Annals of Technology Education Practitioners Association of Nigeria
ATEPAN (September, 2026) 11(1), 89-92
ISSN: 2645-2839 (Print)
eISSN: 2645-2847 (Online)

THE EFFECTS OF FORMATIVE ASSESSMENT CLASSROOM TECHNIQUES (FACTS) ON SENIOR SECONDARY SCHOOL STUDENTS' ACHIEVEMENT IN MATHEMATICS

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Abstract: *The study investigated the effects of Formative Assessment Classroom Techniques (FACTs) on senior secondary school students' achievement in mathematics, and whether the effect varied with gender, school ownership and ability level. Five research questions and five null hypotheses, tested at the .05 level, guided the study. A quasi-experimental non-equivalent (pre-test, post-test) control-group design was used. The population was 3,464 SS1 students in the 16 public and private senior secondary schools of Onitsha North Local Government Area, Anambra State; four schools (two public, two private) contributed 50 students each, giving a sample of 200. Experimental classes were taught mensuration for four weeks using FACTs and control classes with the conventional method. Data were collected with a 30-item Mathematics Achievement Test (test–retest reliability = .82) and analysed with t-tests and analysis of variance. Students taught with FACTs achieved significantly higher than those taught conventionally ($M = 20.52$ vs. 16.01; $t(198) = 11.26$, $p < .001$; $d = 1.59$). Within the FACTs group, achievement did not differ significantly by gender ($p = .110$) or school ownership ($p = .110$); post-test scores did not differ significantly among ability levels ($p = .358$); and the interaction effect was not significant ($p = .628$). Because only four intact classes were involved, gender and ownership are confounded with school and the findings are preliminary. Recommendations include the use of FACTs by mathematics teachers, seminars and workshops on FACTs, training of student teachers in FACTs, and inclusion of FACTs in curriculum development.*
Keywords: *formative assessment classroom techniques, mathematics achievement, gender, school ownership, ability level*

Introduction

Mathematics is regarded as the language of science and technology and a means of sharpening reasoning, and no nation can pursue scientific and technological development without paying attention to its teaching and learning. In Nigeria it is compulsory at the basic and post-basic levels and must be credited in the Senior School Certificate Examination irrespective of a student's intended course of study; the National Policy on Education states its objectives as laying a foundation for everyday living, developing computational skills, precise and logical thinking, problem solving and creativity (Federal Republic of Nigeria [FRN], 2013). Despite this importance, low achievement of students in mathematics at the junior and senior secondary levels has been a persistent concern to educational stakeholders. (WAEC Chief Examiners Report, 2005).

Reasons proposed include students' interest, anxiety, motivation, numerical and reasoning ability, problem-solving skill and instructional strategy. One factor teachers control directly is how they assess. Assessment refers to the methods teachers use to evaluate, measure and document students' academic readiness, learning progress, skill acquisition and educational needs. Summative assessment, an assessment *of* learning, certifies achievement at the end of an instructional period and still dominates classroom practice because most teachers' target is examination preparation (Stiggins, 2002). Formative assessment, an assessment *for* learning, is an ongoing process of finding out where a student is in the learning process and using the evidence to decide what instruction should follow (Assessment Reform Group, 2002; Black & Wiliam, 1998a, 2009). A familiar analogy holds that when the cook tastes the soup it is formative, and when the customer tastes it, summative. In mathematics, formative assessment is designed to make students' thinking visible: how they reason through problems, the depth of their conceptual and procedural understanding, and the prior knowledge they bring to a concept (Hodgen &

Wiliam, 2006; Wiliam, 2011). The concrete strategies through which teachers carry out formative assessment in mathematics lessons are called Formative Assessment Classroom Techniques (FACTs). They include range questions, observation protocols, gallery walks, round-robin activities, focused questions, hinge questions, interviews and conferences, mathematical discourse, neutral feedback and exit cards (NCTM, 2000; see Section 1.3). Recent syntheses indicate that formative assessment has a positive but modest average effect on K-12 achievement, with considerable variation across contexts and designs (Lee et al., 2020; Sortwell et al., 2024; Yao et al., 2024). Evidence on FACTs specifically in Nigerian mathematics classrooms remains limited.

