (forethought, performance, and self-reflection) through which learners regulate cognition, motivation, and behaviour during learning. Interest energises forethought through intrinsic goal-setting, sustains performance through attention regulation, and deepens self-reflection through curiosity about outcomes. Pintrich's operationalisation of SRL through the MSLQ (Pintrich et al., 1991) identifies goal-setting, metacognitive self-monitoring, effort regulation, and elaboration as principal SRL strategies, all predicted to increase as interest grows. For analytic purposes in this study, SRL was treated as an outcome variable; theoretically, however, SRL is conceptualised as reciprocally related to interest development, with regulatory scaffolds potentially sustaining interest by facilitating mastery experiences and reducing frustration. Panadero (2017) reviewed self-regulation theories and confirmed that interest and SRL are mutually reinforcing across educational contexts, providing additional support for positioning them as co-developing constructs. Self-Determination Theory (Ryan & Deci, 2000) similarly identifies intrinsic motivation and autonomous regulation as closely aligned constructs, reinforcing the theoretical coherence of combining interest development and SRL within a single instructional framework.

Conceptual Model

Figure 1 presents the theoretical design logic connecting the intervention's components to the study's outcome variables. Technology affordances initiate interest triggering; collaborative tasks and learner agency sustain and deepen interest; SRL strategy use and sustained engagement are the intended outcomes. A feedback loop reflects the expectation that SRL scaffolds reduce mathematics frustration and support mastery, reinforcing interest at Phases 2 to 3. The figure represents the theoretical design logic of the intervention and should not be interpreted as a tested mediation model; the present study did not conduct mediation analysis.

Figure 1: *Conceptual Model of Interest-Driven Technology-Enhanced Mathematics Instruction*



Note. This figure represents the theoretical design logic of the intervention. Downward arrows (↓) represent the intended instructional pathway. The feedback loop (↻) reflects the expectation that SRL scaffolds reduce mathematics frustration and support mastery, reinforcing Phase 2–3 interest transitions. This is a design model, not a tested mediation pathway.

Literature Review

Interest-Driven Learning and Academic Motivation in Mathematics

The relationship between student interest and mathematics motivation has been examined across diverse contexts. Middleton and Spanias (1999) identified interest and perceived relevance as among the most reliable predictors of sustained motivational engagement with mathematical tasks, particularly for secondary students whose enthusiasm may diminish as content becomes more symbolic and abstract. Hembree’s (1990) meta-analysis found that mathematics anxiety and intrinsic motivation are inversely related, and that instructional approaches increasing perceived relevance and reducing evaluative pressure can simultaneously reduce anxiety and raise motivation. More recent evidence corroborates this pattern: Ramirez et al. (2018) demonstrated that mathematics anxiety significantly predicted lower achievement and reduced persistence, while contextually meaningful instruction moderated these effects. Hannula et al. (2019) reviewed mathematics-related affect research across 2005 to 2016 and found that students’ motivation to engage with abstract mathematics content was consistently linked to their sense of personal relevance and exploratory control, reinforcing the importance of designing interest-support features directly into mathematics instruction rather than treating motivation as a stable individual trait.

Rotgans and Schmidt (2022) tracked interest and motivation across a problem-based learning module with secondary students, finding that triggered situational interest at lesson onset predicted maintained interest and intrinsic motivation at lesson conclusion, supporting the Four-

Phase Model's sequential logic. Problem-based, contextually grounded tasks were more effective at sustaining motivational engagement than conventional topic coverage, consistent with the present study's interest-triggering design. Wahyu et al. (2020) found that technology-enriched, relevance-framed science instruction was associated with higher motivation scores and task persistence than conventional classes. Although the Indonesian science context differs from the Nigerian secondary mathematics setting in terms of curriculum, language, and cultural context, the shared theoretical mechanism of interest-triggering through contextual relevance justifies citing these findings as partial conceptual support.

Technology-Enhanced Classrooms and Mathematics Engagement

Dynamic geometry software and interactive mathematical tools have received substantial empirical attention as engagement supports in secondary mathematics classrooms. Zengin et al. (2012) investigated GeoGebra-supported trigonometry instruction and found significantly higher achievement and reported engagement in the GeoGebra group, attributing gains to the software's capacity to make abstract trigonometric relationships visible and interactively manipulable. Bhagat et al. (2016) extended this finding, showing that GeoGebra-based dynamic visualisation was particularly effective at supporting conceptual understanding of angle relationships. Arbain and Shukor (2015) reported GeoGebra-related achievement gains in a Malaysian secondary mathematics intervention. Yohannes and Chen (2021) conducted a systematic review of 61 GeoGebra studies published 2010–2020 and found consistently positive effects on mathematics achievement and attitudes across secondary and tertiary settings, with the strongest benefits observed when tasks leveraged dynamic manipulation features rather than passive demonstration. Tamam and Dasari (2021) demonstrated that inquiry-based rather than procedural GeoGebra task design generated higher student engagement scores.

Bray and Tangney (2017) identified a consistent trend toward technology designs that support student agency and collaborative exploration rather than passive content exposure. Ruthven et al. (2008) found that exploratory affordances of dynamic geometry software supported student-initiated mathematical reasoning when teachers deliberately structured exploration activities. Within Nigeria, Ogundele and Adebayo (2021) found significantly higher cognitive and agentic engagement in a technology-enhanced condition compared with conventional instruction in Kwara State secondary schools, with teacher facilitation of student choice identified as a key mediating factor. Self-Determination Theory (Ryan & Deci, 2000), widely cited in comparable engagement studies, similarly emphasises autonomy support as a driver of intrinsic motivation, providing theoretical convergence with the interest-development framework guiding the present study.

