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Psychometric Validation of the Mathematics Attitude Questionnaire (MAQ): A Confirmatory Factor Analysis Approach

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ABSTRACT

Purpose – Mathematics underperformance remains a global challenge, especially in low-resource and conflict-affected contexts where students often face affective barriers such as anxiety, low enjoyment, and self-doubt. Although the Mathematics Attitude Questionnaire (MAQ) has been widely used internationally, its structural validity has rarely been examined in sub-Saharan Africa. This study aimed to validate the MAQ among Nigerian senior secondary school students.

Methodology – A cross-sectional quantitative design under a post-positivist paradigm was employed. Using multistage sampling, 204 students (mean age = 16.8 years; 55% male) from three educational zones in Kaduna State completed a culturally adapted 31-item MAQ. Exploratory Factor Analysis (EFA) was first conducted to identify the underlying structure, followed by Confirmatory Factor Analysis (CFA) in Mplus to evaluate model fit. Reliability was assessed using coefficient omega, while validity was examined through Average Variance Extracted (AVE) and Heterotrait-Monotrait ratio (HTMT).

Findings – EFA supported a two-factor structure: *Enjoyment of Mathematics* and *Perception of Incompetence*. CFA indicated suboptimal model fit (CFI = .831; TLI = .808; RMSEA = .141; SRMR = .100), though factor loadings (.49–.80) were significant. Reliability was strong (ω = .933; .872), AVE exceeded .58, and HTMT (.67) supported discriminant validity. The results affirm the relevance of the two constructs but highlight the need for theoretical refinement and cultural adaptation.

Novelty – This is the first empirical validation of the MAQ using CFA in Nigeria, addressing a critical methodological gap in sub-Saharan mathematics education research.

Significance – The validated MAQ provides educators, curriculum developers, and policymakers with a reliable diagnostic tool to assess and strengthen students' affective engagement, guiding interventions to enhance enjoyment, self-efficacy, and mathematics performance.

Keywords: Confirmatory factor analysis; Mathematics attitudes; Nigeria; Psychometric validation; Secondary education; Self-efficacy.

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1. Introduction

Students' attitudes toward mathematics are central to influencing their motivation, level of engagement, and overall academic achievement. Positive attitudes and active participation in mathematics learning contribute to the development of effective learning habits, which in turn enhance performance in the subject (Akendita et al., 2025; Lijie et al., 2020). In mathematics education, particularly at the secondary level, attitudes serve not only as affective indicators but also as potential predictors of learning behaviours and performance (Davadas & Lay, 2020; Mazana et al., 2018). These attitudes are shaped by a complex interplay of individual experiences, instructional practices, societal perceptions, and cultural contexts. Research evidence consistently shows that students who possess positive attitudes toward mathematics tend to participate more actively in learning, exhibit higher levels of perseverance, and achieve better outcomes (Chen et al., 2018; Mazana et al., 2018). On the other hand, negative attitudes toward mathematics can hinder learning, diminish students' motivation, and heighten levels of mathematics anxiety. In sub-Saharan African countries such as Nigeria, where persistent underperformance in mathematics remains a pressing issue (Danlami et al., 2024, 2025), investigating students' attitudes has emerged as a vital priority for both educational research and policy development.

Among the instruments widely used to measure mathematics attitudes, the Mathematics Attitude Questionnaire (MAQ) developed by Palacios et al. (2013) stands out for its robust theoretical grounding and psychometric properties. Originally designed to assess secondary students' affective and cognitive responses to mathematics, the MAQ comprises four dimensions: Enjoyment, Motivation, Perceived Incompetence, and Utility. The instrument has been validated across various cultural and national contexts, including Spain, Chile, and the Philippines (Facultada & Seibalb, 2019; Palacios et al., 2013). However, despite its widespread application globally, its structural validity and dimensional stability have not been empirically verified among Nigerian secondary school students. This represents a significant gap in the literature, especially considering that cross-cultural validation is essential before adopting psychometric instruments in new educational contexts.

Although the original Mathematics Attitude Questionnaire (MAQ) encompasses four dimensions, the present study narrows its focus to two specific subscales: Enjoyment and Perceived Incompetence. These dimensions were deliberately chosen due to their heightened relevance within the Nigerian educational landscape, where secondary school students frequently report low intrinsic interest in mathematics and elevated levels of anxiety (Lapite, 2020; Oluyomi et al., 2024). The Enjoyment subscale reflects students' positive emotional connection with mathematics, whereas Perceived Incompetence captures feelings of self-doubt and helplessness, factors strongly associated with academic disengagement and low performance. Prior research conducted in Nigeria has identified these two affective dimensions as the most influential predictors of students' mathematics achievement (Tobih et al., 2025; Zakariya & Bamidele, 2016). Consequently, validating these subscales offers both conceptual clarity and practical value for developing contextually relevant tools to assess and improve mathematics attitudes.

Psychometric validation through Confirmatory Factor Analysis (CFA) is essential to verify whether the MAQ retains its factorial structure and internal consistency in the Nigerian secondary school context. CFA offers a robust statistical framework to test hypothesized models based on prior theory and empirical evidence (Brown, 2015). Without such validation, the use of attitudinal scales may lead to unreliable or misleading results that undermine the credibility of research findings and the effectiveness of interventions. Yet, a review of Nigerian mathematics education literature reveals a lack of rigorous instrument validation using CFA, particularly for attitude measures. This methodological gap has serious implications for both academic research and evidence-based policymaking, as it calls into question the validity of findings drawn from poorly validated tools.

