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Influence of Multiple-Choice Option Formats on Secondary School Students' Academic Achievement in Mathematics

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Abstract

This study examined the influence of multiple-choice option formats (three, four, and five options) on secondary school students' academic achievement in mathematics. Guided by one composite research question/hypothesis and Cognitive Load Theory, the study adopted a quasi-experimental design. A sample of 150 Senior Secondary II students from three public schools in Abia State, Nigeria, was selected using multistage sampling techniques. A researcher-developed Mathematics Achievement Test (MAT) with a reliability coefficient of 0.80 (KR-20) was used for data collection. Data were analyzed using descriptive statistics and ANCOVA at a 0.05 level of significance. Results showed that students exposed to three- and four-option formats performed significantly better than those exposed to five-option formats, while no significant difference was found between the three- and four-option groups. The study concludes that fewer options enhance test efficiency and student performance without compromising validity. It recommends that educators and examination bodies adopt three- or four-option formats in mathematics assessments.

Keywords: assessment design, cognitive load, mathematics achievement, multiple-choice tests, option formats

Introduction

Assessment is a fundamental element of mathematics education, shaping instruction, curriculum, and student learning outcomes. It remains a central component of the teaching–learning process, serving as a tool for measuring students' understanding, guiding instructional decisions, and ensuring accountability in education. Among the various forms of assessment, multiple-choice testing is one of the most widely used methods for evaluating students' achievement in school subjects (including mathematics) due to its objectivity, ease of scoring, and wide coverage of content areas (Iñarrairaegui et al., 2022).

Multiple Choice Questions (MCQs) consist mainly of three components: the stem (the question), the key (the correct answer) and the distractors (incorrect options). It also offers psychometric advantages, allowing for standardized administration and scoring procedures that are essential in high-stakes examinations (Soto, 2024). As a result, the design of MCQ items—including the number and arrangement of options—has significant implications for both measurement accuracy and students' test-taking experiences. One of the most critical design elements in MCQs is the option format or option number. In MCQs "option number" refers to the number of alternative answers given for each question. Traditional practice often favours four or five options per item. For instance, the West African Examination Council (WAEC), National Business and Technical Examinations Board (NABTEB) and Joint Admissions and Matriculation Board (JAMB) adopt four option format whereas the National Examination Commission (NECO) uses the five option format. However a persistent debate exists regarding the optimal number of options that should be provided in multiple-choice items to achieve both efficiency and validity.

Research suggests that the optimal number of options for MCQs is a topic of ongoing debate. According to a study by Tweed et al. (2020), the number of options in an MCQ can affect the reliability and validity of the assessment. Another study by Rai and Shakya (2022) found that MCQs with 3-4 options are commonly used and effective for assessing student knowledge. Research has also shown that distractors are not always equally functional, and unnecessary options may increase students' cognitive load without improving the test's discriminative power (Chen et al., 2023; Soto, 2024). Some studies reported that three-option MCQs can achieve psychometric properties comparable to those with four or five options, while simultaneously reducing test length and development costs. (Credentialing Insights, 2024; Haladyna & Rodriguez, 2023)

In mathematics education, where problem-solving and reasoning are central, the number of options in a test item could influence students' academic achievement and general performance. Academic achievement refers to the extent to which a student, teacher, or institution has attained their short or long-term educational goals. It's a measure of how much academic content a student learns in a specific period, which can be evaluated through examinations, continuous assessments, or educational benchmarks. According to Wang and Luo (2024), academic achievement is "an important indicator for evaluating the quality of education" and predicting student performance enables educators to tailor instructional approaches, thereby fostering advancements in both student performance and overall educational quality. Hence, effort should be made to optimize students' academic achievement, while constructing test items.

A test with too many options may overwhelm students, while too few may reduce item reliability and increase guessing. Psychometric studies have shown that non-functional distractors (i.e., distractors rarely selected by examinees) contribute little to item quality and may increase cognitive load unnecessarily (Bateson & Dardick, 2020). When non-functional distractors are removed, test reliability and validity remain largely unaffected, and item-writing efficiency improves (Chen et al., 2023). Li (2024) further demonstrated through differential item functioning (DIF) analysis that poorly constructed distractors may introduce construct-irrelevant variance and subtle bias across student subgroups, particularly in mathematics assessments.

Understanding how different option formats affect students' achievement can guide teachers and examination bodies in designing more effective assessment tools. This study is therefore justified by the need to provide empirical evidence on the instructional and psychological implications of varying option formats in mathematics tests. Findings from this research will not only contribute to the improvement of assessment practices in secondary schools but also support test developers, teachers, and policymakers in making informed decisions about constructing fair, efficient, and student-friendly tests. The research is anchored on Cognitive Load Theory (CLT). Cognitive Load Theory, originally proposed by John Sweller, is based on the assumption that human working memory has a limited capacity for processing information at any given time. When instructional or assessment materials impose a cognitive demand that exceeds this capacity, performance deteriorates (Sweller et al., 2019). Although initially developed to guide instructional design, CLT has been applied increasingly to assessment design in education (Wang & Chen, 2021). Hence, it explains how multiple-choice option formats may influence cognitive performance (academic achievement.