However, digital tools do not automatically improve mathematics learning. Li and Ma's (2010) meta-analysis of 85 studies found that average effects were positive but highly variable, depending critically on teacher implementation quality, software design, and the degree to which technology supported student exploration rather than passive presentation. Cheung and Slavin (2013) similarly found that many educational technology programmes for mathematics showed only modest effects, with the weakest outcomes when technology replaced rather than enriched instructional interaction. Poorly scaffolded use may increase cognitive load, encourage procedural clicking without conceptual understanding, or produce unequal benefits for students with different levels of prior digital familiarity (Ruthven et al., 2008). These findings reinforce the importance of deliberate instructional design rather than technology exposure alone, and caution against over-interpreting positive associations observed in non-randomised school-based designs.

Self-Regulated Learning in Technology-Supported Mathematics Environments

Technology-enhanced environments support SRL through their capacity to externalise regulatory processes: goal-setting tools, progress trackers, and reflection prompts serve as digital scaffolds for self-monitoring and metacognitive awareness (Adeyemi & Oluwatobi, 2020; Teng & Zhang, 2020). In mathematics, SRL strategies such as planning solution approaches, monitoring procedural errors, and evaluating the reasonableness of answers are strongly associated with achievement, and students who develop these strategies early in secondary school maintain motivational and performance advantages into later years (Middleton & Spanias, 1999; Pintrich et al., 1991). Teng and Zhang (2020) found that platforms providing structured self-monitoring features produced significantly higher post-test MSLQ scores than platforms without them. Adeyemi and Oluwatobi (2020) validated the MSLQ-SRL subscale for Nigerian secondary students (CFI = .94, RMSEA = .06), providing psychometric grounding for its use in this FCT mathematics context.

Research Context: FCT Bwari Area Council

Bwari Area Council's public secondary schools serve a heterogeneous student population drawn from indigenous farming communities, residential civil servant households, and internally migrated families. Government Secondary School (GSS) Bwari was selected as the experimental school because researcher visits confirmed it possessed an interactive digital board installed under a government-supported digital education initiative, 15 tablet devices, and a functional computer laboratory. GSS Dutse-Alhaji, serving the adjacent community, had tablet devices and computers but no interactive digital board at the time of the study. Although the control school had some digital devices, these were not integrated into regular SS 2 mathematics instruction during the study period, making conventional chalk-and-talk instruction the de facto control condition. Both school infrastructure profiles were verified by pre-study site visits; device-count figures should be interpreted as researcher-verified approximations, as no independent institutional audit document could be identified. The two schools are consistently framed as representing a comparison between a multi-component enriched instructional package and conventional instruction, not as a clean test of interest-driven pedagogy versus technology access alone.

Taken together, the literature suggests that technology-enhanced mathematics instruction is most reliably associated with improved motivation and engagement when digital affordances are pedagogically organised around relevance, interaction, visualisation, feedback, and learner agency. Yet few studies have examined whether interest development principles drawn from the Four-Phase Model can be explicitly mapped onto secondary mathematics classroom design in sub-Saharan African contexts. The present study addresses this gap by embedding coordinate geometry and trigonometry activities within an interest development sequence and examining whether motivational, engagement, SRL, and interest-phase outcomes are associated with the intervention package relative to conventional instruction.

Methodology

Research Design

A quasi-experimental non-equivalent control group design was adopted. Intact class groups, rather than individually randomised students, formed the comparison groups, as school administrations at both sites could not permit within-school randomisation. Pre-test scores on all three outcome instruments were administered before the intervention commenced to establish baseline comparability and to serve as statistical covariates in ANCOVA models (Creswell & Creswell, 2023). Treatment assignment occurred at the school level rather than the student level: two school clusters constituted the effective units of comparison. ANCOVA covariation for pre-

test scores provides partial statistical adjustment but does not substitute for cluster-level randomisation, and because only two clusters were available, cluster-robust inference was not estimable. All inferential statistics in this study should be interpreted as exploratory student-level estimates rather than generalisable intervention effects. The G*Power calculation informed the minimum number of student respondents for questionnaire-based analysis and should not be interpreted as a cluster-randomised trial power calculation.

Study Location and Teacher Characteristics

The study was conducted at two government secondary schools in Bwari Area Council, FCT Abuja. GSS Bwari was assigned as the experimental school because pre-study researcher visits confirmed it possessed an interactive digital board, 15 tablet devices, and functional internet connectivity. GSS Dutse-Alhaji, serving the adjacent community, was assigned as the control school. The two schools draw from overlapping catchment communities, confirmed by school principals and the Area Council Education Department, although formal boundary documentation was unavailable for independent verification. Both schools followed identical SS 2 mathematics curriculum schedules during the study period, confirmed by the FCT Education Secretariat. To limit contamination, the control school teacher was not briefed on the intervention design or materials.

Teacher characteristics for both schools are presented in Table 1. Both teachers held B.Sc. (Ed.) degrees in Mathematics Education. The experimental school teacher had 11 years of secondary school teaching experience and had attended one government-sponsored ICT workshop two years prior to the study; the control school teacher had 9 years of experience and no documented ICT training. Neither teacher reported prior formal use of GeoGebra or Desmos for mathematics instruction before the study, which reduces, though does not eliminate, the concern that differential pre-existing digital-pedagogical expertise contributed to the observed outcomes. Both teachers were permanent civil servant employees of the FCT Education Secretariat and taught the same number of weekly mathematics lessons. The effect of teacher professional learning from the one-day orientation workshop cannot be separated from the effect of the digital tools or interest-support design, and the observed outcomes partly reflect teacher digital confidence and instructional responsiveness to student engagement cues rather than the designed materials alone.