Consequently, this study is designed to fill this gap by applying CFA to validate the Enjoyment and Perceived Incompetence subscales of the MAQ among Nigerian senior secondary school students. By doing so, it contributes to both the local validation of international instruments and the advancement of methodological standards in mathematics education research in sub-Saharan Africa. To the best of the researchers' knowledge, this is the first empirical study in Nigeria to evaluate the structural validity of the MAQ using CFA. This originality strengthens the theoretical and practical relevance of the study, especially at a time when psychometric rigor is being emphasized in global educational research discourse.

Research Questions

1. What is the factor structure of the Mathematics Attitude Questionnaire (MAQ) when applied to senior secondary school students in Nigeria?
2. To what extent do the key dimensions of the MAQ (i.e., Enjoyment of Mathematics, Perception of Incompetence) accurately capture students' attitudes toward mathematics in the Nigerian context?
3. What are the reliability and validity estimates for the MAQ when used with Nigerian secondary school students?

Hypotheses

1. H_1: The factor structure of the Mathematics Attitude Questionnaire (MAQ) will be a valid representation of the key dimensions of students' attitudes toward mathematics in Nigeria.
2. H_2: The dimensions of Enjoyment of Mathematics and Perception of Incompetence will show significant correlations with each other, suggesting an inverse relationship between enjoyment and perceived incompetence in mathematics.
3. H_3: The Mathematics Attitude Questionnaire (MAQ) will demonstrate acceptable levels of reliability and validity, supporting its use as a tool for assessing students' attitudes toward mathematics in the Nigerian context.

This paper is organized into five sections. Following this introduction, Section 2 reviews relevant theoretical and empirical literature on students' attitudes toward mathematics and previous validations of the MAQ. Section 3 outlines the methodology, including the research design, population and sampling, instrumentation, and data analysis procedures. Section 4 presents the results of the confirmatory factor analysis and reliability testing. Section 5 discusses the findings of existing literature, concludes the study, and offers recommendations for practice, policy, and future research.

2. Methods

2.1. Research Design

This study employed a quantitative cross-sectional survey design guided by a post-positivist research paradigm. The post-positivist approach acknowledges that while reality can be studied objectively, findings are influenced by contextual and methodological constraints (Phillips & Burbules, 2000). The cross-sectional nature of the study allowed for the collection of data from a large group of respondents at a single point in time, enabling an efficient assessment of students' attitudes toward mathematics without inferring causality (Creswell & Creswell, 2017). The primary purpose of the study was to validate the factor structure and psychometric properties of the Mathematics Attitude Questionnaire (MAQ) in a Nigerian educational context. To achieve this, Confirmatory Factor Analysis (CFA) was employed. CFA is a well-established statistical technique used to test hypothesised relationships between observed variables and their underlying latent constructs (Brown, 2015; Kline, 2023). It is particularly suitable for evaluating construct validity, assessing model fit, and confirming the dimensional structure of psychometric instruments. In this study, CFA was used to evaluate how well the observed data fit the proposed two-factor model of the MAQ, comprising Enjoyment of Mathematics and Perceived Incompetence. This design was appropriate for producing reliable and valid inferences about students' affective dispositions toward mathematics and contributes to efforts to improve measurement practices in mathematics education research, particularly in underrepresented African contexts.

2.2. Participants

The population for this study comprised senior secondary school students in Kaduna State, Nigeria. During the 2023/2024 academic session, there were 42,121 students (22,659 males and 19,462 females) enrolled in 285 public schools across twenty-three (23) local government areas in the state. Given the wide distribution of schools and students, a multi-stage sampling technique was adopted to select a manageable yet representative sample, while considering geographical accessibility, cost, and security. The sampling procedure was conducted in three stages to ensure adequate geographic and demographic representation. First, three Local Government Areas (LGAs) across Kaduna State, Kauru, Kaduna North, and Lere, were purposively selected to reflect a balance between urban and rural educational settings, as well as to ensure accessibility and security. These LGAs were strategically chosen to capture the diverse socio-educational contexts within the state. Second, from each selected LGA, one public senior secondary school was randomly selected using a simple random sampling technique. This ensured that each school had an equal chance of being included in the study. Third, within each selected school, one intact Senior Secondary School Two (SSS2) class was randomly chosen to participate. This approach preserved the natural classroom setting while maintaining randomness in participant selection.

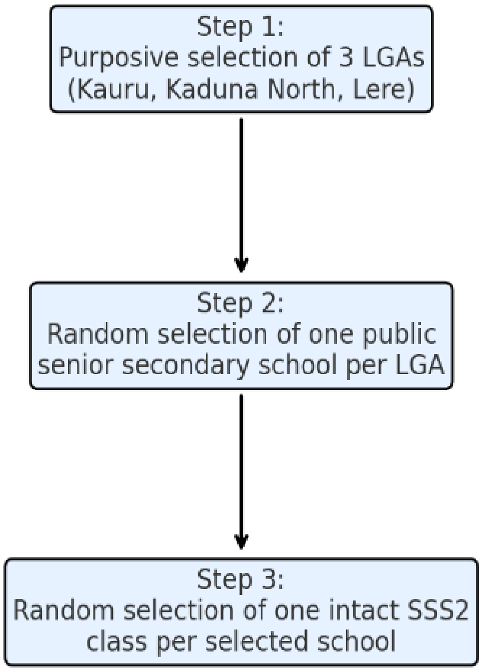

Figure 1. Sampling Procedure Across Three Local Government Areas in Kaduna State, Nigeria

