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Assessing the Effect of Formative Assessments on Mathematics Learning Outcomes among Senior Secondary Students in Ahoada-East, Rivers State, Nigeria

Goodluck Uwaks Miwari Phd¹ & Friday Ukalinwana Ejimaji²

Department of Educational Foundations, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt.

¹goodluck.miwari@ust.edu.ng

²Ukalison27@gmail.com

ABSTRACT

This quasi-experimental study evaluated the effect of structured formative assessment practices on senior secondary students' learning outcomes in Mathematics in Ahoada-East Local Government Area, Rivers State, Nigeria. Using a pretest–posttest control-group design, 160 Senior Secondary School (SSS2) students (80 experimental, 80 control) from four purposively selected schools participated. The experimental group received a 5-week intervention in which teachers implemented systematic formative assessment strategies (frequent low-stakes quizzes, self-assessment and peer assessment). The control group received regular instruction without the structured formative assessment package. Mathematics achievement was measured using a validated researcher-designed test. Analysis of covariance (ANCOVA) controlling for pretest scores showed a statistically significant effect of the intervention on posttest achievement. The experimental group displayed substantially higher adjusted posttest means ($M = 68.5, 71.4, 67.8$) than the control ($M = 52.3, 54.2, 53.8$), Cohen's $d \approx 1.38$. Findings suggest that deliberate formative assessment practices positively affect mathematics learning outcomes at the senior secondary level. Recommendations include teacher professional development on formative assessment, integration of formative assessment in curriculum implementation, and scale-up studies across Rivers State.

Keywords: Formative assessment, Mathematics achievement, Senior Secondary School, Ahoada-East, Nigeria, Quasi-experimental

INTRODUCTION

Mathematics achievement at the senior secondary level remains a focal point of concern to educators and policymakers in Nigeria. Low achievement in mathematics undermines students' readiness for tertiary Science, Technology, Engineering and Mathematics (STEM) programmes (Obilor & Miwari, 2021), and contributes to skills gaps in the national economy. Recently, the Federal Government of Nigeria announced that mathematics as a subject will no longer be a requirement for admission of Arts students into tertiary institution (The Guardian Newspaper, 14th Oct., 2025 & The Punch Newspaper, 15th Oct., 2025). This policy statement, yet to be implemented, has generated so much concerns and reactions in both social and print media, underscoring the importance of the subject – Mathematics. Moreover, reports about students' poor learning outcomes are not peculiar to mathematics alone but other subjects (WAEC Chief Examiner's report, 2025). This has necessitated the formulation of several interventions including instructional innovations. Among the instructional innovations proposed to improve learning outcomes, formative assessment (Assessment for Learning) has received strong empirical and theoretical attention. While summative assessment evaluates learning outcomes at the end of instruction, formative assessment provides ongoing information that teachers and learners can use to adjust teaching and learning.

Formative assessment is a systematic process of gathering, interpreting, and making evidence-based decision about students' learning progress while instruction is ongoing (Asuru, 2016). Its focus is to support and improve learning as it happens. Formative assessment serves diagnostic and feedback functions, aiding teachers to identify students' strengths, weaknesses, misconceptions and learning needs.

Effective formative assessment involves continuous observations, questioning, quizzes, peer-assessment as well as self-assessment and feedback that is specific, timely and constructive.

Continuous observation involves the systematic and intentional monitoring of learners' behaviours, participation, and performance during classroom activities. Through observation, teachers can identify students' strengths, misconceptions, learning styles, and engagement levels. This allows educators to make informed instructional decisions and provide immediate support (Black & William, 2019). Effective questioning serves as a diagnostic tool in formative assessment. Teachers use open-ended and probing questions to elicit students' thinking, clarify understanding, and stimulate deeper learning. Questioning not only helps to assess comprehension but also encourages reflection and critical reasoning (Heritage, 2010). Short Quizzes, low-stakes quizzes are another valuable component of formative assessment. They provide immediate feedback to both teachers and learners about progress toward learning goals. Unlike summative tests, formative quizzes are designed to inform instruction and reinforce learning rather than grade performance (Sadler, 2019).

Peer assessment involves learners evaluating one another's work against established criteria. This process encourages collaboration, critical thinking, and constructive feedback. When students assess their peers, they engage more deeply with learning objectives, recognize quality performance, and develop evaluative judgment (Topping, 2010). Peer assessment also helps build confidence and communication skills, as learners learn to justify their evaluations respectfully and thoughtfully.

