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Attitude towards learning school geometry: an exploratory and confirmatory factor analysis in the Nigerian context

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ABSTRACT

Attitude is a critical factor influencing students' success in learning geometry and mathematics, which has been a subject of global interest in educational research. This study aimed to develop a valid and reliable instrument to measure students' attitudes toward learning geometry in Nigeria, based on the affective, behavioral, and cognitive (ABC) model. The instrument was tested on a sample of 100 secondary school students in Nigeria. To ensure its validity, both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were employed. The EFA results indicated a three-factor structure consisting of 20 items, which was further verified through CFA, showing good model fit indices and supporting the instrument's robustness. The reliability of the instrument was also confirmed, with Cronbach's alpha coefficients ranging from 0.73 to 0.89, suggesting strong internal consistency across the three attitude components. The findings indicate that the developed instrument is a reliable and valid tool for assessing secondary school students' attitudes toward geometry, capturing their emotional, behavioral, and cognitive responses to the subject. This study contributes significantly to the field of mathematics education by offering a context-specific tool for measuring attitudes, which could inform the development of more effective teaching strategies tailored to students' attitudes toward geometry.

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1. INTRODUCTION

Mathematics and geometry, in particular, are considered by most students and individuals (public) with different images. These different views developed as a result of how students or individuals perceived (attitude) geometry and mathematics in their lives. The learning process can influence students' attitudes positively or negatively which can affect the success of learning [1]–[4]. For this, teachers do not only consider the development of students' cognitive aspects in learning to achieve the objectives but also consider attitude as an important aspect of successful learning [5]. Confirmed some factors influencing the students' likeness or dislike of mathematics (geometry inclusive) as environmental factors, social-psychological, and student aptitude based on the instructional process [6]. Identified factors, such as mental, personal issues, and environmental of the learner [7]. A considerable number of research was conducted to strengthen the attitude of the students towards learning geometry, using different approaches that include technology usage and the use of models, while others conducted a survey on attitude in relation to achievement [8].

In Nigerian mathematics curriculum, school geometry is an important component that is found in all levels of education. The complexity of the topics in geometry is spiral in nature, that is what is taught at lower basic school can be found in the next level up to senior secondary school [9]. However, literature in Nigerian found that students continue to demonstrate a negative attitude in geometry, by avoiding answering problems on geometry in both internal and external examinations [10], [11]. Studies affirmed that negative attitude can lead to poor performance and vice-versa in Mathematics and geometry in particular [12], [13], [14], [15]. Other underlying factor is the instructional strategy used by the teacher, and the teacher's personality [16], [17]. Indicate that a teacher-centered approach that encourages memorization by the students in learning school geometry can lead to a negative attitude [18]. Literature supports this [19], [20], that in this situation students only memorize, the procedures, without a deep understanding of the concept, therefore this could lead to the weakness of students in geometry and develop phobia in mathematics in general. However, in Nigeria a substantial number of studies were conducted to alleviate students' attitude toward geometry [20]–[24]. Thus, the studies emphasize survey studies based on the affective component and difficulties in relation to other topics of mathematics, with less consideration to other components of attitude toward learning geometry in Nigeria.

Literature indicates the existence of several factors that can influence students' attitudes toward learning geometry and mathematics in general. Thus, these factors are considered based on the objective and need of their respective study. Among others include, perceived attitude of geometry in relation to mathematics [22], [24]. While others consider attitude base feeling, usefulness, and enjoyment about the object [25]. Despite the fact that attitude scales should measure all the above dimensions, most of the research in Nigeria focused on selected dimensions, such as usefulness, anxiety, and enjoyment. Research by Avcu and Avcu [26], affirrmed the need for a specific attitude scale in the respective mathematics topics. However, from the literature review, the constructs of attitude are based on three components; affective is concerned with feeling, usefulness, and enjoyment about the object [8], [27], [28]. Behavioral is the act or response towards the object, in view of this, the study makes several novel contributions to the field of mathematics education, particularly in the context of geometry learning [18], [27]. It is the first to apply the affective, behavioral, and cognitive (ABC) model to measure secondary school students' attitudes toward geometry, specifically in the Nigerian educational context. Also, the instrument's rigorous validation through exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) ensures its robustness for future educational research and interventions. Moreover, this study offers new insights into the attitudes of Nigerian secondary school students toward geometry, addressing a gap in the literature and providing a foundation for improving instructional strategies tailored to students' attitudes, which directly influence their engagement and academic success in mathematics.