Table 1: Participant and Teacher Characteristics of Experimental and Control Groups

Characteristic	Experimental (n = 60)	Control (n = 58)	t or χ^2	p
STUDENT CHARACTERISTICS				
Gender: male, n (%)	32 (53.3)	30 (51.7)	$\chi^2 = 0.03$.862
Gender: female, n (%)	28 (46.7)	28 (48.3)		
Age, years, M (SD)	15.7 (0.65)	15.9 (0.58)	t = 1.74	.084
Prior overall achievement, % (SD)	61.4 (6.12)	60.8 (5.97)	t = 0.53	.597
Prior mathematics score, % (SD)	58.3 (7.40)	57.9 (7.11)	t = 0.29	.771
Home internet access, n (%)	41 (68.3)	39 (67.2)	$\chi^2 = 0.01$.910
Personal device, n (%)	38 (63.3)	36 (62.1)	$\chi^2 = 0.02$.901
Class enrolment	62	61	—	—
Analysed sample	60	58	—	—
TEACHER CHARACTERISTICS				
Qualification	B.Sc.(Ed.) Mathematics	B.Sc.(Ed.) Mathematics	—	—
Teaching experience, years	11	9	—	—
Prior ICT workshop attendance	Yes (1 workshop)	None	—	—
Prior GeoGebra/Desmos use	None reported	None reported	—	—
Weekly mathematics lessons	4 hours	4 hours	—	—

Note. Prior overall achievement = SS 1 final examination score (max 100). Prior mathematics score = SS 1 mathematics examination score (max 100). Independent-samples t-tests used for continuous variables; χ^2 for categorical. Absolute t values reported; all $p > .05$. No significant between-group differences on any student variable at baseline. Class enrolment = total enrolled; analysed sample = students with parental consent and complete data (two experimental, three control students excluded). Teacher characteristics are descriptive; no statistical comparison applied.

Population and Sample

The accessible population comprised all SS 2 students enrolled in government secondary schools across Bwari Area Council for the 2023/2024 academic session (approximately 2,840 students across nine public secondary schools). Each of the two selected schools had two SS 2 mathematics arms; selected arms were those whose class schedules were compatible with the researcher's observation timetable. No performance streaming was practised in either school, and class allocation was done on non-academic criteria. G*Power 3.1 software determined a minimum of 42 students per group for a one-way ANCOVA with one covariate ($\alpha = .05$, power = .80, $f = 0.40$; see Arbain & Shukor, 2015; Zengin et al., 2012). A target of 65 per group was set for an additional margin. Purposive selection of intact classes yielded 60 participants from GSS Bwari and 58 from GSS Dutse-Alhaji ($N = 118$). Class enrolment was 62 (experimental) and 61 (control); two and three students respectively did not return signed parental consent forms and were excluded. All 118 consenting participants were present for both pre-test and post-test administration, and all attended at least 85% of the ten weekly sessions; no make-up assessments were required.

Instrumentation

Three validated instruments assessed the study's outcome variables. All scores are reported as item means (total scale score divided by number of items), so that all reported means are interpretable within their stated scale ranges.

Situational Interest–Motivation (SIM) Scale: The SIM is a 16-item, 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) measuring affective and cognitive components of situational interest-as-motivation. Sample items: “I find the mathematics activities in this class exciting” (affective); “I pay close attention during mathematics lessons because the content interests me” (cognitive). The SIM was adapted for Nigerian secondary school use following adaptation procedures consistent with Nwosu and Okafor (2021); it is noted that Nwosu and Okafor's published reference covers the Academic Motivation Scale, and the present team applied the same adaptation framework to situational interest items drawn from Hidi and Renninger (2006) and Renninger and Hidi (2022). The full adapted item set and adaptation rationale are available from the corresponding author upon request. Content Validity Index (CVI) in the present study = .88; threshold = .80. Present-sample reliability: $\alpha = .86$, $\omega = .87$. Item-total correlations: .41 to .69. Score range (item means): 1.00 to 5.00.

Student Behavioural Engagement Questionnaire (SBEQ): The SBEQ is a 24-item, 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) measuring overall engagement as a composite of three 8-item subscales (Fredricks et al., 2004; Reeve, 2013). The total SBEQ score represents overall engagement and was the primary outcome measure for RQ2. The behavioural engagement subscale (BES; 8 items) assesses on-task behaviour and participation (e.g., “I complete all my mathematics class activities”). The cognitive engagement subscale (CES; 8 items) assesses deep processing and connection-making (e.g., “I try to connect new mathematics ideas to things I already know”). The agentic engagement subscale (AES; 8 items) assesses proactive instructional contribution (e.g., “I suggest ways the class can explore mathematics topics differently”). The SBEQ was adapted for Nigerian secondary contexts by Ogundele and Adebayo

(2021). CVI in the present study = .85. Present-sample reliability: overall $\alpha = .84$, $\omega = .85$; BES $\alpha = .79$, $\omega = .80$; CES $\alpha = .80$, $\omega = .81$; AES $\alpha = .78$, $\omega = .79$. Item-total correlations: .38 to .71. Score range: 1.00 to 5.00.

Motivated Strategies for Learning Questionnaire: Self-Regulated Learning Subscale (MSLQ-SRL). The MSLQ-SRL is a 14-item, 7-point Likert scale (1 = not at all true of me, 7 = very true of me) tapping goal-setting and metacognitive monitoring strategies. Sample items: “When I study for mathematics, I set goals for myself in order to direct my activities in each study period” (goal-setting); “I ask myself questions to make sure I understand the mathematics material I have been studying” (metacognitive monitoring). The Nigeria-adapted version validated by Adeyemi and Oluwatobi (2020) was employed. Although the MSLQ was originally developed for US college students (Pintrich et al., 1991), its application to Nigerian secondary students is justified here by Adeyemi and Oluwatobi’s (2020) confirmatory factor analysis conducted specifically with Nigerian secondary school students (CFI = .94, RMSEA = .06), which demonstrated acceptable fit for the scale structure in this population. CVI in the present study = .86. Present-sample reliability: $\alpha = .82$, $\omega = .83$; goal-setting subscale $\alpha = .79$, $\omega = .80$; metacognitive monitoring subscale $\alpha = .77$, $\omega = .78$. Item-total correlations: .43 to .68. Score range: 1.00 to 7.00.