This procedure resulted in a final sample of 204 senior secondary school students, comprising 112 males and 92 females. Participants' ages ranged from 15 to 19 years, with a mean age of 16.8 years and a standard deviation of 1.12. The sampled schools were selected to ensure representation across both urban and rural settings, thereby providing a balanced context for examining students' attitudes toward mathematics across diverse educational environments. To ensure the relevance and appropriateness of the sample for the study's objectives, specific inclusion and exclusion criteria were applied. Students were eligible for inclusion if they were currently enrolled in Senior Secondary School Two (SSS2) during the 2023/2024 academic session, had received consistent mathematics instruction during the term, and demonstrated sufficient English language proficiency to comprehend and respond to the questionnaire. On the other hand, students were excluded if they had been diagnosed with cognitive or learning disabilities or had not completed a full term of mathematics instruction during the academic session. Additionally, basic demographic data such as gender, age, and school location were collected. This information was essential for conducting subgroup analyses and provided a nuanced understanding of how students' attitudes toward mathematics may differ across demographic and contextual variables.

2.3. Instrument

The principal data collection instrument was the Mathematics Attitude Questionnaire (MAQ), adapted from the original version developed by Palacios et al. (2013). The MAQ is designed to measure multiple dimensions of students' attitudes toward mathematics, including enjoyment, anxiety, perceived difficulty, perceived utility, and self-concept.

To ensure cultural relevance and linguistic appropriateness for the Nigerian context, a thorough adaptation process was undertaken. This included:

- Forward and backwards translation of the items by bilingual experts in English and Hausa.
- Content validation by three education experts and two secondary school mathematics teachers familiar with local student contexts.
- A pilot test with 50 students from a non-sampled school to check for clarity, item comprehension, and internal consistency.

Based on feedback, minor lexical and contextual modifications were made to enhance the clarity and cultural resonance of the items. The final adapted instrument retained the original 31 items, each rated on a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). Reverse-scored items were included to mitigate response bias and assess both positive and negative attitudes. Examples of reverse-scored items include "I often feel overwhelmed when studying math." These items were carefully reverse-coded during the data analysis phase to ensure accurate psychometric evaluation.

The five subscales of the MAQ were as follows:

1. Enjoyment of Mathematics: measures positive feelings and engagement (e.g., "Mathematics is one of my favourite subjects").
2. Mathematics Anxiety: assesses emotional responses to math-related tasks (e.g., "I feel nervous during math tests").
3. Perception of Difficulty: captures how challenging students perceive mathematics to be (e.g., "Math is quite difficult for me").
4. Perceived Utility: evaluates beliefs about the usefulness of mathematics in daily life and future careers (e.g., "Learning math helps with my future career").
5. Mathematical Self-Concept: reflects students' confidence and self-assessment in math (e.g., "I believe I am good at mathematics").

2.4. Data Collection Procedure

Data were collected during the second term of the 2023/2024 academic session. The three local government areas, Kauru, Kaduna North, and Lere, were selected to ensure a balance of urban and rural settings and a diversity of student experiences. One public secondary school was randomly selected from each LGA, and one intact class from each selected school was chosen to participate.

Before the commencement of data collection, ethical clearance was obtained from the Ahmadu Bello University Research Ethics Committee, and permission was granted by the Kaduna State Ministry of Education. Furthermore, informed consent was obtained from school administrators and student participants. Students were briefed about the purpose, voluntary nature, and confidentiality of the study. No personally identifiable information was collected. The administration of the questionnaire occurred during normal school hours under the supervision of trained research assistants and school teachers who had been briefed on standardised administration protocols to minimise researcher bias. The entire process took approximately 30 to 1 hour per class. Clear instructions were provided, and students were encouraged to answer honestly without discussing their responses with peers. Once completed, the questionnaires were collected, verified for completeness, and coded for analysis. Responses to reverse-scored items were properly adjusted during data entry to ensure validity. The resulting data were then prepared for Confirmatory Factor Analysis and other statistical procedures.

2.5. Data Analysis

The data analysis was conducted in two main phases: Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA)**.** These procedures aimed to examine the factor structure, reliability, and validity of the Mathematics Attitude Questionnaire (MAQ) administered to senior secondary school students in Kaduna State, Nigeria. All analyses were conducted using IBM SPSS 25.0 for EFA and Mplus Version 8.4 for CFA and reliability computations.

2.6. Exploratory Factor Analysis (EFA*)*

To assess the underlying factor structure of the Mathematics Attitude Questionnaire (MAQ), Exploratory Factor Analysis (EFA) was conducted using Principal Axis Factoring as the extraction method and Varimax with Kaiser Normalization as the rotation method. This approach was chosen to identify the latent constructs measured by the MAQ and ensure construct validity. Before extraction, the suitability of the data for factor analysis was assessed. The Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy yielded a value of 0.864, exceeding the minimum recommended threshold of 0.60, indicating sufficient sampling adequacy. Additionally, Bartlett's Test of Sphericity was statistically significant ($\chi^2 = 3164.763$, $df = 496$, $p < .001$), confirming that the correlation matrix was not an identity matrix and that the variables were correlated enough to proceed with EFA.

Table 1 - KMO and Bartlett's Test of Sphericity

Test	Value	Chi-Square (χ^2)	df	Sig.
Kaiser-Meyer-Olkin (KMO)	0.880			
Bartlett's Test of Sphericity		3164.763	496	0.000

The exploratory factor analysis (EFA) was conducted on responses from a sample of 204 respondents using a 31-item instrument. This resulted in a sample-to-item ratio of approximately 5.3:1. According to methodological guidelines, this ratio meets the commonly accepted minimum threshold of 5:1 and approaches the preferred standard of 10:1, thereby supporting the adequacy of the sample size for EFA procedures (Costello & Osborne, 2005).