Assessments take many forms, but all provide a snapshot of what students understand at a particular time. Summative assessments document how much has been learned at the end of a unit, semester or year, while formative assessments monitor progress during instruction to provide ongoing feedback to students and teachers (Black & Wiliam, 1998a; Stiggins, 2002). In the assessment-for-learning tradition, the first priority in the design of an assessment is to promote learning rather than to rank or certify (Assessment Reform Group, 2002; Hodgen & Wiliam, 2006). Theoretically, formative assessment works by helping learners and teachers identify the gap between current and desired performance and act to close it (Sadler, 1989; Black & Wiliam, 2009), and the quality of feedback determines how far it improves learning (Hattie & Timperley, 2007). Igbokwe and Eze's (2019) observation that the quality of teachers' assessment has a lasting effect on achievement is consistent with this view.

Following the mathematics-assessment literature adopted in the thesis (NCTM, 2000), four key formative practices are recognised, each supported by specific techniques (Table 1): assessing prior knowledge, assessing students at work, probing students' thinking, and using assessment to plan instruction. Teachers who use these techniques take a more active role in interpreting students' responses and adapting lessons, while students take part in their own assessment (Stiggins, 2002; Wiliam, 2011).

Table 1. Formative assessment classroom techniques (FACTs) for mathematics

Key practice	**Technique**	**Description**
Assessing prior knowledge	Range questions	Posed at the start of a lesson to determine the scope of students' understanding (e.g., "What do you know about the multiples of 6?").
Assessing students at work	Observation protocols	Designed, carefully recorded observations of proficiency in problem solving, computation, communication and disposition; records of progress on which to base instructional decisions.
	Gallery walks	Students rotate among stations to post a comment, strategy, question or solution; the teacher records involvement with an observation protocol.
	Round-robin activities	Groups of three take turns performing successive steps of a computation at the board so the teacher can intervene before a misconception takes hold.
Probing students' thinking	Focused questions	Individual thinking followed by pair discussion and reporting (think-pair-share), engaging all students.

	Hinge questions	Engaging, clarifying and refocusing questions depending on what students are saying or doing.
	Interviews and conferences	Individual interviews, usually outside class time, to understand what a student is thinking.
	Mathematical discourse	Small-group and whole-class conversation under norms of accountable talk, including "math congress" forums.
Using assessment to plan instruction	Neutral feedback	Descriptive comments on the work, not the student, without signals that the work is wrong; comments given without a grade prompt more serious use of feedback.
	Exit cards	Brief (about five-minute) end-of-lesson responses used to judge what was learned and to plan the next lesson.

Syntheses give a consistent but modest picture. Kingston and Nash (2011) estimated a weighted mean effect of about 0.20 standard deviations for K-12 formative assessment (0.17 in mathematics), well below the 0.4–0.7 range popularly cited from Black and Wiliam (1998a). Lee et al. (2020) and, more recently, a meta-analysis of 258 effect sizes from 118 studies (Yao et al., 2024) reported an overall effect of about 0.25 and found larger effects in studies conducted outside North America and Western Europe and in quasi-experimental designs. An umbrella review of 13 meta-analyses concluded that effects range from trivial to large and that the robustness of the evidence is generally low (Sortwell et al., 2024).

Primary studies point the same way. In a Slovak study of 202 secondary students, ten chemistry lessons using FACTs produced significantly higher scores than conventional teaching, for both lower- and higher-order cognitive skills (Babinčáková et al., 2020). In Kenya, Grade 11 students taught mathematics through a formative assessment approach outperformed a conventional group after controlling for pre-test scores (Wafubwa & Csíkos, 2022), and a 12-week quasi-experiment with Grade 10 students found gains in mathematics achievement and attitudes (Kültür & Kutlu, 2021). Boström and Palm (2023) examined the effect on secondary mathematics achievement of changes in teachers' formative assessment practice after a professional development programme. In Nigeria, James and Folorunso (2012) reported a significant effect of formative testing with feedback and remediation on junior secondary mathematics achievement.