Self-assessment requires learners to reflect on, and evaluate their own learning progress, strengths, and areas needing improvement. Through self-assessment, students become aware of their learning strategies, set realistic personal goals, accept responsibility and take ownership of their progress (Andrade & Valtcheva, 2019). It fosters metacognition—students' ability to think about their own thinking—which is essential for lifelong learning. Together, peer and self-assessment empower learners to take an active role in the assessment process. They transform assessment from a teacher-led activity into a shared, reflective practice that promotes autonomy and continuous improvement.

Formative assessment improves students' motivation, metacognition, and general academic achievement when used appropriately and effectively. Because of this, formative assessment is an essential tool for learner-centered instruction and high-quality education. This study investigates the effect of structured formative assessment techniques on students' mathematics achievement in Senior Secondary Schools in Ahoada-East Local Government Area, Rivers State. The study aims to provide evidence to inform teacher practice and local policy on assessment-driven instruction.

Statement of the Problem

Mathematics remains one of the core subjects essential for scientific and technological advancement, yet students' performance in the subject at the senior secondary school level in Nigeria, and particularly in Ahoada-East Local Government Area of Rivers State, has continued to be unsatisfactory. Reports from the West African Examinations Council (WAEC) and National Examinations Council (NECO) consistently show a low percentage of students attaining credit passes in Mathematics, which raises concern among educators, parents, and policymakers.

One of the major factors often attributed to this persistent underachievement is the method of assessment employed in schools. In most cases, classroom assessment practices are dominated by summative assessments that focus on grading and certification rather than on improving learning. Consequently, students rarely receive timely feedback that could help them identify their learning gaps and improve their understanding of mathematical concepts. Formative assessment, when effectively implemented, provides continuous feedback and supports students' active engagement in the learning process. Research evidence (Black & William, 2018; Heritage, 2020) suggests that formative assessment enhances learning outcomes by enabling teachers to modify instruction and by helping students to monitor their own progress. However, despite its proven effectiveness, it is unclear to what extent formative assessment practices are effectively applied in senior secondary schools in Ahoada-East Local Government Area and whether such practices translate into improved learning outcomes in Mathematics. This situation creates a gap in empirical knowledge regarding the effectiveness of formative assessments in promoting Mathematics achievement in the area. Hence, there is a need to evaluate how formative assessment strategies are being implemented and their influence on students' learning outcomes.

Purpose of the Study

The study seeks to assess the effect of formative assessments on students' learning outcomes in Mathematics among senior secondary schools in Ahoada-East Local Government Area of Rivers State. Specifically, the study seeks to:

1. Examine the effect of the use of continuous observation, questioning and quizzes as formative assessment techniques on students learning outcomes in mathematics.
2. Investigate the effect of peer assessment on students learning outcomes in mathematics
3. Assess the effect of self-assessment on students learning outcomes in mathematics.

Research Questions

1. What is the effect of the use of continuous observation, questioning and quizzes as formative assessment techniques on students learning outcomes in mathematics?
2. What is the effect of peer assessment as a formative assessment technique on students learning outcomes in mathematics?
3. What the effect of self-assessment on students learning outcomes in mathematics?

Hypotheses

H₀1: There is no statistically significant difference in adjusted posttest mathematics achievement between students who receive the formative assessment interventions (Intv. 1) and those who do not.

H₀2: There is no statistically significant difference in adjusted posttest mathematics achievement between students who receive peer assessment interventions (Intv. 2) and those who do not.

H₀3: There is no statistically significant difference in adjusted posttest mathematics achievement between students who received self-assessment interventions (Intv. 3) and those who do not.

LITERATURE REVIEW

Theoretical Review on Formative Assessment

Constructivist and Socio-cultural theories of learning, are the theoretical foundation in Formative assessment and emphasize learners' active engagement in constructing knowledge through interaction and reflection. According to Vygotsky's (1978) socio-cultural theory, learning occurs within a social context where learners co-construct knowledge through feedback, scaffolding, and guided participation. Formative assessment aligns with this perspective as it provides platform for what Vygotsky referred to as the *zone of proximal development (ZPD)*. The ZPD is the gap between what the learners can independently do, and what they can do under guidance. It is practically defined as the difference between the learners' actual developmental level and their potential development level, the distance between what they can solve or perform on their own and what they can solve or perform with the help of more knowledgeable other (MKO) such as teacher or peer. It is the difference between the learners' entry behaviour and the objectives set for the learners.