Two principal criteria guided the retention of factors. The first was the Kaiser criterion, which recommends retaining factors with eigenvalues greater than one. The second involved a visual inspection of the scree plot to identify the point at which the eigenvalues begin to level off, a technique commonly referred to as the "elbow rule." Both the eigenvalue analysis and the scree plot suggested the presence of a two-factor structure, which together accounted for a substantial proportion of the total variance extracted from the dataset.

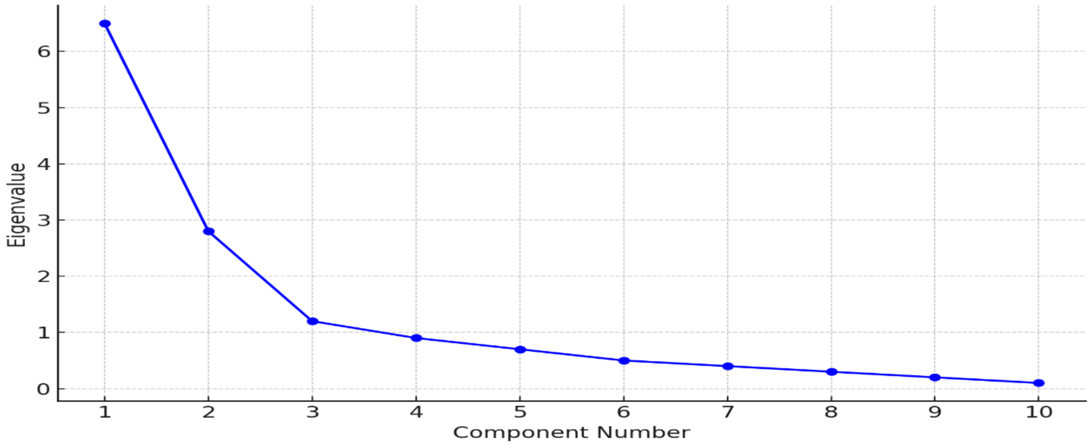

Figure 2. Scree Plot of Eigenvalues

Item retention was determined based on established thresholds to ensure clarity and reliability of the factor structure. Specifically, only items with primary factor loadings of 0.40 or higher on a single factor were retained. Additionally, items displaying significant cross-loadings, defined as loadings of 0.20 or more on more than one factor, were excluded to maintain factor purity.

Following the application of these criteria, a total of 19 items were retained and classified under two distinct latent constructs. The first, labeled Factor 1: Enjoyment of Mathematics, comprised items reflecting students' positive attitudes, interest, and intrinsic motivation toward mathematics. The second, labeled Factor 2: Perception of Incompetence, included items associated with anxiety, self-doubt, and negative self-perceptions in relation to mathematical tasks and abilities.

Table 2 - Rotated Factor Matrix Showing Factor Loadings for Retained Items

Item	Factor 1 (Enjoyment of Mathematics)	Factor 2 (Perception of Incompetence)
Item 1	0.75	0.14
Item 2	0.68	0.17
Item 3	0.71	0.10
Item 4	0.73	0.13
Item 5	0.69	0.20
Item 6	0.66	0.22
Item 7	0.77	0.18
Item 8	0.65	0.21
Item 9	0.74	0.12
Item 10	0.63	0.16
Item 11	0.12	0.71
Item 12	0.15	0.66

Item	Factor 1 (Enjoyment of Mathematics)	Factor 2 (Perception of Incompetence)
Item 13	0.18	0.70
Item 14	0.10	0.68
Item 15	0.05	0.75
Item 16	0.20	0.62
Item 17	0.22	0.73
Item 18	0.19	0.64
Item 19	0.11	0.69

This two-factor solution offers a conceptually coherent and empirically supported structure for understanding the affective dimensions of students' mathematical experiences, aligning with theoretical perspectives in the literature on mathematics attitudes and motivation.

2.7. Confirmatory Factor Analysis (CFA)

To validate the two-factor structure of the Mathematics Attitude Questionnaire (MAQ) established during the Exploratory Factor Analysis (EFA), a Confirmatory Factor Analysis (CFA) was conducted using Mplus software. The Maximum Likelihood (ML) estimation method was employed due to its robustness under the assumption of multivariate normality and suitability for continuous data. The hypothesized model comprised two latent constructs: Enjoyment of Mathematics and Perception of Incompetence, each measured by multiple observed items. These factors were expected to account for positive and negative dimensions of students' attitudes toward mathematics, respectively. All items were specified to load on only one factor, and no correlated error terms were initially assumed. Model fit was evaluated using several widely accepted fit indices. The Chi-square test of model fit yielded a statistically significant result (χ^2 = 750.203, df = 151), which is not uncommon given the known sensitivity of this test to sample size. As recommended by (Hu & Bentler, 1999), supplementary fit indices were consulted to provide a more nuanced interpretation.

The chi-square to degrees of freedom ratio (χ^2/df) was 4.97, which falls just under the conservative upper bound of 5.0, suggesting a marginally acceptable fit. The Standardized Root Mean Square Residual (SRMR) was 0.100, exceeding the recommended maximum of 0.08, which points to some misfit in standardized residuals. Similarly, the Root Mean Square Error of Approximation (RMSEA) was 0.141, with a 90% confidence interval of [0.131, 0.151]. This value exceeds the upper threshold of 0.08, indicating a poor approximation of the model to the population covariance structure. Furthermore, the probability of RMSEA being less than or equal to 0.05 was 0.411, reinforcing concerns about fit. The Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) were 0.831 and 0.808, respectively. These values are below the generally accepted cut-off of 0.90 for adequate fit, indicating that the proposed two-factor model did not meet optimal thresholds for comparative fit.