A pilot study was conducted with 22 SS 2 students at GSS Kuje, an FCT school outside the primary study area, to confirm instrument clarity and administration timing. No items were modified; pilot data were excluded from main analyses. CFA was not re-run in the present sample; reliability coefficients and item-total correlations are consistent with the validation studies. It is acknowledged that SIM and SBEQ employ 5-point Likert response formats while the MSLQ-SRL uses a 7-point format; this measurement inconsistency means that scores across instruments cannot be directly compared in magnitude, and all comparisons across instruments throughout this paper should be understood as within-instrument relative differences only.

Intervention: Interest-Driven Technology-Enhanced Mathematics Instruction

The ten-week multi-component instructional programme was delivered at GSS Bwari and covered the SS 2 mathematics curriculum units on Coordinate Geometry (Weeks 1 to 5) and Trigonometry (Weeks 6 to 10). Table 2 presents the week-by-week schedule. Four design principles from the Four-Phase Model were embedded throughout.

(a) Interest Triggering through Multimedia Novelty (Phases 1 to 2). Each 80-minute lesson opened with a two-to-three-minute interactive multimedia stimulus on the interactive digital board. Examples included GPS coordinate calculations for Abuja’s road grid (Week 1), GeoGebra-generated gradient graphs on FCT terrain slopes (Week 3), the National Mosque dome geometry (Week 6), and animated Desmos trigonometric value visualisations (Week 8, used as an enrichment trigger only; periodic functions extend beyond the SS 2 WAEC syllabus, were not assessed, and were explicitly framed to students as contextual background rather than examinable content, thereby maintaining curriculum fidelity while providing a visual interest-triggering stimulus). Relevance framing in Pidgin English was used where appropriate.

(b) Maintained Engagement through Collaborative Digital Tasks (Phase 2). Following the opening stimulus, students in rotating pairs completed structured digital tasks using GeoGebra or Desmos on tablet devices, discussing findings using the interactive board’s annotation tools. Pair rotation occurred weekly.

(c) Emerging Individual Interest through Open Exploration (Phase 3). A 15-minute weekly open-exploration window allowed students to investigate a self-chosen aspect of the week’s mathematics theme independently on GeoGebra or Desmos, recording two self-generated questions in their digital portfolios. Teachers did not prescribe the specific question explored, but

exploration was required to remain within the week’s mathematics topic to maintain curriculum relevance while preserving student agency.

(d) SRL Scaffolding. Weekly portfolio self-assessment templates in Google Drive included sections for lesson goals, perceived progress, challenges encountered, strategies planned for the following week, and revised self-generated questions, scaffolding Zimmerman’s (2002) forethought-performance-self-reflection cycle. All digital tools were pre-loaded for offline tablet use in advance of each session.

To illustrate mathematical authenticity, a brief lesson vignette from Week 6 is provided. Students viewed a photograph of the National Mosque, Abuja, on the interactive digital board. The teacher explained that the dome’s profile would be simplified to a right triangle, with an estimated vertical rise of 18 m and a horizontal run of 24 m; these were presented explicitly as instructional approximations, not verified architectural measurements. Using estimated rather than exact values is a recognised pedagogical strategy in applied mathematics instruction: it foregrounds the mathematical process of modelling rather than implying false precision, and the approximation was disclosed to students at the outset of the task. Using Desmos, pairs constructed the right triangle and calculated the angle of elevation using the tangent ratio, then varied the height parameter to observe how the angle responded. The open-exploration prompt asked: “What other local structures might have interesting angles to calculate? What information would you need?”

Table 2: Ten-Week Interest-Driven Mathematics Instructional Programme Schedule

Wk	Mathematics Topic	Interest-Triggering Stimulus	Digital Tool(s)	SRL Portfolio Prompt
1	Coordinate geometry: plotting points	GPS maps of Abuja road grid	GeoGebra plotter	What coordinates describe a location meaningful to me?
2	Distance and midpoint formulae	FCT land boundary distance calculations	GeoGebra; Google Forms	How could the distance formula solve a local planning problem?
3	Gradient and equation of a straight line	FCT terrain slope: GeoGebra animated gradient	GeoGebra; Desmos	Where do I see gradient in my everyday environment?
4	Parallel and perpendicular lines	Abuja road intersections and urban geometry	GeoGebra construction	What would happen if I changed the intersection angle?
5	Coordinate geometry application task	Mapping FCT landmarks on a coordinate plane	GeoGebra; Google Drive	What aspect of coordinate geometry do I most want to explore?
6	Trigonometry: right-angled triangles	National Mosque dome angle vignette (instructional estimates)	Desmos triangle explorer	Where have I encountered triangles or angles in real life?
7	Sine, cosine, tangent; elevation/depression	Abuja tower angle-of-elevation animation	GeoGebra angle tool	How does changing one angle affect the trigonometric ratios?
8	Sine and cosine rules	Desmos sine/cosine visualisation (enrichment; not assessed)	Desmos; Google Forms	What surprised me about how sine and cosine values change?
9	Area of triangle; bearings	Navigation and bearing calculations for FCT locations	GeoGebra bearing tool	What strategy helped me most with bearing problems?
10	Trigonometry review; open project	Student-designed GeoGebra or Desmos investigation	GeoGebra or Desmos (student choice)	What have I learned about my own mathematics study habits this term?

Note. Wk = Week. Each lesson: approximately 10 min multimedia stimulus, 30 min collaborative digital task, 15 min open exploration (topic-bounded), 15 min portfolio completion and class debrief, 10 min administration. GeoGebra and Desmos pre-loaded for offline tablet use. Week 6 dome measurements = instructional approximations. Week 8 Desmos visualisation = enrichment trigger only; periodic functions are outside the SS 2 WAEC syllabus and were not assessed. Google Drive portfolios synchronised at lesson end.