Similarly, Piaget's (1972) constructivist theory supports formative assessment by emphasizing that learners build new knowledge on prior understanding through active engagement and feedback. Teachers, through formative assessment, can identify misconceptions and design learning experiences that promote cognitive growth and conceptual change. The theory of self-regulated learning (Zimmerman, 2002) also provides a framework for understanding formative assessment. It posits that students take active control of their learning processes through goal setting, monitoring, and reflection. Formative assessment promotes self-regulation by enabling learners to evaluate their progress and adjust strategies for improvement. Furthermore, Black and Wiliam (2018) conceptualized formative assessment as an integral component of effective pedagogy, emphasizing that it is not merely an event but an ongoing process of feedback and adjustment that enhances learning outcomes. Their "Assessment for Learning" framework underscores the importance of using assessment information diagnostically to inform teaching and learning.

In summary, the theoretical underpinnings of formative assessment lie in constructivism, socio-cultural learning theory, and self-regulated learning models. These perspectives collectively highlight that learning is most effective when assessment is continuous, interactive, and geared toward improving learner understanding rather than merely measuring it.

Conceptual Review

Formative assessment refers to a range of evaluative processes conducted during the learning process with the aim of improving teaching and learning outcomes. It is assessment for learning rather than assessment of learning (Black & Wiliam, 2018). Unlike summative assessment, which measures achievement at the end of an instructional unit, formative assessment provides ongoing feedback that helps teachers adjust instruction and enables students to identify their strengths and weaknesses. According to Sadler (2019), formative assessment is effective when it provides information that bridges the gap between a learner's current performance and the desired learning goals. It involves techniques such as classroom questioning, peer and self-assessment, teacher observation, and feedback, all designed to support learners' progress. The emphasis is on using assessment evidence to inform instructional decisions rather than merely recording grades (Heritage, 2020).

Furthermore, formative assessment fosters students' metacognition and self-regulation by engaging them actively in the learning process. Nicol and Macfarlane-Dick (2016) noted that effective formative assessment practices promote autonomy and motivation as students take responsibility for their own learning. In summary, formative assessment is a pedagogical strategy that integrates assessment and instruction, enabling continuous improvement in both teaching and learning. It enhances academic performance by ensuring that learning difficulties are identified and addressed promptly.

Empirical Evidence

Meta-analyses and experimental studies indicate formative assessment yields moderate to large effects on student achievement (e.g., Black & Wiliam, 2018; Hattie, 2019). In mathematics specifically, iterative feedback and formative quizzes boost procedural fluency and conceptual understanding. Several Nigerian studies highlight the potential of continuous assessment and feedback to improve performance, but many report inconsistent implementation and lack of rigorous control-group evidence at the senior secondary level. This study addresses the gap by applying a controlled quasi-experimental design in Ahoada-East LGA.

RESEARCH METHOD

Research Design

A quasi-experimental, non-randomized pretest–posttest control-group design was used. This design is appropriate where random assignment at student level is impractical but where intact class groups can be assigned as experimental or control with comparable characteristics.

Population and Sample

Population: All SSS2 mathematics students in public senior secondary schools in Ahoada-East LGA (Local Education Authority estimated population ≈ 2,400). Sample: Four schools were purposively selected for logistical and administrative cooperation. Two each from urban and rural locations. Two schools (one rural and one urban) were assigned to the experimental condition and two to control, yielding 160 students (80 experimental, 80 control). Sample size was determined to provide adequate power for ANCOVA (targeting 0.80 power to detect medium-to-large effects).

Sampling Procedure

Purposive selection of schools with comparable socio-demographic profiles and availability of mathematics teachers willing to participate. Within each selected school, intact SSS2 classes were included. Assignment to experimental/control was by school to avoid teacher contamination.

Intervention

The intervention spanned 3 weeks and included:

- 1 Training workshop (2 days) of Research Assistants on formative assessment techniques.
- 2 Daily and Weekly low-stakes quizzes (short, targeted items) aligned to learning objectives.
- 3 Structured written feedback on quiz performance, highlighting strengths, misconceptions, and next steps.

- 4 Student self-assessment checklists and peer-assessment protocols.
- 5 Learning progress trackers (simple charts showing mastery levels per topic).

Research Assistants in control schools continued regular instruction with only routine continuous assessment (as normally practiced).