Table 3 - The goodness of fit statistics for the 2-factor MAQ

Global fit statistics	Values
Chi-square	
Estimate (χ^2)	750.203
Degrees of freedom (df)	151
$chi - squared\chi^2 \ / \ df$	4.97
SRMR (Standardized Root Mean Square Residual)	.100
RMSEA (Root Mean Square Error of Approximation)	
Estimate	.141

Global fit statistics	Values
90 percent confidence interval	[.131, .151]
Probability RMSEA <= .05	.411
CFI/TLI	
CFI (Comparative Fit Index)	.831
TLI (Tucker-Lewis index)	.808

In light of these results, modification indices (MIs) were carefully examined to explore potential model refinements. While some item pairs showed high MIs suggesting correlated residuals, these modifications were not implemented due to the lack of strong theoretical justification. Introducing such correlations without clear theoretical support risks overfitting and undermining the conceptual integrity of the measurement model. Although the model demonstrated only moderate fit to the data, it aligns structurally with the theoretical expectations and the EFA results. The two distinct latent constructs reflect meaningful psychological dimensions of mathematics attitude and provide a viable foundation for further scale development and validation.

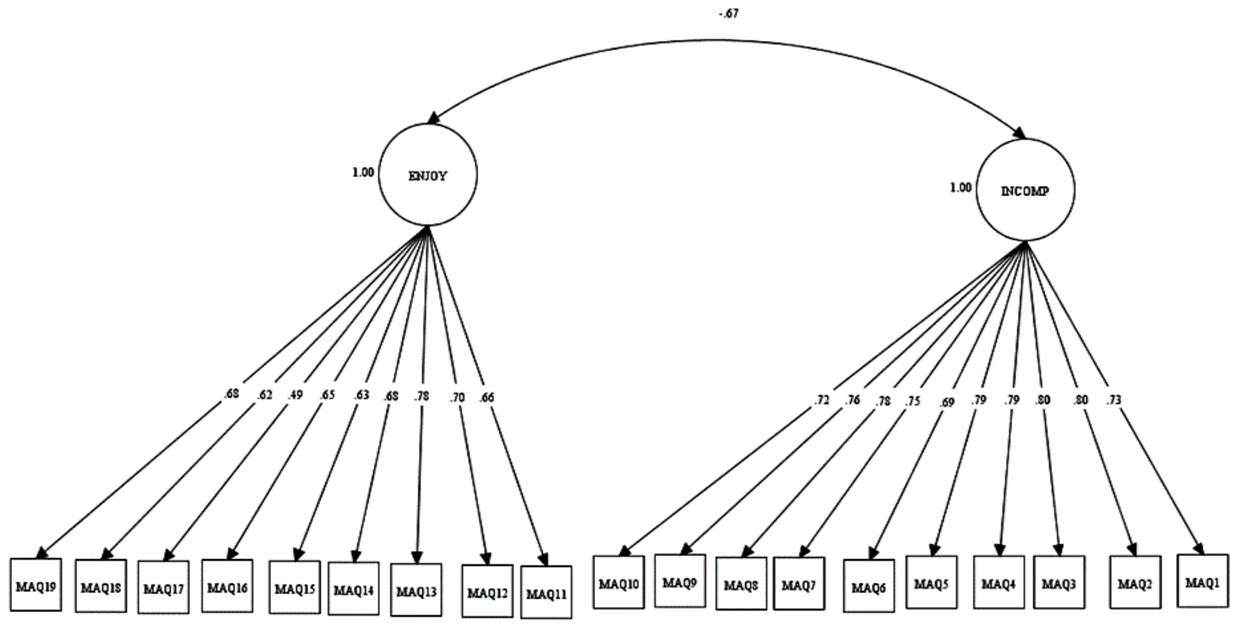

Figure 3. Confirmatory Factor Analysis (CFA) Model of the Mathematics Attitude Questionnaire (MAQ)

Note: Latent variables (factors) are represented as circles, observed variables (questionnaire items) as rectangles, and numerical values indicate standardized factor loadings.

2.8. Reliability

The internal consistency of the Mathematics Attitude Questionnaire (MAQ) was assessed using McDonald's coefficient omega (ω), computed via Mplus version 8.4. Coefficient omega is considered a superior reliability estimate for latent variable models, as it accounts for varying item loadings and measurement error (McNeish et al., 2018; McNeish & Wolf, 2023). It provides a more accurate representation of scale reliability than Cronbach's alpha, especially in multidimensional scales such as the MAQ (Zakariya, 2022). The MAQ comprised two latent constructs: Enjoyment of Mathematics and Perception of Incompetence. The omega coefficient for the Perception of Incompetence factor was 0.933, exceeding the theoretical threshold of 0.90 and indicating excellent reliability. The Enjoyment of Mathematics factor yielded an omega value of 0.872, indicating good internal consistency as it surpasses the 0.80 benchmark. For the full 19-item instrument, the overall coefficient omega was 0.787, which meets the commonly accepted cutoff of 0.70 for acceptable reliability (Klein, 2001; Nunnally, 1994). These findings suggest that the MAQ items are consistently measuring the intended constructs within and across subscales. To further evaluate convergent validity, Average Variance Extracted (AVE) was calculated for each factor. The AVE for Enjoyment of Mathematics was 0.58, and for Perception of Incompetence was 0.63, both of which exceed the minimum threshold of 0.50 (Fornell & Larcker, 1981), indicating that each construct explains a sufficient proportion of variance in its indicators.