A meta-analysis found gender differences in mathematics performance to be small and declining (Friedman, 1989), and more recent Nigerian evidence describes gender differences in mathematical proficiency as dissipating, with only subtle differences in performance (Awofala, 2017). Nonetheless, teaching styles may suit boys and girls differently: girls tend to value understanding and working at their own pace, whereas boys emphasise speed and accuracy in competitive settings (Boaler, 1997). Formative studies in mathematics have often found no gender effect (James & Folorunso, 2012). These findings motivate examining whether FACTs work equally for both genders.

School type is often linked to achievement, and choice-oriented reforms assume that some school types produce better outcomes. Evidence is mixed. Lubienski and Lubienski (2006) found mathematics achievement in public schools slightly higher than in demographically similar private schools, and Braun et al. (2006) reported comparable findings. In Lagos State, Olutola et al. (2021) found significant differences between public and private senior secondary students' achievement and attitude in mathematics

Learners differ in ability, cognitive structure and learning problems, and it is commonly reasoned that these differences affect how they respond to instruction. In the formative assessment literature, lower-attaining students are expected to benefit most because feedback and adjustment target their specific difficulties, thereby narrowing the spread of attainment (Black & Wiliam, 1998b). Whether this holds for FACTs in Nigerian classrooms has not been tested to our knowledge,

Poor performance in senior secondary mathematics in Anambra State and Nigeria at large continues despite government investment in infrastructure and teacher motivation. Assessment practice that emphasises examinations over learning may contribute. Formative assessment is associated with modest but positive average effects, and many teachers practise formative routines without awareness or under-use them. Little evidence exists on the effect of a package of FACTs on Nigerian students' mathematics achievement or on whether that effect depends on gender, school ownership and ability level. This study addresses that gap.

Statement of the Problem

Educators use several kinds of assessment, including formative, summative and diagnostic. Over the years attention has been paid mainly to summative assessment as the basis for judging student performance. Most FACTs are not used effectively by mathematics teachers, partly through lack of awareness; some teachers apply them without knowing that they are formative assessment tools. Local evidence supports this: science teachers in Anambra State were aware of some innovative formative assessment techniques but did not use most of them (Nwuba et al., 2023), and a Ghanaian study found that about half of senior high school teachers lacked the concept of formative assessment although they practised some of its routines unknowingly (Kwadwo & Oduro-Okyireh, 2019). Where FACTs are under-used and other forms of assessment are prioritised, students' achievement in mathematics may be adversely affected. The study therefore examined the effect of FACTs on senior secondary school students' achievement in mathematics.

Research Questions

The following research questions were raised to guide the study:

1. Is there any difference in achievement of students taught with Formative Assessment Classroom Techniques (FACTs) and Conventional method?
2. What is the effect of Formative Assessment Classroom Techniques (FACTs) on students' achievement in Mathematics based on gender?
3. What is the effect of Formative Assessment Classroom Techniques (FACTs) on students' achievement in Mathematics based on school ownership?
4. What is the effect of Formative Assessment Classroom Techniques (FACTs) on students' achievement in Mathematics based on student ability level?
5. What is the interaction effect between gender, school ownership and student ability level achievement in Mathematics?

Hypotheses

The following hypotheses were formulated at 0.05 level of significance:

1. There is no significant difference in the mean achievement scores of students taught with Formative Assessment Classroom Techniques (FACTs) and Conventional method.
2. There is no significant difference in the mean achievement score of students taught with Formative Assessment Classroom Techniques (FACTs) based on gender.
3. There is no significant difference in the mean achievement score of students taught with Formative Assessment Classroom Techniques (FACTs) based on school ownership.
4. There is no significant difference in the mean achievement score of students taught with Formative Assessment Classroom Techniques (FACTs) based on ability levels.