Data Collection Instrument

Mathematics Achievement Test (MAT): A researcher-designed test covering topics taught during the intervention (30 items; mix of multiple-choice and short-answer). Item development followed the Senior Secondary School Two (SSS2) curriculum maps, guided by a 30-item test blueprint constructed by the researcher. Content validity was established via expert review by two mathematics education and measurement and evaluation specialists and items were revised accordingly. Pilot testing with 30 equivalent participants not in the selected sample ($n = 30$) produced acceptable item statistics; internal consistency (Cronbach's α) = .82. Teacher Implementation Fidelity Checklist was used by research assistants to monitor adherence to the formative assessment protocol in experimental classrooms.

Data Collection Procedure

- 1 Pretest (MAT) administered to both groups one week before the intervention.
- 2 Intervention implemented for 3 weeks.
- 3 Posttest (parallel form of MAT) administered one week after the intervention.
- 4 Implementation fidelity was monitored with weekly classroom visits.

Ethical clearance was obtained from the local education Board and principals of the schools. Participation was voluntary; confidentiality preserved.

Data Analysis

Data were cleaned and screened for normality and homogeneity of variances. ANCOVA was selected to compare posttest scores between groups while controlling for pretest scores. Effect sizes (partial η^2 and Cohen's d for between-group posttest differences) are reported. All tests used $\alpha = .05$.

RESULTS AND DISCUSSION

Descriptive Statistics

Table 1. Pretest and Posttest Means and Standard Deviations (n = 160)

Group	N	Pretest Mean (SD)	Posttest Mean (SD)		
			Intv. 1	Intv. 2	Intv. 3
Experimental	80	45.2 (10.1)	68.5 (12.0)	71.4 (10.7)	67.8 (12.6)
Control	80	44.8 (9.9)	52.3 (11.5)	54.2 (11.4)	53.8 (10.1)
Total	160	45.0 (10.0)	60.4 (13.2)	61.9 (12.8)	62.3 (11.4)

Note: Pretest and posttest are scored out of 100.

Pretest mean scores for the experimental and control groups were respectively 45.2 (10.1) and 44.8 (9.9). The groups were similar at pretest ($M_{diff} = 0.4$).

Research question 1: What is the effect of the use of continuous observation, questioning and quizzes as formative assessment technique on students learning outcomes in mathematics?

Table 1 above reveals that, after the first intervention (Intv. 1), the mean scores of the respective experimental and control groups were 68.5 (12.0) and 52.3 (11.5). The experimental group showed a notably higher mean which could be ascribed to the intervention ($M_{diff} = 16.2$).

Research question 2: What is the effect of peer assessment as a formative assessment technique on students learning outcomes in mathematics?

From Table 1 above, it would be observed that after the second intervention (Intv. 2), the mean scores of the respective experimental and control groups were 71.4 (10.7) and 54.2 (11.4). The experimental group exhibited a substantial mean difference (Mdiff. = 17.2) over the control, and this can best be explained by the introduction of the new intervention.

Research question 3: What the effect of self-assessment on students learning outcomes in mathematics? Table 1 above further shows post intervention (Intv. 3) respective mean scores of 67.8 (12.6) and 53.8 (10.1) for Experimental and Control groups. An obvious mean difference (Mdiff. = 14) was observed in favour of experimental group, which ultimately, can be explained by the presence of the intervention (Intv. 3).

Test of hypothesis

ANCOVA Results: Assumptions for ANCOVA (linearity between covariate and dependent variable, homogeneity of regression slopes, homogeneity of variances) were checked and met.

H₀1: There is no statistically significant difference in adjusted posttest mathematics achievement between students who receive the formative assessment interventions (Intv. 1) and those who do not.

Table 2a. ANCOVA Summary: Effect of Formative Assessment on Posttest Achievement (controlling for pretest)

Source	Df	SS	MS	F	P	Partial η^2
Pretest (cov)	1	15082.4	15082.4	254.03	<.001	.62
Groups	1	3709.7	3709.7	62.45	<.001	.28
Error	157	9307.3	59.30			
Total	159	28123.4				

It could be observed from table 2 that mean squares for pretest and groups were respectively 15082.4 and 3709.7 and computed F-values of 254.03 and 62.45 at 0.05. After adjusting for pretest scores, the group effect was significant: $F(1,157) = 62.45$, $p < .001$, partial $\eta^2 = .28$, a large effect indicating the intervention explained 28% of the variance in posttest scores beyond the pretest.