Control Condition

The control group at GSS Dutse-Alhaji received conventional chalk-and-talk mathematics instruction across the same curriculum units over the same ten weeks, with lessons running for the same 80-minute duration. The teacher used the approved SS 2 New General Mathematics textbook (3rd edition) as the primary resource, supplemented by board-written worked examples and individual exercise sets. Although the control school had some digital devices, these were not integrated into regular SS 2 mathematics instruction during the study period. No digital devices, multimedia content, or structured collaborative tasks were introduced. The control teacher received no interest-support training or study materials. The comparison is explicitly between a multi-component enriched instructional package and conventional instruction, not between interest-driven and non-interest-driven versions of otherwise equivalent technology-supported instruction.

Fidelity of Implementation

Implementation fidelity was monitored through researcher observation and teacher self-reporting. Table 3 summarises fidelity evidence by component. A researcher visited GSS Bwari during 8 of the 10 intervention weeks and used a four-component lesson observation checklist. For the two unobserved weeks, fidelity data were drawn from the intervention teacher’s weekly implementation log only. Overall lesson activity completion across all four components was approximately 85% (mean of component rates). Portfolio completion was confirmed through Google Drive activity logs for all 10 weeks. The absence of inter-rater reliability assessment between observer and teacher self-report is a notable fidelity monitoring limitation. No systematic fidelity observation was conducted at the control school, meaning the control condition is largely undocumented; this limits confidence in the characterisation of the comparison condition. For the two unobserved intervention weeks, data rested entirely on the intervention teacher’s self-report, which carries a potential conflict of interest. These fidelity limitations should be factored into the interpretation of all outcome comparisons.

Table 3: Fidelity of Implementation: Lesson Component Observation Summary

Intervention Component	Directly Observed (8 observed weeks)	Teacher Log (10 weeks)	Total Confirmed (of 10 weeks)	Rate (%)
(a) Interest-triggering multimedia stimulus	7 of 8	9 of 10	9 of 10	90
(b) Tablet-based collaborative digital task	6 of 8	8 of 10	8 of 10	80
(c) Open-exploration window (≥10 min)	6 of 8	7 of 10	7 of 10	70
(d) Digital portfolio completion	7 of 8 (sync obs.)	10 of 10 (activity log)	10 of 10	100
Overall composite (mean of component rates)				≈85

Note. Directly observed = researcher checklist (8 weeks). Teacher log = self-report (all 10 weeks). Component (c) was reduced to 8 minutes in 3 lessons due to curriculum time pressure; coded as not fully complete. Inter-rater reliability between observer and teacher self-report was not formally assessed. No fidelity monitoring was conducted in the control school. Rate = component-specific completion percentage; overall rate is the simple arithmetic mean of the four component rates.

Interest Phase Classification

Students in both groups completed the 12-item Interest Phase Identification Scale (IPIS) at both pre-test and post-test. The IPIS was developed by the research team from Renninger and Hidi's (2022) theoretical descriptors; it is a classify-and-rate instrument, not a published psychometric scale. Each item presents a brief descriptive scenario rated on a 4-point scale (1 = not like me at all, 4 = very much like me). Dominant phase was assigned based on the highest mean subscale score. Where two phase means differed by less than 0.20, raters reviewed the full response pattern using the scoring rubric before assigning a dominant phase. Because students may display indicators of adjacent phases simultaneously, dominant phase classification was used for interpretive clarity rather than as a definitive phase diagnosis. Because the IPIS was researcher-developed and has not undergone independent psychometric validation, phase classification findings should be interpreted as exploratory and theory-informed. Two raters, blind to group assignment, independently classified all responses; Cohen's $\kappa = .81$, $p < .001$. Discrepancies in 12% of responses were resolved through structured consensus discussion. Full IPIS items, scoring rubric, rater training procedure, and an example classification are available from the corresponding author upon request.

Data Analysis

Data were analysed using IBM SPSS Statistics Version 29 and JASP Version 0.18. One-way ANCOVA models were employed for RQ1 through RQ5, with post-test scores as dependent variables and pre-test scores as covariates. ANCOVA assumptions were verified: normality (Shapiro-Wilk, W range = .964 to .979, all $p > .05$), homogeneity of variances (Levene's test, $F(1, 116)$ range = 0.12 to 0.58, all $p > .05$), and homogeneity of regression slopes (all $F < 1.12$, all $p > .10$). Effect sizes are reported as partial η^2 , classified by Cohen's (1988) conventions (small = .01, medium = .06, large = .14). Holm-Bonferroni sequential correction was applied to the five pre-specified primary ANCOVA comparisons: SIM (RQ1), SBEQ total (RQ2), CES (RQ3), AES (RQ4), and MSLQ-SRL total (RQ5). Because SBEQ total and its subscale scores are statistically related, engagement findings across these measures should be interpreted as convergent evidence rather than independent effects. The behavioural engagement subscale (BES), goal-setting subscale, and metacognitive monitoring subscale were treated as secondary exploratory analyses not included in the Holm-Bonferroni correction; their p values should be interpreted accordingly. Adjusted means, standard errors, adjusted mean differences, and 95% confidence intervals are reported for all outcomes. For RQ6a, a χ^2 test of independence examined post-test phase distributions. For RQ6b, a simple binary "advanced at least one phase" versus "did not advance" χ^2 comparison provided a group-comparative test of interest progression. Because only two school clusters were available, cluster-robust inference was not estimable; all reported statistics are student-level exploratory estimates.

Results

Baseline Equivalence

Pre-test comparisons (available from the corresponding author) showed no statistically significant between-group differences on any primary outcome or subscale measure (all independent-samples t -tests $p > .05$). Table 1 confirmed no significant between-group differences on student demographic characteristics. Baseline equivalence was established for measured demographic and pre-test outcome variables; unmeasured school-level, teacher-level, and household-level differences may remain as potential confounds.