5. There is no significant interaction effect of gender, school ownership and ability level on students' achievement in Mathematics.

Methodology

The study employed a quasi-experimental non-equivalent (pre-test, post-test) control-group design, adopted because intact classes were assigned to the experimental and control groups (Shadish et al., 2002). Both groups took the pre-test (O1) and post-test (O2); the experimental group received treatment using FACTs (X1) and the control group received conventional teaching (X2). The population comprised 3,464 SS1 students (1,255 male, 2,209 female) in the 16 public and private senior secondary schools of Onitsha North Local Government Area, Anambra State (Post Primary Schools Service Commission, Onitsha Zone, 2023). Four schools were selected and 50 SS1 students, the standard class size specified by state policy, were drawn from each, giving a sample of 200 (Table 2). The experimental group comprised Government Technical College (GTC, public, male) and Queen of the Rosary College (QRC, private, female); the control group comprised Dennis Memorial Grammar School (DMGS, private, male) and Ado Girls Secondary School (Ado, public, female). Consequently, within each group gender and school ownership coincide with the two classes. The instrument was the Mathematics Achievement Test (MAT), 30 multiple-choice items with four options each, on four mensuration topics: perimeter and area of sectors and segments; surface area of cube and cuboid; volume of cone and cylinder; and volume and surface area of compound shapes. A table of specification allocated items to cognitive levels (five knowledge, five comprehension, five application and fifteen higher-order items). Face validity was established by the researcher's supervisor and three secondary-school mathematics teachers, whose corrections were adopted; content validity was established through the table of specification. Reliability was estimated by the test–retest method: the test was administered twice, one month apart, to 25 students and the Pearson product-moment coefficient was .82. The Mathematics Achievement Test (MAT) was scored as follows: questions answered correctly was scored 1 mark each making a total of 30 marks while incorrect answers was scored 0 marks. The hypotheses were tested using t-test and Analysis of variance (ANOVA) statistics. All hypotheses were tested at 0.05 level of significance ($p<0.05$).

Results and Analysis

Table 1. t-test comparison of post-test achievement of students taught with FACTs and the conventional method

Group	*N*	Mean	*SD*	df	*t*	*p*	Decision
Experimental (FACTs)	100	20.52	3.75	198	11.26	< .001	Reject H1
Control (conventional)	100	16.01	1.40				

Note. Mean difference = 4.51, 95% CI [3.72, 5.30]; $d = 1.59$. Welch $t(125.88) = 11.26$, $p < .001$; Mann–Whitney $U = 8{,}978.5$, $p < .001$.

The p value is below .05, so the null hypothesis is rejected: students taught with FACTs achieved significantly higher than those taught with the conventional method (Table 4; Figure 1a).

Table 2. t-test comparison of achievement of FACTs students by gender

Group	*N*	Mean	*SD*	df	*t*	*p*	Decision
Male (GTC)	50	19.92	3.52	98	−1.61	.110	Not reject H2
Female (QRC)	50	21.12	3.92				

The p value exceeds .05, so the null hypothesis is not rejected: there is no significant difference in the achievement of male and female students taught with FACTs. Supplementary condition × gender ANOVA across all four classes showed that the FACTs advantage was present for both genders (male: +3.92; female: +5.10; both $p < .001$), with no significant interaction, $F(1, 196) = 2.20$, $p = .140$.

Table 3. t-test comparison of achievement of FACTs students by school ownership

Group	*N*	Mean	*SD*	df	*t*	*p*	Decision
Public (GTC)	50	19.92	3.52	98	−1.61	.110	Not reject H3
Private (QRC)	50	21.12	3.92				

The *p* value exceeds .05, so the null hypothesis is not rejected: there is no significant difference in the achievement of public and private school students taught with FACTs. The supplementary condition × ownership ANOVA gave a non-significant interaction, $F(1, 196) = 2.35$, $p = .127$, with a significant FACTs advantage in both public (+3.90) and private (+5.12) classes (both $p < .001$). Because the two experimental classes differ in gender and ownership simultaneously, Tables 5 and 6 are the same comparison.