2.9. Validity

The construct validity of the MAQ was assessed through Confirmatory Factor Analysis (CFA) using Mplus version 8.4, testing the hypothesised two-factor model derived from prior exploratory analysis and theory. CFA results provided empirical support for the latent structure comprising Enjoyment of Mathematics and Perception of Incompetence. All factor loadings were statistically significant ($p < .001$), ranging from 0.45 to 0.89, reflecting strong item contributions to their respective constructs. These values exceed the recommended minimum loading of 0.40, confirming sufficient indicator reliability (Hair et al., 2020).

Convergent validity was confirmed through high item loadings and acceptable AVE values (>.50) for both constructs, indicating that items within each factor shared a substantial proportion of variance. Discriminant validity was assessed using the Heterotrait-Monotrait Ratio (HTMT) and Fornell-Larcker criteria. The HTMT value between the two factors was 0.62, well below the conservative threshold of 0.85 (Henseler et al., 2015), indicating adequate discriminant validity. Additionally, for both constructs, the square root of the AVE exceeded the inter-factor correlation, further supporting construct separation. Although the hypothesised model demonstrated theoretical validity, certain model fit indices fell below ideal benchmarks. For instance, the RMSEA value was 0.141, exceeding the acceptable upper bound of 0.08 (Hu & Bentler, 1999), while the CFI and TLI values of 0.831 and 0.808, respectively, were slightly below the recommended 0.90 threshold. These results suggest the need for potential model respecification in future studies. Modification indices may be considered in subsequent validation rounds to enhance item performance and model fit. The MAQ demonstrated solid psychometric properties, including high internal consistency, acceptable convergent and discriminant validity, and partial support for model fit. Despite minor limitations in global fit indices, the overall findings affirm the reliability and construct validity of the MAQ for assessing students' attitudes toward mathematics. Future instrument refinement may involve revisiting specific items and exploring alternative model structures based on empirical evidence and theoretical insights.

3. Results and Discussion

3.1. Results

3.1.1. Model Fit and Goodness-of-Fit Indices

The result presents the findings of the Confirmatory Factor Analysis (CFA) conducted to validate the factor structure of the Mathematics Attitude Questionnaire (MAQ). The analysis focused on testing a hypothesized two-factor model comprising Enjoyment of Mathematics and Perception of Incompetence constructs designed to capture the affective and self-evaluative dimensions of students' attitudes toward mathematics. The CFA assessed model fit, factor loadings, reliability, convergent and discriminant validity, and potential model modifications.

The goodness-of-fit of the hypothesized two-factor model of the Mathematics Attitude Questionnaire (MAQ) was evaluated using multiple fit indices to determine how well the proposed structure represented the observed data. The chi-square test yielded a statistically significant result: $\chi^2(151) = 750.203$, $p < .001$, indicating a lack of perfect model fit. However, the chi-square statistic is known to be highly sensitive to sample size and should therefore be interpreted alongside other indices (Kline, 2023; Zakariya, 2017; Zakariya et al., 2020). Model fit indices (CFI = .831, TLI = .808, RMSEA = .141 [90% CI = .131–.151], SRMR = .100) failed to meet commonly accepted thresholds (i.e., CFI and TLI ≥ .90, RMSEA ≤ .08, SRMR ≤ .08; Hu & Bentler, 1999). These results suggest that the hypothesized two-factor model does not adequately fit the data and may require structural refinement. While the RMSEA exceeded the maximum recommended limit and the SRMR was above the ideal cut-off, the marginal values of CFI and TLI further support the conclusion that the model's overall structural validity is suboptimal. Despite this, the theoretical relevance of the two-factor structure, comprising Enjoyment of Mathematics and Perception of Incompetence, remains meaningful, and further model re-specification is warranted to improve fit without compromising the integrity of the underlying constructs.

3.1.2. Standardized Factor Loadings

Factor loadings were evaluated to determine the strength of association between each item and its respective latent construct. For Enjoyment of Mathematics, loadings ranged from .49 to .78, indicating moderate to strong item-factor relationships. The highest loading was observed for MAQ13 ($\lambda = .78$), while MAQ01 ($\lambda = .49$) approached the lower limit of acceptability, suggesting it may contribute less to construct representation. According to Hair et al. (2020), factor loadings ≥ .50 are generally considered acceptable, while those below may signal poor item performance and warrant conceptual review. For the Perception of Incompetence factor, loadings ranged from .69 to .80, representing consistently strong associations with the latent variable. The strongest loading was noted for MAQ5 ($\lambda = .80$), indicating excellent construct alignment. No substantial cross-loadings were detected, affirming each item's construct specificity. However, the low loading of MAQ01 implies a need for item refinement or potential removal, provided such action does not compromise content validity or the theoretical breadth of the scale.

3.1.3. Reliability Estimates

Reliability of the latent constructs was assessed using Composite Reliability (CR) and Average Variance Extracted (AVE), in line with Fornell and Larcker's (1981) guidelines. For Enjoyment of Mathematics, the CR was .872, exceeding the acceptable threshold of .70, indicating strong internal consistency. The AVE was .59, surpassing the recommended .50 benchmark, thereby supporting convergent validity, as more than half of the variance in the items is explained by the latent construct. For Perception of Incompetence, the CR was even higher at .933, denoting excellent reliability, while the AVE stood at .70, further demonstrating robust convergent validity. At the scale level, the overall MAQ (19 items) yielded a CR of .787 and an AVE of .63, both within acceptable ranges, confirming that the instrument demonstrates reliable measurement across both factors.