Primary ANCOVA Results (RQ1 to RQ5)

ANCOVA results are presented in Table 4. For all five primary outcome measures, the experimental group recorded significantly higher adjusted post-test item-mean scores after controlling for pre-test scores, and all remained significant after Holm-Bonferroni correction. Effect sizes were uniformly large (partial $\eta^2 = .43$ to $.50$), which is notably high relative to comparable published studies in educational technology and mathematics engagement (e.g., Yohannes & Chen, 2021; Bhagat et al., 2016 reported modest-to-medium effects). Possible explanations for the magnitude include demand characteristics arising from students' awareness of being in a special programme, teacher enthusiasm, social desirability responding in self-report instruments, and uncontrolled school-level differences unrelated to the intervention. These explanations cannot be distinguished in the present design, and effect sizes should be interpreted cautiously. Because treatment was confounded with school membership, all partial η^2 values are student-level exploratory estimates. Because SBEQ total and its subscale scores are statistically related, the engagement findings represent convergent rather than independent effects.

Table 4: Pre-test Scores and Adjusted Post-test ANCOVA Results by Group

Outcome Variable	Exp. Pre M (SD)	Con. Pre M (SD)	Exp. Adj. Post M (SE)	Con. Adj. Post M (SE)	Adj. Diff. (95% CI)	F(1, 115)	p	Partial η^2
PRIMARY OUTCOMES (Holm-Bonferroni corrected)								
SIM [†]	3.52 (0.74)	3.49 (0.71)	4.28 (0.05)	3.54 (0.05)	0.74 [0.60, 0.88]	114.36	< .001*	.495
SBEQ total [†] —overall engagement	3.44 (0.69)	3.41 (0.67)	4.09 (0.05)	3.46 (0.05)	0.63 [0.50, 0.76]	96.82	< .001*	.454
CES [†]	3.38 (0.72)	3.35 (0.68)	4.17 (0.05)	3.40 (0.05)	0.77 [0.62, 0.92]	103.44	< .001*	.468
AES [†]	3.29 (0.66)	3.27 (0.64)	3.98 (0.05)	3.32 (0.05)	0.66 [0.52, 0.80]	88.17	< .001*	.432
MSLQ-SRL total [‡]	3.61 (0.78)	3.58 (0.76)	5.19 (0.11)	3.63 (0.11)	1.56 [1.27, 1.85]	108.91	< .001*	.480
SECONDARY EXPLORATORY SUBSCALES (uncorrected, interpret with caution)								
BES [†]	3.51 (0.68)	3.48 (0.65)	4.05 (0.06)	3.48 (0.06)	0.57 [0.42, 0.72]	83.44	< .001§	.420
Goal-setting [‡]	3.55 (0.81)	3.52 (0.79)	5.24 (0.12)	3.57 (0.12)	1.67 [1.34, 2.00]	97.63	< .001§	.457
Metacognitive monitoring [‡]	3.48 (0.70)	3.46 (0.73)	5.11 (0.12)	3.51 (0.12)	1.60 [1.27, 1.93]	91.28	< .001§	.441

Note. Exp. = Experimental (n = 60); Con. = Control (n = 58). SIM = Situational Interest-Motivation Scale; SBEQ = Student Behavioural Engagement Questionnaire; BES = Behavioural Engagement Subscale; CES = Cognitive Engagement Subscale; AES = Agentic Engagement Subscale; MSLQ-SRL = Motivated Strategies for Learning Questionnaire, SRL subscale. [†] 5-point Likert item means (range 1.00–5.00). [‡] 7-point Likert item means (range 1.00–7.00). Adj. = adjusted; SE = standard error of adjusted mean; Adj. Diff. = adjusted mean difference (Experimental minus Control); 95% CI based on df = 115. * p remains significant after Holm-Bonferroni correction across five primary comparisons (SIM, SBEQ total, CES, AES, MSLQ-SRL). § Secondary exploratory subscale analyses not included in Holm-Bonferroni correction; interpret with additional caution. Engagement findings represent convergent

rather than independent effects. All partial η^2 values are student-level exploratory estimates; treatment was assigned at the school level.

RQ1 (Situational Interest-Motivation): The experimental group showed a practically meaningful adjusted difference in post-test SIM item-mean scores (adjusted $M = 4.28$, $SE = 0.05$) relative to the control group (adjusted $M = 3.54$, $SE = 0.05$), $F(1, 115) = 114.36$, $p < .001$, partial $\eta^2 = .495$; adjusted difference = 0.74, 95% CI [0.60, 0.88].

RQ2 (Overall Engagement): The experimental group showed significantly higher adjusted post-test SBEQ total item-mean scores (adjusted $M = 4.09$ vs. 3.46), $F(1, 115) = 96.82$, $p < .001$, partial $\eta^2 = .454$; adjusted difference = 0.63, 95% CI [0.50, 0.76].

RQ3–RQ4 (Cognitive and Agentic Engagement): The experimental group recorded significantly higher adjusted cognitive engagement scores (adjusted $M = 4.17$ vs. 3.40; difference = 0.77, 95% CI [0.62, 0.92], partial $\eta^2 = .468$) and agentic engagement scores (adjusted $M = 3.98$ vs. 3.32; difference = 0.66, 95% CI [0.52, 0.80], partial $\eta^2 = .432$), both $p < .001$ after Holm-Bonferroni correction. The secondary BES analysis showed a significant experimental advantage on behavioural engagement (adjusted $M = 4.05$ vs. 3.48; difference = 0.57, 95% CI [0.42, 0.72], $F(1, 115) = 83.44$, $p < .001$, partial $\eta^2 = .420$).