Table 4. Post-test achievement of FACTs students by ability level: descriptive statistics and ANOVA

Ability level	*n*	Pre-test *M* (*SD*)	Post-test *M* (*SD*)
Low	42	7.69 (2.96)	20.57 (3.90)
Average	30	15.77 (0.68)	21.17 (3.90)
High	28	22.18 (1.61)	19.75 (3.34)
All	**100**	**14.17 (6.42)**	**20.52 (3.75)**

Source	Sum of squares	df	Mean square	*F*	*p*
Between groups	29.26	2	14.63	1.04	.358
Within groups	1,365.70	97	14.08		
Total	1,394.96	99			

Note. Ability groups were formed from pre-test scores. Kruskal–Wallis $H(2) = 1.34$, $p = .511$; $\eta^2 = .02$. The *p* value exceeds .05, so the null hypothesis is not rejected: post-test achievement of students taught with FACTs did not differ significantly among low-, average- and high-ability students. Descriptively (Figure 1b), low-ability students gained about 12.9 points from pre-test to post-test, average-ability students 5.4 points, and the high-ability group's mean fell by 2.4 points, so the groups converged near 20 points. Because groups were formed from the pre-test, these changes are partly a regression-to-the-mean artefact (Campbell & Kenny, 1999).

Table 5. Analysis of variance of FACTs post-test scores by class and ability level

Source	Sum of squares	df	Mean square	*F*	*p*
Class (gender/ownership)	28.98	1	28.98	2.07	.154
Ability level	29.26	2	14.63	1.04	.356
Class × ability level	13.12	2	6.56	0.47	.628
Error	1,316.60	94	14.01		

The *p* value for the interaction exceeds .05, so the null hypothesis is not rejected: there is no significant interaction effect of gender, school ownership and ability level on achievement. Because gender and ownership are aliased, class is used as a combined factor here.

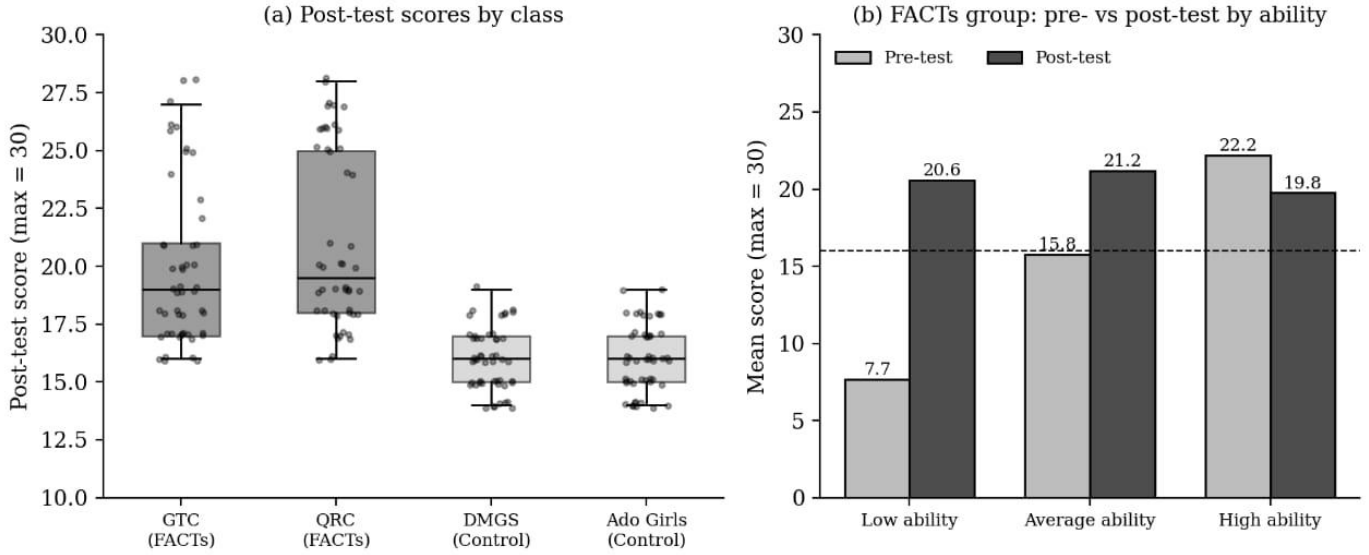


Figure 1. (a) Post-test scores by class; boxes show the interquartile range and median, and points are individual students. (b) Mean pre-test and post-test scores of FACTs students by ability level; the dashed line marks the control group's post-test mean (16.0).

