Cypriot Journal of Educational Sciences

Volume 20, Issue 4, (2025) 247-256

www.cjes.eu

Effect of formative assessment, feedback, and remediation on students' academic achievement in Physics

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Suggested Citation:
Olutola, A.T., Rimi, A.B., & Olatoye, R.A. (2025). Effect of formative assessment, feedback, and remediation on students' academic achievement in Physics. *Cypriot Journal of Educational Science*, *20*(4), 247-256. https://doi.org/10.18844/cjes.v20i4.9529

Received from March 2, 2025; revised from July 9, 2025; accepted from September 1, 2025.
Selection and peer review under the responsibility of Prof. Dr. Hafize Keser, Ankara University, Turkey (retired)

iThenticate Similarity Rate: 9%

Abstract

This study examined the effect of formative assessment, feedback, and remediation on students' academic achievement in physics. Although existing research highlights the value of assessment for learning, limited evidence explains how the combination of formative assessment elements influences performance while considering individual learner characteristics. Addressing this gap, the study aimed to determine the effectiveness of formative assessment strategies and explore the roles of gender and mathematical ability. A quasi-experimental pretest-posttest control group design was implemented using intact classes, with a sample of one hundred and eighty-four senior secondary students assigned to two experimental groups and one control group. Data were collected using the Physics Achievement Test and the Mathematical Ability Test, both validated and confirmed to be reliable. Analysis of data was carried out using Analysis of Covariance with post hoc comparison. Findings demonstrated that formative assessment practices incorporating feedback and remediation improved students' achievement in physics, while gender and mathematical ability showed no meaningful influence on performance. The study concludes that structured formative assessment enhances learning outcomes by enabling continuous monitoring and support. These findings imply the need for instructional approaches that integrate ongoing assessment and targeted intervention to strengthen student understanding.

***Keywords*:** Academic achievement; formative assessment; feedback; physics education; remediation.

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1. INTRODUCTION

The evaluation of students' academic performance constitutes a fundamental component of any educational initiative, as it provides insights into the extent to which specific instructional objectives have been accomplished (Wass et al., 2001; McCarthy et al., 2025). Assessment is an integral element of the educational system and is indispensable to the teaching and learning process, as educational practitioners are unlikely to achieve their objectives without its systematic application (Uzunboylu, 2019; Olutola & Owolabi, 2019). Within the school context, assessment assumes a pivotal role, particularly in monitoring and enhancing the teaching and learning process. In the absence of assessment, educators are unable to identify students' strengths and weaknesses or determine the degree to which instructional goals have been met (Olutola et al., 2016). The outcomes of assessment serve not only as a source of motivation for teachers and students but also as valuable feedback for educators, learners, and other stakeholders in the educational system (Owolabi, 2004).

Teachers routinely conduct evaluations of student learning to achieve a variety of internal objectives. These evaluations are commonly referred to as teacher-made tests, continuous assessment, school-based assessment, and local tests (Olutola, 2016). Such assessments allow educators to determine the extent of students' mastery of knowledge and skills, diagnose learning difficulties, evaluate whether instructional objectives have been met, and appraise students' performance for certification purposes (Olutola & Owolabi, 2019).

Formative assessment, as defined by Eyong (2017) and Kang and Lam (2024), is a type of evaluation conducted during instruction to monitor students' learning progress and provide continuous feedback to both students and teachers regarding the effectiveness of the teaching and learning process. According to Christiana et al. (2015) and Yespolova et al. (2025), successful formative assessment depends on the use of high-quality assessment instruments and the application of data derived from these instruments to enhance instructional practices. Ajogbeje (2012) emphasizes that formative testing involves segmenting course content into smaller instructional units, specifying objectives for each formative test, implementing group-based remediation where deficiencies are identified, and administering summative assessments upon completion of all instructional units. Summative assessment is also employed at the conclusion of each term or session to evaluate the overall attainment of instructional objectives.