2. METHOD

The study utilized a descriptive survey design, the participants were intentionally chosen from secondary schools in Sokoto State, Nigeria, resulting in a sample of 100 students, including 70 males and 30 females, who represented the demographic characteristics of the target population for the pilot study. The instrument consists of 24-item questionnaire developed in alignment with the ABC model of attitude. Each component was designed to measure distinct aspects of student attitudes toward geometry: the Affective component (items 1-8) focused on personal feelings such as enjoyment and motivation related to geometry; the Behavioral component (items 9-16) assessed students' actions and responses toward learning geometry, such as class attendance and engagement in geometry tasks; and the cognitive component (items 17-24) captured beliefs and perceptions about the relevance and difficulty of geometry. Each item on the questionnaire used a 5-point Likert scale, ranging from "strongly agree" to "strongly disagree," allowing for a nuanced assessment of students' agreement or disagreement with each statement.

Prior to its deployment, the instrument underwent face validation by a panel of five experts in mathematics education and measurement, who reviewed each item for clarity, relevance, and alignment with the study's objectives. Feedback from this panel prompted minor revisions to enhance the clarity and precision of several items. The finalized instrument, comprising eight items per attitude component, was then administered to the selected sample of students, who responded independently within a classroom setting.

The data collected from the completed questionnaires were analyzed using several procedures. Initially, principal components analysis (PCA) was performed to identify the factor structure underlying the 24 items, ensuring that they were appropriately grouped according to the ABC dimensions. To determine if the data were suitable for factor analysis, the Kaiser-Meyer-Olkin (KMO) measure was calculated, yielding a value of 0.69, which exceeded the recommended threshold of 0.60. Additionally, Bartlett's test of sphericity was found to be significant ($p<0.001$), confirming that the data met the necessary assumptions for factor analysis [29].

To verify the internal consistency of each component, Cronbach's alpha was computed for the ABC factors. Subsequently, CFA was performed to validate the three-factor model identified through PCA. The CFA evaluated how well the observed data matched the proposed structure, and the fit indices indicated that the three-component model was a good fit, thereby confirming the model's validity and reliability for assessing attitudes toward geometry [29], [30].

3. RESULTS AND DISCUSSION

In this section, the results obtained from the analysis of the instrument, including PCA, the KMO measure, Bartlett's test, and CFA, are presented. The PCA identified key factors underlying the attitude scale, with the KMO and Bartlett's Test confirming sampling adequacy and data suitability for factor analysis [29]. Finally, CFA validated the factor structure, ensuring the instrument's reliability and alignment with the three-component model.

3.1. Principal component analysis

A 24-item scale measuring students' attitudes toward learning geometry was analyzed using PCA in SPSS v.20. A preliminary investigation was carried out to assess the strength of the inter-correlations among the items and to check the data's suitability for factor analysis. The correlation matrix revealed numerous coefficients greater than 0.3, and the KMO value of 0.69 exceeded the recommended threshold of 0.60, confirming the adequacy of the sample [26]. Additionally, Bartlett's test of sphericity was statistically significant as in Table 1, providing evidence that the data was suitable for factor analysis [29], [30]. PCA revealed seven components with eigenvalues above 1, which together accounted for 64.89% of the variance. A scree plot inspection showed clear breaks after the second and fourth components as in Figure 1. Based on Cattell's scree test, three components were retained for further analysis, and this was supported by the results from parallel analysis (PA) as in Table 2, which indicated that only three components had eigenvalues greater than those from PA with the same sample size [30], [31].

To enhance the interpretation of these components, Varimax rotation was performed, yielding a simple structure with strong loadings for all three components as in Table 3. The three-component solution explained a total of 43.1% of the variance, with the components contributing 16.47%, 14.03%, and 12.56%, respectively. These findings align with previous research, confirming the robustness of the three-factor model [31]‒[33].