Discussion of Findings

Students taught mathematics with FACTs achieved significantly higher than those taught with the conventional method. This agrees with recent experimental evidence on FACTs and formative assessment (Babinčáková et al., 2020; Kültür & Kutlu, 2021; Wafubwa & Csíkos, 2022) and with Nigerian evidence on formative testing with feedback (James & Folorunso, 2012). It is consistent with the view that eliciting evidence during a lesson and acting on it improves learning (Black & Wiliam, 2009; Sadler, 1989): in the FACTs lessons, range questions surfaced prior knowledge, questioning and round-robin activities exposed reasoning, and exit cards fed planning of the next lesson, although these mechanisms were not measured.

The size of the difference (d = 1.59) is much larger than the average effects in syntheses (about 0.2–0.25; Kingston & Nash, 2011; Yao et al., 2024), although effects are reported to be larger in quasi-experimental studies and outside North America and Western Europe (Yao et al., 2024). With only four classes, the treatment is confounded with school and teacher, the control group's baseline is unknown, and the lessons were short and content-aligned with the test, so the result is best read as strong preliminary evidence rather than a precise estimate.

Gender had no significant influence on the achievement of students taught with FACTs, and the FACTs advantage was similar for male and female classes. This agrees with Wafubwa and Csíkos (2022), who found no gender influence on the effect of a formative assessment approach on mathematics achievement, with James and Folorunso (2012) and with the view that gender differences in mathematics are small (Friedman, 1989; Awofala, 2017). If anything, the female class scored higher, which may reflect girls' preference for understanding-oriented experiences (Boaler, 1997), but the difference was not significant. It should be noted that the classes were single-sex.

School ownership had no significant influence on the achievement of students taught with FACTs. This contrasts with Olutola et al. (2021) who found significant public–private differences in achievement, but is consistent with analyses showing that public-school students do as well as demographically similar private-school students (Braun et al., 2006; Lubienski & Lubienski, 2006). A possible reading is that a common, well-structured instructional approach reduces differences associated with school type, but with one class per ownership category this cannot be separated from school-specific effects.

Post-test achievement did not differ significantly across ability levels, and low-ability students gained the most from pre-test to post-test. This is compatible with the claim that formative assessment helps lower attainers most and narrows the spread of attainment (Black & Wiliam, 1998b). However, because ability groups were defined from the pre-test, regression to the mean would produce the same convergence without any treatment effect (Campbell & Kenny, 1999). A control group classified by ability would be needed to establish differential benefit.

There was no significant interaction between school context (gender and ownership) and ability level. The FACTs advantage therefore did not depend on a particular combination of these characteristics in this sample, although the design could not estimate the full three-way interaction.

Conclusion

Based on the results, students taught mathematics with FACTs performed better than those taught with the conventional method. Gender and school ownership had no significant influence on the achievement of students taught with FACTs. Post-test achievement did not differ significantly among ability levels, with lower-ability students showing the largest gains. There was no significant interaction effect of gender, school ownership and ability level. Because the design involved only four intact classes, these conclusions are tentative.

Recommendations

Based on the findings, the following recommendations are made. First, mathematics teachers should use FACTs in teaching mathematics. Second, seminars and workshops should be organised for mathematics teachers in secondary schools on the use of FACTs. Third, mathematics student teachers should be trained on the use of FACTs in the mathematics methodology course. Fourth, curriculum planners should include FACTs in curriculum development.

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