A number of researches have been carried out on the relationship between MCQ option numbers and academic achievement in mathematics. Okoro (2020) investigated the effect of multiple-choice item formats on mathematics achievement among secondary school students in Nigeria. The design of the study **is** Quasi-experimental (non-equivalent control group). Data collected from a sample of 240 secondary school students using Mathematics Achievement Test (MAT) were analyzed with ANCOVA. Result showed that Students who took tests with four-option items performed significantly better than those with three-option items, indicating that option format can influence performance levels. Mwangi (2021) explored multiple-choice item formats and gender differences in mathematics achievement in a Quasi-experimental study involving 300 students. The Instrument for data collection was a researcher-developed mathematics test. Result of Data analysis done with Two-way ANOVA showed that Three-option formats reduced gender gaps in performance and lowered test anxiety compared to five-option formats. Brown (2021) evaluated the impact of different distractor numbers on test reliability and student confidence utilizing Experimental design. Data collected from a Sample of 220 students using Mathematics Achievement Test and confidence questionnaire were analyzed with Item analysis and

regression .Result showed that Tests with three distractors produced higher item discrimination and lower anxiety levels.

Further studies have been done on option formats. Garcia (2021) investigated the relationship between option number and cognitive load in mathematics testing. The study adopted Experimental Design using a **s**ample of 150 students. Data collected using Cognitive Load Scale and mathematics test were analyzed using Repeated measures ANOVA. Result showed that reducing option numbers lowered cognitive load, resulting in higher achievement. Ibrahim (2022) examined how four- versus five-option tests affect secondary students' mathematics achievement in urban schools utilizing quasi-experimental design. Data were collected from a **sa**mple of 280 students using Standardized mathematics test. Data analysis done with ANCOVA showed that Students exposed to four-option formats performed better with less reported anxiety than those exposed to five-option formats. Afolabi (2023) assessed the relationship between multiple-choice formats, test-taking strategies, and achievement in Nigerian mathematics classrooms using quasi-experimental. Participants consists of 320 students. Data were collected using Mathematics Achievement Test and strategy questionnaire and analyzed using multiple regression and ANOVA. Result showed that students taking tests with three-option formats adopted more effective guessing strategies and scored higher. Martinez (2023) evaluated the efficiency of different option numbers in standardized testing in a quasi-experimental study involving 350 students. Data collected with mathematics achievement test were analyzed using Rasch modeling and ANOVA. Findings indicate that Four-option formats balanced difficulty, reliability, and anxiety better than three- or five-option formats. Johnson (2025) explored cognitive load and performance under different MCQ option numbers by utilizing experimental design**.** Data were collected from 270 students using mathematics test, cognitive load scale, and anxiety inventory and analyzed using Multivariate regression and ANOVA. Result showed that cognitive load decreased and achievement improved with fewer distractors.

The reviewed literature indicated varied results on the effect of option numbers on achievement in mathematics and hence calls for further research in that area. This creates the need to determine the effect of multiple choice option formats (three, four and five options) on students' academic achievement in secondary school mathematics. This is the purpose of this study.

Research Question

1. What are the mean achievement scores of students who were exposed to three, four and five multiple-choice option formats in mathematics?

Hypothesis

H_{01}: There is no significant difference in the mean achievement scores of students who were exposed to three, four and five multiple-choice option formats in mathematics.

Methodology

This study adopted a quasi-experimental, non-equivalent control group pretest-posttest design. This design is suitable because the researcher cannot randomly assign individual students to groups but can assign intact classes to experimental conditions. Three experimental groups were used. The independent variable is the multiple-choice option formats (three-option, four-option and five-option), while the dependent variable is students' mathematics achievement. The population of the study consisted of all Senior Secondary Two (SS II) students in public secondary schools in Abia State, Nigeria for the 2024/2025 academic session. This level was selected because students at this stage have acquired foundational mathematics skills and are preparing for standardized examinations. A sample of 150 students was drawn from three co-educational public secondary schools using a multistage sampling approach.

Stage 1: Purposive sampling was used to select three schools with qualified mathematics teachers handling SSII classes.

Stage 2: From each school, one intact class was selected by simple random sampling.

Stage 3: One school each was assigned to the 3 option formats by simple balloting.