Table 1. KMO and Bartlett's test

KMO and Bartlett's test		
KMO measure of sampling adequacy		.692
Bartlett's test of Sphericity	Approx. Chi-Square	915.036
	Df	276
	Sig.	.000

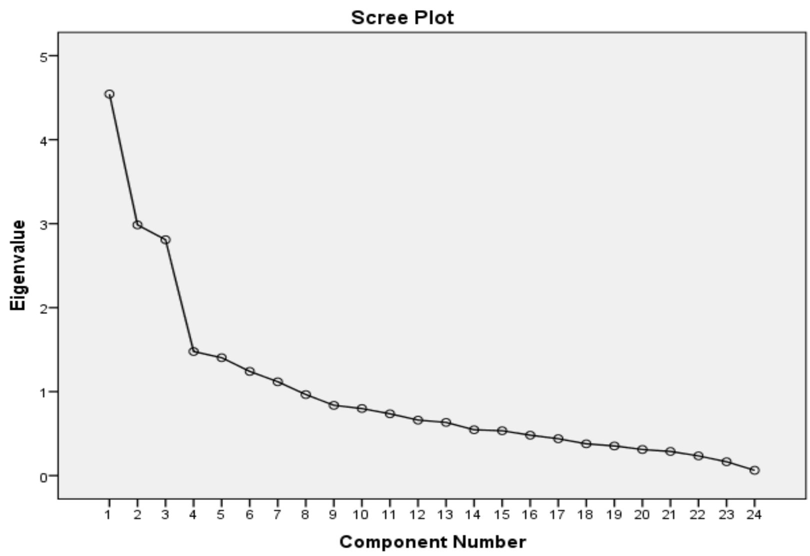

Figure 1. Scree plot

Table 2. Comparison of eigenvalues from PCA and PA

Component	Eigenvalue from PCA	Criterion value from PA	Decision
1	4.543	2.0237	Accept
2	2.985	1.8337	Accept
3	2.808	1.7012	Accept
4	1.478	1.5956	Reject
***	****	*****	*****
23	.165	.3615	Reject
24	.063	.3009	Reject

Table 3. Result analysis of items factor loading

No. Items	Component		
	1	2	3
Item 8	.707		
Item 11	.706		
Item 9	.678		
Item 7	.677		
Item 6	.644		
****	**	*	
Item 1			
Item 3			
Item 5			
Item 21		.941	
Item 2		.886	
Item 24		.873	
Item 19		.774	
Item 15			.805
Item 14			.723
Item 16			.709
Item 17			.589
Item 18			.578
Item 13			.478
Item 20			.451
Item 22			

However, to further confirm the internal consistencies of the three components, the Cronbach's alpha reliability test was conducted on each factor. The results indicate strong internal reliability, with Cronbach's alpha values of 0.816, 0.897, and 0.735 for the ABC components, respectively as suggested [34] as in Table 4. These values suggest that each component reliably measures its intended dimension of attitude, supporting the instrument's consistency across items within each factor. The findings of this study are in line with previous research, where similarly high internal consistency values were reported for the ABC factors, thereby supporting the validity of these constructs as independent yet interrelated factors of attitude [32], [33]. For example Walker *et al.* [33] and Tapia and Marsh [35], both highlighted that reliable measurement of these components is crucial for accurately assessing student attitudes in educational settings, ensuring that the results are both meaningful and applicable to improving educational practices.

Based on the interpretations of each item in each component, it was realized that: component 1, component 2, and component 3 were measuring ABC attitudes respectively. This was consistent with previous research on ABC components [27], [28], [36], [37]. In general, out of the 24 items that were extracted, 20 items were rotated and loaded to their respective components whereas 4 items (item 1, item 3, item 5, and item 22) did not load on any component. Literature suggested that those items should be removed [32], [33]. Thus, the new attitude scale comprised three components, involving 20 items.

Table 4. Result of the reliability test

Component	No. Items	Cronbach's alpha
Affective	9	.816
Behavioral	4	.897
Cognitive	7	.735

3.2. Confirmatory factor analysis

After identifying the items associated with each factor through PCA, a CFA was conducted to validate these item loadings on the three factors as in Figure 2. The CFA tested the model's fit to ensure that each item significantly corresponded to its designated factor, verifying the structure suggested by the PCA results. It confirms that the three-factor model accurately represents the data, supporting the construct validity of the instrument [32]. These findings not only support the validity of the model but also affirm the instrument's capacity to reliably capture distinct, yet interrelated, aspects of students' attitudes, including their emotional responses (affective), behavioral tendencies (behavioral), and cognitive evaluations (cognitive) toward geometry learning. Such confirmation aligns with the findings of previous research, such as Walker *et al*. [33], Tapia and Marsh [35], Avcu and Avcu [26], which similarly demonstrated the model's effectiveness in evaluating attitudes in educational settings, thereby reinforcing the construct validity of the instrument in this study.