Ojugo (2013) asserts that formative assessment is critical for both students and teachers because it enables the identification of learning difficulties and the adoption of remedial strategies to improve performance in the subject area. Remediation, as defined by Ajogbeje and Alonge (2012), involves guiding students to recognize their errors and engage in corrective actions. Cleland et al. (2010) describe remediation as a process comprising three stages: diagnosis, remedial intervention through re-teaching, and re-evaluation.

Within the Nigerian context, studies by Ajogbeje and Alonge (2012), Afemikhe (1985), Ajogbeje (2012), and Erinosho (1988) have demonstrated the effectiveness of formative assessment combined with remediation. These investigations indicate that targeted remediation following formative assessment leads to enhanced academic achievement. Afemikhe (1985) observed that students who received formative assessment with remediation scored higher than those who received formative assessment with feedback only or those who received instruction without formative assessment in mathematics. Similarly, Erinosho (1988) and Ajogbeje (2012) examined the individual components of formative evaluation, including remediation, feedback, and formative tests, in the context of physics and mathematics, respectively. Their findings revealed that students who received remediation demonstrated superior performance compared to those who received only feedback.

Erinosho (1988) further argued that positive feedback on successful performance fosters students' interest and encourages further engagement with the subject, whereas negative feedback can lead either to corrective

action and improved subsequent performance or to feelings of inadequacy and declining interest, resulting in continued poor performance. These findings underscore the importance of implementing formative assessment with feedback and remediation strategies effectively in secondary schools.

Mathematical ability is defined as the capacity to utilize and manipulate numbers effectively in clerical, administrative, scientific, and other numerically oriented tasks (Nizolomon, 2013). It involves the comprehension and application of numerical concepts. Research by Tremblay et al. (2000) supports the notion that mathematical ability can predict achievement in statistics, as further suggested by Harlow et al. (2002), implying that gender and numerical ability do not jointly account for differences in students' achievement in practical geography assessments.

Gender remains a significant and relevant factor in education due to its association with academic achievement and participation in certain professions (Sotonade, 2004). Cultural norms often limit access to particular professions based on gender, including farming, engineering, and trade (Erinosho, 1997; Olatoye & Afuwape, 2004). Consequently, using gender as a moderating variable in experimental research can provide valuable practical insights. However, findings regarding the impact of gender on academic performance have been inconsistent and appear to vary by subject area. For instance, Olatoye (2008) reported no significant difference in science achievement between male and female students. Similarly, Tamir (1990) found no significant gender differences in biology and chemistry performance but observed that males outperformed females in physics.

Finally, a common practice in many school systems is for students' assessment scripts to be retained in teachers' offices and eventually discarded, with feedback often provided only after final examinations. This delayed feedback has limited utility for improving student performance, particularly in subjects such as physics. The prevalent approach of continuous testing without timely feedback and remediation contributes to the persistent mass failure of secondary school students in examinations administered by the West African Examination Council, the National Examination Council, and the National Business and Technical Examination Board (Information on Nigeria Education, 2009).

1.1. Purpose of study

The present study is designed to investigate the Effect of Formative Assessment, feedback, and remediation on Senior Secondary School Students' Physics Achievement in Katsina state, Nigeria.

The following research hypotheses were generated for the study:

H01: There is no significant Main effect of formative assessment on senior secondary school students' achievement in Physics

H02 There is no significant main effect of gender on senior secondary school students' achievement in Physics exposed to formative assessment.

H03: There is no significant main effect of mathematical ability on senior secondary school students' achievement in Physics exposed to formative assessment.

H04; There is no significant interaction effect of formative assessment and gender on senior secondary school students' achievement in Physics

H05: There is no significant interaction effect of formative assessment and mathematical ability on senior secondary school students' achievement in Physics

H06: There is no significant interaction effect of gender and mathematical ability on senior secondary school students' achievement in Physics

H07: There is no significant interaction effect of formative assessment, gender, and mathematical ability on senior secondary school students' achievement in Physics

2. METHOD AND MATERIALS

2.1. Research design

The research design used for this study was a 3x2x2 pre-test, post-test experimental design with two experimental groups and one control group. Mathematical ability and gender were used as moderating variables.