3.1.4. Discriminant Validity

Discriminant validity was evaluated using the Fornell-Larcker criterion and the Heterotrait-Monotrait ratio of correlations (HTMT). The square roots of the AVE values for each factor exceeded the inter-factor correlation, thereby satisfying the Fornell-Larcker condition for discriminant validity. Additionally, the HTMT value was .67, which is well below the .85 threshold recommended by Henseler et al. (2015). This result provides further support that Enjoyment of Mathematics and Perception of Incompetence are empirically distinct constructs, thus affirming the structural validity of the two-factor model.

3.1.5. Model Modifications

Although the hypothesised two-factor model provided a foundational structure for the data, initial fit indices suggested the need for refinement. As such, model modifications were considered to enhance structural validity while maintaining theoretical and ethical integrity. Examination of modification indices (MIs) suggested that allowing certain error terms to correlate could significantly improve model fit. Specifically, correlated residuals were considered between items such as "I enjoy solving mathematics problems" and "I feel excited when learning new mathematics topics," which reflect overlapping expressions of affective engagement. In line with Brown (2015), such adjustments were only retained when strong conceptual justification existed, namely, when items addressed closely related subthemes within the same latent construct.

In a few cases, items with low factor loadings (< .50) or high cross-loadings were reviewed. For example, one item related to routine calculation was found to load weakly onto the Enjoyment factor. However, no item was deleted at this stage, as doing so would risk undermining content validity by narrowing the scope of the construct, particularly given the importance of diverse affective and cognitive dimensions within mathematics attitudes. It is important to note that model re-specification was not conducted solely to improve statistical fit, but was informed by both empirical evidence and theoretical consistency. As Brown (2015) cautions, post-hoc model modifications without conceptual grounding can lead to overfitting and loss of construct clarity.

3.2. Discussion

The results of the Confirmatory Factor Analysis (CFA) offered critical insights into the psychometric properties of the hypothesised two-factor structure of the Mathematics Attitude Questionnaire (MAQ). However, the model exhibited suboptimal fit. The Comparative Fit Index (CFI = 0.831) and Tucker-Lewis Index (TLI = 0.808) fell below the recommended cut-off value of 0.90, while the Root Mean Square Error of Approximation (RMSEA = 0.141) exceeded the acceptable threshold of 0.08. The Standardised Root Mean Square Residual (SRMR = 0.100) was also above the benchmark of 0.08 (Hu & Bentler, 1999), further confirming poor fit. Although the chi-square statistic was significant, it is recognised that this index is sensitive to sample size, particularly in large samples (Kline, 2023). Consequently, these fit indices collectively suggest that the two-factor model may not adequately capture the complexity of the constructs measured by the MAQ. Theoretically, this misfit could be attributed to several factors. First, the multidimensional nature of students' attitudes toward mathematics, comprising affective, cognitive, and motivational dimensions, may not be fully captured by the two factors specified. Second, cultural and contextual influences unique to students in Kaduna State may have affected item interpretation and response patterns. Previous research highlights the importance of cultural adaptation and linguistic precision in ensuring accurate measurement (Van de Vijver & Leung, 2021). Item wording may also have introduced ambiguities, especially if translations or local idiomatic expressions were not adequately validated. These findings echo concerns raised by scholars advocating for more culturally responsive psychometric instruments in sub-Saharan Africa (Serpell & Simatende, 2016; Zakariya et al., 2025).

Despite the poor overall fit, the two latent constructs, Enjoyment of Mathematics and Perception of Incompetence, were validated through significant and interpretable factor loadings. Factor loadings for Enjoyment of Mathematics ranged from 0.49 to 0.78, indicating moderate to strong relationships between items and the latent variable. Perception of Incompetence exhibited loadings from 0.69 to 0.80, suggesting consistently strong item alignment. These findings reinforce the content and construct validity of both dimensions, aligning with existing literature that emphasizes enjoyment and self-perceived competence as key indicators of students' attitudes toward mathematics (Mamolo & Sugano, 2020; Mazana et al., 2018; Zakariya et al., 2024). The negative correlation between the two factors (r = -0.67) suggests an inverse relationship, whereby increased enjoyment corresponds with decreased perceptions of incompetence. This association is consistent with Self-Efficacy Theory (Bandura, 1997), which posits that positive emotional engagement enhances confidence and persistence in learning tasks. Similarly, the Theory of Planned Behaviour (Ajzen, 1991) supports the view that attitudes (e.g., enjoyment) and perceived behavioural control (e.g., competence) are crucial predictors of intention and behaviour, including academic performance (Akendita et al., 2025; Lee & Shin, 2022).

The study's findings provide key insights into the use of the MAQ in assessing students' attitudes. The validated constructs are relevant and meaningful for diagnosing students' affective responses to mathematics. Enjoyment of Mathematics reflects intrinsic motivation, curiosity, and engagement, all of which are predictors of long-term academic success (Maamin et al., 2021; Singh et al., 2002; Wang et al., 2021). On the other hand, Perception of Incompetence signals potential learning barriers and points to the need for targeted interventions that bolster self-efficacy and reduce anxiety (Alfred et al., 2024). Practically, teachers can use the MAQ to identify students requiring motivational support or targeted instructional interventions. Curriculum developers and policymakers can integrate findings from such diagnostics to design more inclusive, engaging, and differentiated learning experiences. For instance, recognising low enjoyment levels could prompt the adoption of more student-centred teaching methods, while high levels of perceived incompetence might necessitate scaffolding and formative assessment strategies (Carcueva, 2024; Millones-Liza et al., 2023; Ross & Rajkoomar, 2024).