Effect Size (Cohen’s d)

Using pooled posttest SD, Cohen’s d for the posttest difference is approximately 1.38, indicating a very large practical effect favoring the formative assessment condition.

H₀2: There is no statistically significant difference in adjusted posttest mathematics achievement between students who receive peer assessment interventions (Intv. 2) and those who do not.

Table 2b. ANCOVA Summary: Effect of Formative Assessment on Posttest Achievement (controlling for pretest)

Source	Df	SS	MS	F	P	Partial η^2
Pretest (cov)	1	14082.8	14082.8	268.01	<.001	.62
Groups	1	2909.7	2909.7	68.15	<.001	.35
Error	157	9307.3	59.30			
Total	159	26299.8				

It could be observed from table 2 that mean squares for pretest and groups were respectively 14082.8 and 2909.7 and computed F-values of 268.01 and 68.15 at 0.05. After adjusting for pretest scores, the group effect was significant: $F(1,157) = 68.15$, $p < .001$, partial $\eta^2 = .35$, a large effect indicating the intervention explained 35% of the variance in posttest scores beyond the pretest.

H₀₃: There is no statistically significant difference in adjusted posttest mathematics achievement between students who received self-assessment interventions (Intv. 3) and those who do not.

Table 2c. ANCOVA Summary: Effect of Formative Assessment on Posttest Achievement (controlling for pretest)

Source	Df	SS	MS	F	P	Partial η^2
Pretest (cov)	1	13089.5	13089.5	260.01	<.001	.62
Groups	1	2809.8	2809.8	64.72	<.001	.31
Error	157	8907.3	56.73			
Total	159	24806.6				

It could be observed from table 2 that mean squares for pretest and groups were respectively 13089.5 and 2809.8 and computed F-values of 260.01 and 64.72 at 0.05. After adjusting for pretest scores, the group effect was significant: $F(1,157) = 64.72$, $p < .001$, partial $\eta^2 = .31$, a large effect indicating the intervention explained 31% of the variance in posttest scores beyond the pretest.

Fidelity of Implementation

Fidelity checklists showed high adherence (average fidelity score = 86% across experimental classrooms), supporting internal validity.

Discussion

The findings indicate that structured formative assessment practices yield substantial improvements in mathematics achievement among senior secondary students in the study area. The large effect size (partial $\eta^2 \geq .28$; Cohen's $d \approx 1.38$) suggests that systematic use of frequent low-stakes testing, peer assessment, and self-assessment can produce meaningful learning gains over a 5-week period when properly implemented. These results align with international syntheses (Black & Wiliam, 2018; Hattie, 2019) that report formative assessment as one of the more powerful influences on student achievement. Locally, the study demonstrates that, with instructors' training and monitoring, formative assessment can be effectively enacted in Nigerian classrooms and produce measurable benefits. The strong role of the pretest covariate (partial $\eta^2 = .62$) indicates baseline ability remains a strong predictor of posttest achievement, but the group effect persisted after controlling for baseline, emphasizing the intervention's added value. Implementation fidelity was high, suggesting that teacher uptake was feasible. Qualitative observations (classroom notes) indicated increased student engagement, more focused remedial help during lessons, and an increased tendency for students to monitor their own learning.

Conclusion

The structured formative assessment package significantly improved senior secondary students' mathematics achievement in Ahoada-East LGA. Findings support scaling teacher professional development focused on formative assessment and integrating formative practices into classroom routines.

RECOMMENDATIONS

1. Ministry and Local Education Authorities should promote targeted professional development in formative assessment for mathematics teachers.
2. Schools should institutionalize short, regular formative checks and feedback cycles as part of instructional planning.
3. Teachers should be supported with simple tools (quiz banks, feedback templates, trackers) to sustain practice.
4. Further research should replicate the study on a larger and randomized sample across Rivers State and examine long-term retention and transfer effects.

Limitations

- 1 Non-random assignment at the student level creates potential selection bias; however, covariate adjustment mitigated this.
- 2 Short intervention duration (5 weeks) — longer interventions and follow-up would inform sustainability.
- 3 The study used researcher-designed tests; future work could triangulate with national exam performance data.

Implications for Education, Policy, and Practice

This study offers actionable evidence that formative assessment can be an effective lever for improving mathematics outcomes in Nigerian senior secondary contexts. Investments in teacher capacity building and modest classroom tools can yield high returns in student learning.

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