2.2. Participants

The population for this study consisted of all Senior Secondary School Two (SS II) students studying Physics in the Rimi Educational Zone of Katsina State. A purposive sample of one hundred and eighty-four SS II students was drawn from three schools to serve as participants in the study. These schools were assigned to the two experimental groups, Formative Assessment with Feedback and Remediation, and Formative Assessment with Feedback only, and the control group, which received no formative assessment. The schools were purposively selected to ensure sufficient geographical separation, thereby minimizing the possibility of interaction or interference among the groups.

2.3. Data collection instruments

Two instruments were employed for data collection in this study: the Physics Achievement Test (PAT) and the Mathematical Ability Test (MAT). The PAT was used to assess students' achievement in Physics, whereas the MAT was administered to evaluate students' mathematical ability.

2.3.1. Validation of Research Instruments

The research instrument employed for both the pre-test and post-test was the Physics Achievement Test (PAT). The test items were derived from past Physics questions issued by the Joint Admission and Matriculation Board (JAMB). Although these items were sourced from a standardized national examination, they were reviewed by experienced Physics teachers who provided feedback, resulting in the modification or elimination of certain items. Prior to the main study, the PAT was administered to forty-five students who did not participate in the experiment but shared a similar cultural background and studied Physics. This was done to evaluate the consistency and clarity of the test items. The test was administered twice to these students, with a two-week interval between administrations, yielding a test-retest reliability coefficient of 0.83 for the PAT. Likewise, the mathematical ability test demonstrated a reliability coefficient of 0.90.

2.4. Procedures

The study was conducted in a natural school setting, utilizing the regular school timetable and intact classes. Initially, the researcher administered a pre-test, specifically the Physics Achievement Test (PAT), before the commencement of the day's lessons. Following this, the research assistants, who were the regular Physics teachers, implemented the lessons according to the prepared lesson plans.

Three distinct sets of lesson plans were developed for the study, each aligned with the test blueprint. The first set, designed for experimental group 1, consisted of twelve lessons incorporating formative assessment with feedback and remediation. These lessons were structured to reflect the treatment focus for this group and were delivered over a six-week period. The second set, intended for experimental group 2, also comprised twelve lessons, but included formative assessment with feedback only, without remediation. The third set of lesson plans was prepared for the control group and followed the standard expository teaching approach without any formative assessment.

During the intervention, experimental group 1 received expository instruction followed by formative assessment with feedback and remediation, while experimental group 2 received expository instruction followed by formative assessment with feedback only. The control group experienced only expository teaching with no formative assessment. At the end of the second week of instruction, the first formative assessment was administered to experimental group 1 with feedback and remediation, and to experimental group 2 with feedback only. Both assessments were graded by the teachers.

Subsequently, the second formative assessments were administered at the end of the fourth week, and the third assessments at the end of the fifth week, following the same treatment protocols for each experimental group. Throughout the five-week instructional period, the control group did not receive any formative assessments. Six weeks after the completion of the instructional period, all three groups were re-evaluated using the same Physics Achievement Test (PAT) as a post-test. To ensure fidelity to the lesson procedures and minimize deviations by the research assistants, the researcher conducted periodic visits to the schools throughout the experimental process.

3. RESULTS

The results of this study are presented as shown below.