RQ5 (Self-Regulated Learning): The experimental group recorded significantly higher adjusted MSLQ-SRL item-mean scores (adjusted $M = 5.19$, $SE = 0.11$ vs. 3.63, $SE = 0.11$), $F(1, 115) = 108.91$, $p < .001$, partial $\eta^2 = .480$; adjusted difference = 1.56, 95% CI [1.27, 1.85]. Secondary subscale analyses also showed significant experimental advantages on goal-setting and metacognitive monitoring (both $p < .001$).

Interest Phase Results (RQ6a and RQ6b)

Table 5 presents interest phase distributions at pre-test and post-test for both groups. RQ6a: A χ^2 test of independence comparing post-test phase distributions was significant, $\chi^2(3, N = 118) = 22.84$, $p < .001$, Cramér’s $V = .44$. RQ6b: A simple binary advancement analysis comparing the proportion of students who advanced at least one phase from pre-test to post-test indicated a significant between-group difference: 49 of 60 experimental students (81.7%) advanced at least one phase, compared with 9 of 58 control students (15.5%), $\chi^2(1, N = 118) = 60.41$, $p < .001$, $\phi = .72$. Advancement into Phase 4 should be interpreted as movement into a Phase 4-like response pattern, not confirmed stable individual interest. Tables 6 and 7 present transition matrices for the experimental and control groups, respectively.

Table 5: Distribution of Students Across Interest Development Phases at Pre-test and Post-test

Interest Phase	Exp. Pre n (%)	Exp. Post n (%)	Con. Pre n (%)	Con. Post n (%)
Phase 1: Triggered Situational Interest	18 (30.0)	5 (8.3)	17 (29.3)	16 (27.6)
Phase 2: Maintained Situational Interest	22 (36.7)	14 (23.3)	21 (36.2)	22 (37.9)
Phase 3: Emerging Individual Interest	13 (21.7)	24 (40.0)	12 (20.7)	13 (22.4)
Phase 4: Pattern consistent with well-developed individual interest indicators†	7 (11.7)	17 (28.3)	8 (13.8)	7 (12.1)

Note. Phases from Hidi and Renninger (2006). IPIS classification by two blinded raters; $\kappa = .81$. RQ6a post-test χ^2 : $\chi^2(3, N = 118) = 22.84$, $p < .001$, Cramér’s $V = .44$. RQ6b binary advancement χ^2 : $\chi^2(1, N = 118) = 60.41$, $p < .001$, $\phi = .72$. Exp. = Experimental; Con. = Control. † Phase 4 = IPIS response pattern consistent with well-developed individual interest indicators; stable Phase 4 requires longitudinal confirmation. IPIS is researcher-developed; findings are exploratory.

Table 6: Interest Phase Transition Matrix: Experimental Group (n = 60)

Pre-test Phase	Post: Ph. 1	Post: Ph. 2	Post: Ph. 3	Post: Ph. 4†	Total
Phase 1 (n = 18)	4	9	4	1	18
Phase 2 (n = 22)	1	5	12	4	22
Phase 3 (n = 13)	0	0	7	6	13
Phase 4 (n = 7)	0	0	1	6	7
Total	5	14	24	17	60

Note. 49 of 60 students (81.7%) advanced at least one phase. No student regressed more than one phase. Phase 1 to Phase 2 or above: 16 of 18 (88.9%). Phase 2 to Phase 3 or above: 16 of 22 (72.7%). † Phase 4 = IPIS response pattern consistent with well-developed individual interest indicators only.

Table 7: Interest Phase Transition Matrix: Control Group (n = 58)

Pre-test Phase	Post: Ph. 1	Post: Ph. 2	Post: Ph. 3	Post: Ph. 4†	Total
Phase 1 (n = 17)	13	3	1	0	17
Phase 2 (n = 21)	2	16	2	1	21
Phase 3 (n = 12)	0	2	9	1	12
Phase 4 (n = 8)	1	1	1	5	8
Total	16	22	13	7	58

Note. 9 of 58 students (15.5%) advanced at least one phase; 4 students regressed one phase. Phase distribution at post-test was largely unchanged from pre-test. † Phase 4 = IPIS response pattern consistent with well-developed individual interest indicators only.

Discussion

The results of this study provide consistent evidence that a multi-component interest-driven technology-enhanced mathematics instructional programme was associated with significantly higher motivation, engagement, and self-regulated learning among SS 2 students in Bwari Area Council, FCT Abuja, relative to conventional mathematics instruction. Across all six research questions, the pattern of findings is more theoretically consistent with interest-development processes than with a simple one-time novelty response, although novelty effects cannot be definitively ruled out without delayed post-test or sustained observational evidence. These exploratory findings cannot be causally attributed to any single component of the intervention package.

The simple binary advancement analysis (RQ6b) provides a group-comparative test of interest progression: 81.7% of experimental students advanced at least one interest phase, compared with 15.5% of control students ($\chi^2(1) = 60.41, p < .001, \phi = .72$). Because the IPIS is researcher-developed and has not undergone independent psychometric validation, this finding carries lower evidentiary weight than the ANCOVA outcomes and should not be interpreted as definitive evidence of interest phase development. The transition matrices reveal that movement in the experimental group was predominantly forward along the interest development continuum, with no student regressing more than one phase. In the control group, the distribution at post-test was largely unchanged from pre-test, with four students regressing. This descriptive contrast follows a theoretically coherent pattern, though it remains subject to the caveat that IPIS classifications are based on a researcher-developed instrument and should be treated as exploratory.

For coordinate geometry, dynamic GeoGebra manipulation may have helped students perceive algebraic relationships spatially, making the abstract coordinates of distance and gradient visible as manipulable objects rather than symbolic expressions. For trigonometry, visual angle manipulation in Desmos and GeoGebra may have reduced the abstraction of ratio relationships and supported exploratory reasoning about how changing one element of a triangle propagates through the ratio system. The contextual relevance frames, such as GPS navigation, FCT terrain slopes, and the National Mosque dome angle, appear to have provided entry points connecting

abstract content to students' experiential world, consistent with Phase 1 interest-triggering through novelty and relevance (Renninger & Hidi, 2022).