The instrument used for data collection is a Mathematics Achievement Test (MAT). This consists of a 50-item multiple-choice test developed by the researchers based on the following topics in SS II mathematics scheme of work at the time of the study: circle theorem, trigonometry and bearing. Three versions were created with the same test content but different option formats (three-option, four-option and five-option) for posttest. All the groups used four-option format during pretest. Hence, MAT was used to

measure students' achievement before and after treatment. Each correct answer attract 2 marks while an incorrect answer attract zero mark. The maximum obtainable mark is 100 whereas the minimum obtainable mark is zero. Draft of the instrument alongside table of specification were reviewed by three experts, two from Mathematics Education and the other from Measurement and Evaluation to ensure face and content validity. The MAT was pilot-tested on 40 students not included in the main study. Kuder-Richardson Formula 20 (KR-20) was used to determine internal consistency and a reliability coefficient of 0.80 was obtained.

The experiment lasted for six weeks. The MAT based on 4 option was administered as pretest to all the groups. All the groups were taught the same mathematics topics by their regular mathematics teachers following a uniform lesson plan prepared by the researchers. The researchers supervised treatment delivery to ensure treatment fidelity and standardization. Group A practiced using three-option tests, Group B practiced using four-option tests, while group C practiced using five-option tests. The MAT (posttest) were administered again to all the groups to measure achievement. Group A used mathematics tests with three-option multiple-choice items; Group B used four-option multiple-choice items, while Group C used five-option multiple-choice items.

Data collected were analyzed using mean (adjusted or estimated marginal mean) and standard error to answer the research question while ANCOVA was used to test the hypothesis at a 0.05 level of significance. The null hypothesis was rejected if the significance level is less than the set alpha level of .05. Pairwise comparison of the groups were done using Bonferoni procedure.

Results

The results of the study are presented in line with the research question and hypothesis.

Research Question:

What are the mean achievement scores of students who were exposed to three, four and five multiple-choice option formats in mathematics?

Table 1: Mean Achievement Scores of Students based on Option Number

Dependent Variable: Posttest Scores

			95% Confidence Interval	
Option Number	Mean	Std. Error	Lower Bound	Upper Bound
3.00	64.245[a]	1.983	60.326	68.163
4.00	59.995[a]	1.983	56.077	63.914
5.00	51.780[a]	1.978	47.871	55.689

a. Covariates appearing in the model are evaluated at the following values: Pretest Scores = 44.0000.

Descriptive statistics revealed that students exposed to the three-option format obtained the highest posttest mean score (M = 64.25, SE = 1.98), followed by those in the four-option group (M = 59.99, SE = 1.98), while the five-option group recorded the lowest mean score (M = 51.78, SE = 1.98).

Hypothesis (H_{01}):
There is no significant difference in mean achievement scores of students exposed to three-, four-, and five-option multiple-choice test formats in mathematics.

Table 2: ANCOVA of Mean Achievement Scores based on Option Format.

Dependent Variable: Posttest Scores

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	4802.206[a]	3	1600.735	8.183	.000	.144
Intercept	11574.574	1	11574.574	59.172	.000	.288
Aptitude	671.913	1	671.913	3.435	.066	.023
Options	4010.958	2	2005.479	10.253	.000	.123
Error	28558.787	146	195.608			
Total	549745.000	150				
Corrected Total	33360.993	149				

a. R Squared = .144 (Adjusted R Squared = .126)

The ANCOVA results (see Table 2) indicated a statistically significant effect of option format on students' mathematics achievement, F (2, 144) = 10.253, p = .000. Consequently, H_{01} was rejected. The implication is that there is significant difference in the mathematics achievement of students based on multiple choice option number. This suggests that the number of options in multiple-choice items significantly influences students' performance in mathematics.

Table 3: Pairwise Comparison of Achievement Scores based on Option Number

Dependent Variable: Posttest Scores

(I) Option Number	(J) Option Number	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
3.00	4.00	4.249	2.811	.398	-2.558	11.057
	5.00	12.465*	2.801	.000	5.682	19.247
4.00	3.00	-4.249	2.811	.398	-11.057	2.558
	5.00	8.215*	2.801	.012	1.433	14.998
5.00	3.00	-12.465*	2.801	.000	-19.247	-5.682
	4.00	-8.215*	2.801	.012	-14.998	-1.433

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Pairwise comparison results (see Table 3) showed that the mean difference between the three- and four-option groups (4.249) was not statistically significant, p = .398. Students who answered three-option items (M = 64.25) had slightly higher scores than those who answered four-option items (M = 59.99), but this difference was not large enough to reach statistical significance.

Furthermore, a statistically significant difference was found between students in the three-option and five-option groups, with a mean difference of 12.47, p < .001. Students exposed to three-option formats performed significantly better than their counterparts who took tests with five-option formats. The pairwise comparison between the four- and five-option formats, shown in table 3, revealed a significant difference (mean difference = 8.22, p = .012), indicating that students in the four-option group scored significantly higher than those in the five-option group.