Table 1

ANCOVA of the effect of treatment and moderating variables on students' achievement in physics

Hypothesis	Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
	Corrected Model	13590.350[a]	12	1132.529	5.760	.000
	Intercept	50084.748	1	50084.748	254.733	.000
	Pretest	4423.325	1	4423.325	22.497	.000
HO_1	Treatments	3633.190	2	1816.595	9.239	.000
HO_2	Gender	.022	1	.022	.000	.992
HO_3	Mathematical ability	1919.558	1	1919.558	9.763	.002
HO_4	Treatments * Gender	263.340	2	131.670	.670	.513
HO_5	Treatments * Mathematical ability	490.311	2	245.155	1.247	.290
HO_6	Gender * Mathematical ability	25.817	1	25.817	.131	.718
HO_7	Treatments * Gender * Mathematical ability	1747.493	2	873.747	4.444	.013
	Error	33621.476	171	196.617		
	Total	576008.000	184			
	Corrected Total	**47211.826**	**183**			

In As presented in Table 1, there is a significant main effect of treatment on students' achievement in Physics [$F(2, 171) = 9.239$; $p < 0.05$]. In contrast, gender does not have a significant effect on achievement [$F(1, 171) = 0.000$; $p > 0.05$], indicating that whether a student is male or female does not influence performance in Physics. Conversely, mathematical ability exerts a significant main effect on achievement [$F(1, 171) = 9.763$; $p < 0.05$].

The two-way interaction between treatment and gender does not significantly affect achievement [$F(2, 171) = 0.670$; $p > 0.05$]. This suggests that the effectiveness of the treatment is not dependent on gender; in other words, the treatment is equally effective for both male and female students. Similarly, the interaction effect of treatment and mathematical ability on achievement is not significant [$F(1, 171) = 1.247$; $p > 0.05$], and there is no significant interaction between gender and mathematical ability [$F(1, 171) = 0.131$; $p > 0.05$].

However, the three-way interaction among treatment, gender, and mathematical ability has a significant effect on students' achievement in Physics [$F(2, 171) = 4.444$; $p < 0.05$]. This finding implies that the treatment is effective regardless of students' gender and level of mathematical ability. In summary, of the seven null hypotheses tested, four are upheld, while three, specifically hypotheses one, three, and seven, are rejected. These rejected hypotheses state that there is no significant main effect of formative assessment on achievement, no significant main effect of mathematical ability on achievement, and no significant interaction effect of formative assessment, gender, and mathematical ability on achievement in Physics;

Table 2

Univariate tests of the mean scores of the three groups

	Sum of Squares	Df	Mean Square	F	Sig.
Contrast	3633.190	2	1816.595	9.239	.000
Error	33621.476	171	196.617		

Table 2 indicates a statistically significant difference in the mean scores of students among the three groups: formative assessment with feedback and remediation, formative assessment with feedback without remediation, and no formative assessment [$F(2, 171) = 9.239$; $p < 0.05$]. This finding demonstrates that student performance differed significantly across the groups, implying that the effectiveness of the treatments was not equivalent. Therefore, pairwise comparisons are warranted to determine which group or groups account for the observed differences.

Table 3

Pair-wise comparison of the three groups

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[b]
Formative Assessment with Feedback and Remediation	Formative Assessment with Feedback only.	3.157	2.741	.753
	No formative Assessment	10.862*	2.560	.000
Formative Assessment with Feedback only	Formative Assessment with Feedback and Remediation.	-3.157	2.741	.753
	No formative Assessment	7.705*	2.860	.023
No formative Assessment	Formative Assessment with Feedback and Remediation.	-10.862*	2.560	.000
	Formative Assessment with Feedback only	-7.705*	2.860	.023

The primary purpose of the pairwise comparison is to clarify the sources of the significant differences identified in Table 3. In this analysis, each group was compared with the others on a two-by-two basis. The results indicate that there is no significant mean difference between the group receiving formative assessment with feedback and remediation and the group receiving formative assessment with feedback only. Conversely, a significant difference exists between the group exposed to formative assessment with feedback and remediation and the group that did not receive any formative assessment. Specifically, formative assessment with feedback and remediation led to significantly higher achievement than the no formative assessment group. Similarly, a significant difference was observed between the group receiving formative assessment with feedback only and the no formative assessment

group, with the feedback-only group performing significantly better than the group without formative assessment.