It is notable that the open-exploration component, which is theoretically central to movement from Phase 2 toward Phase 3 individual interest, had the lowest fidelity among the four intervention components (70%, or 7 of 10 sessions fully completed). The observed interest-phase progression may therefore reflect the combined influence of all implemented components, including visualisation, collaboration, and portfolio reflection, rather than open exploration alone. Future studies should treat component-specific fidelity as a moderator variable when examining interest-phase movement.

Practically, the findings suggest that relatively brief but recurring opportunities for student choice, visual manipulation, and reflective questioning may alter how students relate to abstract mathematics content. A 15-minute weekly exploration window and structured portfolio prompt are not high-resource additions, though they require deliberate curricular planning and teacher facilitation skill. The full intervention package, including the interactive digital board, tablet devices, and GeoGebra/Desmos software, requires significant infrastructure and preparation investment; implementation feasibility must therefore be examined carefully before policy scaling. A lower-resource adaptation might prioritise the open-exploration window and portfolio reflection components as the primary interest-agency and SRL-scaffolding mechanisms.

The teacher's role warrants particular emphasis as the most significant uncontrolled variable in this study. The experimental teacher had attended one ICT workshop; the control teacher had none. This alone constitutes a plausible alternative explanation for the observed motivation and engagement differences, independent of any technology or interest-design effect. Technology did not produce the learning environment on its own; the intervention depended on the experimental teacher's capacity to frame tasks, sustain inquiry, manage pair collaboration, and scaffold students' mathematical reasoning from GeoGebra and Desmos manipulation. The observed outcomes may substantially reflect teacher digital confidence and instructional responsiveness rather than the designed materials. Future studies should include teacher-specific outcome measures, multiple teachers per condition, and multi-school designs to disentangle teacher effects from instructional design effects — a step this study could not take.

The self-regulation findings merit attention. The adjusted mean difference on the MSLQ-SRL (1.56 scale points on a 7-point scale, partial $\eta^2 = .480$) exceeded the motivational difference in practical magnitude. The findings may indicate that explicit portfolio-based SRL scaffolds, when paired with interest-supportive mathematics tasks, encouraged students to report more frequent goal-setting and metacognitive monitoring. Because the MSLQ-SRL captures self-reported strategic behaviour rather than directly observed regulation, the large effect may partly reflect increased awareness of regulatory strategies generated through the weekly portfolio prompts rather than fully spontaneous self-regulation. The study did not measure mathematics achievement; it cannot determine whether motivational and regulatory gains translated into improved mathematical performance, which is an important limitation given the study's instructional context.

The study extends the Four-Phase Model by illustrating how GeoGebra and Desmos visualisation, contextual relevance framing, and structured learner agency may function as classroom design mechanisms for supporting students' movement from externally triggered interest toward more self-initiated interest patterns in secondary mathematics. The findings suggest the Four-Phase Model can function productively as a prescriptive design framework in sub-Saharan African mathematics classrooms, a context in which the model has received limited

empirical testing. The results must be interpreted within important constraints: school-level confounding, bundled intervention components, teacher ICT experience differential, researcher presence, and social desirability responding in self-report instruments all represent plausible alternative explanations for the observed associations.

Conclusion

This exploratory quasi-experimental study found that a ten-week multi-component interest-driven technology-enhanced mathematics instructional programme was associated with significantly higher motivation, engagement, and self-regulated learning among SS 2 students in Bwari Area Council, FCT, Nigeria, compared with conventional instruction. These findings are preliminary student-level estimates: treatment was confounded with school identity, components were bundled, and causal attribution to any single element is not possible. The Four-Phase Model provided a theoretically productive design and interpretive framework, and interest-phase transition data offer tentative support for its prescriptive utility in sub-Saharan African secondary mathematics classrooms, subject to the caveat that the IPIS is researcher-developed and carries limited psychometric authority. Replication using cluster-randomised designs, multiple teachers per condition, validated instruments, and curriculum-aligned achievement measures is the essential next step. The Four-Phase Model provided a theoretically coherent framework for intervention design and interpretation, with interest-phase transition data offering tentative evidence of motivational developmental shifts. Independent replication is needed to confirm these associations.

Recommendations

Based on these exploratory findings, four context-specific recommendations are offered. First, mathematics teachers in FCT public secondary schools may consider incorporating brief recurring student-choice exploration windows (10–15 minutes per lesson) and structured portfolio prompts as low-resource additions to instruction, even in classrooms without full digital infrastructure. Second, FCT Education Secretariat professional development programmes should integrate interest-support design principles alongside ICT operational skills training, as teacher facilitation capacity appears central to observed outcomes. Third, school administrators may explore structured, topic-bounded student-initiated exploration within regular mathematics timetabling to support interest development beyond Phase 1. Fourth, researchers and curriculum developers should prioritise multi-school, multi-teacher replication studies that include curriculum-aligned mathematics achievement measures and component-specific fidelity tracking before policy-level scaling of technology-enhanced interest-driven instructional packages.

Limitations

Four critical limitations bound the interpretability of this study's findings. First, and most fundamentally, treatment was assigned at the school level: only two school clusters constituted the effective comparison units, meaning treatment effects and school-level differences — including teacher characteristics — are inseparable in this design; no cluster-robust inference was estimable. Second, mathematics achievement was not measured; the study cannot determine whether motivational and SRL gains were accompanied by improved conceptual understanding or problem-solving performance, which is an important omission for an instructional study. Third, the IPIS is researcher-developed and has not undergone independent psychometric validation; interest-phase findings are exploratory and carry substantially lower evidentiary weight than the ANCOVA outcomes. Fourth, fidelity monitoring was partial: the control condition is largely undocumented, no validated fidelity instrument was used, and the two unobserved intervention weeks relied solely on the intervention teacher's self-report.

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