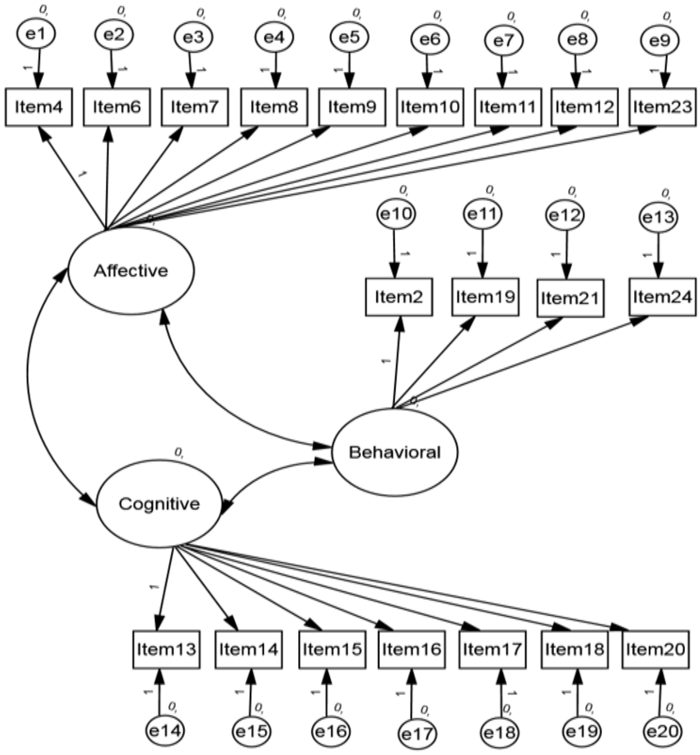

Figure 2. Path diagram of CFA

Based on the analysis, baseline comparisons show that the model fits the data (IFI, TFI, CFI>0.9; Chi-square>0.05) as in Table 5. Each of the items significantly loads on their respective factor as in Table 6, suggesting that each of the three factors significantly predicts their items as suggested by the PCA. However, the three factors do not significantly correlate as in Table 7, suggesting that the three factors were independently predicting their respective items. In view of these results, the three factors were therefore confirmed and further confirmed the ABC model. The result aligned with the previous findings [32], [33], [35]. These earlier studies provide substantial evidence that this tripartite model captures the complexity of attitudes and their impact on academic performance. For instance, Walker *et al*. [33] confirmed the model's reliability in various academic settings, underlining its significance in understanding students' emotional, behavioral, and cognitive responses toward academic challenges. Similarly, Tapia and Marsh [35] provided a comprehensive analysis showing how the integration of the three components offers a more nuanced perspective of student attitudes compared to unidimensional measures. Therefore, the findings from this study not only validate the ABC model but also underscore its relevance and applicability in measuring attitudes toward geometry, contributing to the development of more effective instructional strategies.

Table 5. Model fit baseline comparisons

Model	IFI delta2	TLI rho2	CFI	Chi-square
Default model	.964	.957	.962	191.73 (.09)
Saturated model	1.000		1.000	
Independence model	.000	.000	.000	

Table 6. Regression coefficient

Item		Factor	Estimate	S.E.	C.R.	P
Item4	<---	Affective	1.000	.683	1.464	***
Item10	<---	Affective	1.881	.593	3.175	.001
Item11	<---	Affective	2.398	.674	3.560	***
Item12	<---	Affective	1.669	.543	3.075	.002
Item23	<---	Affective	1.418	.462	3.071	.002
Item2	<---	Behavioral	1.000	.167	5.988	***
Item13	<---	Cognitive	1.000	.483	2.070	.002
Item20	<---	Cognitive	.834	.362	2.304	.021

Note: ***p<0.001

Table 7. Result of covariance for three components

Factor			Estimate	S.E.	C.R.	P
Cognitive	<-->	Affective	-.011	.015	-.745	.457
Affective	<-->	Behavioral	.060	.030	2.024	.043
Cognitive	<-->	Behavioral	-.003	.041	-.073	.942

4. CONCLUSION

The analysis of the results from the PCA and CFA supported a robust three-factor structure, aligned with the ABC components. Furthermore, the findings suggest that the instrument provides a reliable measure for evaluating attitudes, which could be invaluable for educators and researchers aiming to understand and improve students' engagement with geometry. However, caution should be exercised when generalizing these findings to students at other educational levels.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state that no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board.

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article.

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