4. DISCUSSION

The findings of this study, corresponding to the first hypothesis, indicate that formative assessment has a significant main effect on the achievement of senior secondary school students in Physics. Among the three treatment groups, formative assessment combined with feedback and remediation was the most effective, as indicated by the mean differences presented in Table 2. Specifically, the group receiving formative assessment with feedback and remediation significantly outperformed the group that did not receive any formative assessment. Furthermore, students exposed to formative assessment with feedback only also achieved significantly higher results than those in the "no formative assessment" group. These results corroborate the findings of Ugwumaduka and Ogunyemi (2021), who examined the influence of formative assessment, feedback, and remediation on students' academic performance in Basic Science. Their study tested three null hypotheses at the 0.05 level of significance using ANCOVA and estimated marginal means. They reported a significant main effect of treatment on academic achievement ($F(3, 268) = 118.71$, $p < 0.05$), a non-significant main effect of gender ($F(1, 268) = 1.687$, $p > 0.05$), and no significant interaction effect between treatment and gender on achievement ($F(3, 267) = 0.018$, $p > 0.05$). Consequently, gender does not significantly influence the achievement of students in Physics, a finding that aligns with those of Ugwumaduka and Ogunyemi (2021) and Ajogbeje et al. (2013).

Additionally, the study revealed a significant main effect of mathematical ability on students' achievement in Physics. This finding is consistent with Nizolomon (2013), who investigated the relationship between the mathematical ability of female senior secondary school students and their performance in mathematics across five local government areas in Bayelsa State. The study reported a significant positive relationship between mathematical ability and academic achievement. Similarly, Sakiyo and Hamza (2018) examined the impact of formative testing on students' achievement in junior secondary school Mathematics in Taraba State, Nigeria. Their study, which formulated one research question and three hypotheses, demonstrated significant differences in achievement across students exposed to formative testing ($F = 7.314$, $df = 1, 101$; $p < 0.05$), formative testing with feedback ($F = 15.413$, $df = 2, 157$; $p < 0.05$), and formative testing with feedback and remediation ($F = 11.756$, $df = 3, 207$; $p < 0.05$). Based on these results, they recommended that Mathematics teachers integrate formative testing and continuous assessment into their instructional practices.

Furthermore, the study identified a significant interaction effect of formative assessment, gender, and mathematical ability on students' achievement in Physics. This outcome is in agreement with prior research by Ajogbeje et al. (2013) and Ugwumaduka and Ogunyemi (2021), which examined the combined effects of formative assessment, feedback, and remediation on students' academic performance. In those studies, the main effect of treatment on achievement was significant ($F(3, 268) = 118.71$, $p < 0.05$), the main effect of gender was not significant ($F(1, 268) = 1.687$, $p > 0.05$), and there was no significant interaction between treatment and gender on performance.

5. CONCLUSION

Based on the findings of this study, it can be concluded that formative assessment, feedback, and remediation exert a significant influence on the achievement of senior secondary school students in physics. In contrast, gender and mathematical ability were found to have no significant effect on students' performance in the subject.

In light of these findings, the following recommendations are proposed:

1. Physics teachers and instructors should be encouraged to administer regular formative assessments, as these have a demonstrable positive impact on students' achievement in physics. All

assessments should be graded, documented, and accompanied by corrective feedback to support student learning.

2. Educators should provide timely feedback and implement remediation following formative assessments to address specific learning difficulties, thereby enhancing students' understanding and performance in physics.

3. Policy makers and educational authorities should ensure the systematic and effective implementation of formative assessment strategies in the teaching of physics across secondary schools.

4. Teachers should consider students' mathematical ability and prior knowledge when planning and delivering physics instruction, in order to tailor teaching approaches that optimize learning outcomes.

Conflict of Interest: The authors declare no conflict of interest.

Approval: The study adheres to the ethical guidelines for conducting research.

Funding: This research received no external funding.

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