Nevertheless, the results also suggest areas for refinement. The stronger composite reliability and loadings of the Enjoyment of Mathematics factor indicate that it is a robust measure. In contrast, Perception of Incompetence, although validated, showed relatively lower reliability and may benefit from the inclusion of additional items or revision of existing ones to enhance conceptual coverage. These adjustments could improve construct representation, especially for dimensions closely related to mathematics anxiety and self-doubt (Doruk et al., 2016; Laranang & Bondoc, 2020). Several limitations must be acknowledged. First, the study was geographically restricted to Kaduna State, limiting the generalisability of the findings. The cultural and educational context of the sample may not reflect broader national or international populations. Second, the study employed a cross-sectional design, which prevents causal inferences regarding the relationship between attitudes and mathematics achievement. Third, the reliance on self-report measures introduces the potential for social desirability bias, particularly in sensitive constructs such as academic self-perception and enjoyment. Furthermore, the hypothesised model may have been overly simplistic in treating mathematics attitude as comprising only two dimensions. Literature suggests that more nuanced models, including components such as mathematics anxiety, motivation, and perceived value, may better capture the complexity of student attitudes (Radišić et al., 2024). Future studies should consider testing alternative models with additional latent variables or higher-order constructs. Future research should focus on several key areas. First, cross-validation of the MAQ in diverse cultural and linguistic contexts across

Nigeria and beyond will be necessary to establish external validity. Second, longitudinal studies are recommended to assess how students' attitudes evolve over time and in response to instructional interventions. Third, mixed-methods approaches that incorporate qualitative data could offer richer insights into the affective and motivational experiences of learners. Fourth, further psychometric work, including exploratory and bifactor modelling, could uncover latent structures not captured in the current two-factor model. Finally, integrating advanced measurement techniques such as Item Response Theory (IRT) and invariance testing across gender or school type would deepen the scale's psychometric robustness.

The study contributes to the growing body of work on mathematics attitudes by validating a contextually adapted instrument in a Global South setting. It supports the applicability of major theoretical frameworks, such as Self-Efficacy Theory and the Theory of Planned Behavior, in interpreting affective responses to mathematics among Nigerian learners. Practically, the validated MAQ offers a diagnostic tool for educators and researchers seeking to understand and enhance mathematics engagement. His study provides evidence for the factorial validity of the MAQ's two core constructs, despite limitations in overall model fit. The findings underscore the need for culturally sensitive, theoretically grounded, and psychometrically rigorous tools in mathematics education research. The novelty of this study lies in its application of CFA to validate an attitudes instrument in a conflict-affected, low-resource setting, an area underrepresented in the global literature. The results serve as a foundation for refining the MAQ and improving mathematics learning through effectively informed pedagogies.

4. Conclusions

This study validated the two-factor structure of the Mathematics Attitude Questionnaire (MAQ), comprising Enjoyment of Mathematics and Perception of Incompetence, among secondary school students in Kaduna State, Nigeria. Consistent with Self-Efficacy Theory (Bandura, 1997), the observed negative correlation between Enjoyment and Perceived Incompetence underscores the role of self-belief in shaping students' emotional engagement and competence in mathematics. Moreover, the findings align with the Theory of Planned Behavior (Ajzen, 1991), affirming that students' attitudes influence their intentions and, ultimately, their academic behavior and outcomes in mathematics. Despite suboptimal model fit indices, the study offers meaningful insights into the attitudinal dimensions influencing mathematics learning. The validated constructs have practical relevance for improving mathematics instruction and student engagement.

Teachers should actively promote enjoyable mathematics learning by using real-life examples, gamified content, and collaborative learning. They must also monitor and reduce students' perceived incompetence through targeted feedback, differentiated instruction, and affirming classroom dialogue that builds mathematical confidence. Curriculum developers should integrate materials that balance cognitive demand with affective support, embedding motivational prompts and success experiences within math tasks. Policymakers must prioritize continuous professional development that equips teachers to recognize and respond to affective barriers, such as low self-efficacy and math-related anxiety.

The generalizability of the findings is constrained by the sample, which is limited to secondary school students in Kaduna State, Nigeria. The cross-sectional design limits causal inferences; longitudinal studies would better capture how attitudes develop over time. The exclusive reliance on self-report data may introduce social desirability bias, affecting the reliability of students' responses. Additionally, the use of a two-factor model may oversimplify the multifaceted nature of mathematics attitudes, excluding critical factors like anxiety, utility beliefs, or motivation.

Future studies should expand the model to include other constructs, such as mathematics anxiety and intrinsic motivation, to enhance conceptual coverage and model fit. Researchers should test the MAQ in diverse cultural and educational settings to evaluate its cross-contextual robustness. Longitudinal and mixed-methods approaches are recommended to capture changes in attitudes over time and to validate quantitative findings with qualitative depth. Incorporating behavioral or observational measures would also mitigate self-report limitations and offer a richer picture of students' mathematical dispositions. This study contributes a validated, context-sensitive instrument for measuring key affective components of mathematics attitudes in under-researched educational settings, adding value to international literature and providing actionable insights for local teaching and curriculum reforms.

Conflict of Interest

The authors declare no conflicts of interest.

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