Interpretation of Findings

The results indicate that reducing the number of options in multiple-choice test items significantly improves students' mathematics achievement. Specifically, students exposed to three- and four-option formats performed better than those exposed to five-option formats. The absence of a significant difference between the three- and four-option formats suggests that using three options may be equally effective, while also improving test-taking efficiency.

These findings are consistent with Cognitive Load Theory, which posits that reducing unnecessary information lowers extraneous cognitive load, allowing students to allocate more cognitive resources to problem-solving.

Discussion

The purpose of this study was to examine the influence of multiple-choice option formats (three-, four-, and five-option items) on students' academic achievement in secondary school mathematics. The results revealed that option format significantly affected mathematics achievement, with students exposed to three- and four-option tests performing better than those exposed to five-option tests. These findings contribute to the growing body of research that emphasizes the psychometric and pedagogical implications of test design on students' cognitive outcomes.

The significant differences in achievement across option formats support the assertion of Cognitive Load Theory (Sweller et al., 2019), which posits that human working memory has a limited capacity, and excessive information processing can hinder learning and performance. In this study, the five-option format may have increased cognitive load by requiring students to process additional distractors, thereby reducing their efficiency in retrieving and applying mathematical knowledge. Conversely, three- and four-option formats likely reduced extraneous load, allowing students to focus on relevant problem-solving processes.

These findings align with previous research indicating that reducing the number of distractors improves test performance without compromising measurement quality. For example, Okoro (2020) found that students who took four-option tests performed significantly better than those who took three-option tests, while Mwangi (2021) and Garcia (2021) reported that three-option formats minimized cognitive load and improved achievement scores. Similarly, Johnson (2025) observed that tests with fewer distractors improved cognitive processing efficiency and led to better mathematics outcomes.

Notably, the results also showed no statistically significant difference between three- and four-option formats, suggesting that both are equally effective in assessing mathematics achievement. This outcome is consistent with international psychometric literature (e.g., Haladyna & Rodriguez, 2023; Chen et al., 2023), which indicates that non-functional distractors rarely contribute meaningfully to item discrimination. Eliminating such distractors does not reduce test reliability but may improve efficiency and student performance.

Implications for Educational Practice and Policy

The findings of this study have important implications for teachers, test developers, and examination bodies such as West African Examinations Council, National Business and Technical Examinations Board, Joint Admissions and Matriculation Board and National Examinations Council**.** First, the use of three- or four-option formats may be preferable to traditional five-option formats, as it can maintain psychometric quality while improving student performance. Second, adopting fewer options can reduce item-writing time and increase efficiency without compromising validity or reliability. Third, minimizing cognitive load during testing may help mitigate test anxiety, particularly in high-stakes contexts like mathematics examinations. The examination bodies currently adopting four option format are encouraged to continue with that, and if possible, try out the three option format for subject like mathematics. Consequently the National Examinations Council is enjoined to consider reducing the number of options in their multiple choice tests. From a theoretical perspective, the results provide empirical support for Cognitive Load Theory by demonstrating that reducing the number of distractors enhances students' achievement.

Conclusion

In conclusion, the study demonstrates that multiple-choice option format significantly influences students' mathematics achievement. Three- and four-option formats produced higher achievement scores than five-option formats, and no significant difference was found between three and four options. These findings support the growing consensus that fewer distractors can optimize both test efficiency and student performance. By aligning test design with principles

from Cognitive Load Theory educators and policymakers can create fairer, more effective, and psychologically supportive assessment practices in mathematics and beyond.

Furthermore, the findings contribute to the ongoing psychometric debate regarding the optimal number of options in multiple-choice items. They support the growing empirical consensus that three or four options are sufficient to maintain validity and reliability while enhancing efficiency and fairness in assessment.

Recommendations

Based on the findings of this study, the following recommendations are made for teachers, examination bodies, tertiary institutions, and future researchers:

1. Teachers should adopt three- or four-option formats in test construction.
2. Examination bodies such as West African Examinations Council, National Business and Technical Examinations Board and Joint Admissions and Matriculation Board and National Examinations Council should review their test design frameworks to align with current empirical evidence on option formats. Hence they should adopt three- or four-option formats.
3. Universities and colleges of education should incorporate, in pre-service and in-service teacher education programs, specialized modules on test development that emphasize principles of cognitive load management, functional distractor analysis, in test design.
4. Future researchers should investigate the impact of option formats on other psychological variables such as test anxiety, motivation, and confidence. Longitudinal studies and experimental designs across different subjects and educational levels would provide a broader evidence base.

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