Validation of Attitude towards Mathematics Inventory (ATMI): Psychometric Properties beyond the Western World

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Abstract

This study aimed to validate the 15-item attitudes towards mathematics instrument (ATMI) in secondary schools in Harare, Zimbabwe. It was motivated by concerns that some students underperform in mathematics due to negative attitudes, which are rarely assessed by standardised instruments. Such attitudes may hinder educational outcomes and affect Zimbabwe's industrialisation efforts under the National Development Strategy 1 (NDS 1). The study assumed that attitudes are social construct and culturally specific, highlighting the need for a locally validated tool. Guided by the enjoyment, self-confidence, and perceived value of mathematics conceptual framework, the descriptive survey and explanatory research designs were used to analyse survey data gathered from 208 form three learners aged 16 to 17 years. Exploratory factor analysis and confirmatory factor analysis were the multivariate techniques used to examine the instrument's psychometric properties. The major findings of the study is that a three- factor structure of ATMI was reaffirmed with 12 items, and attitudes toward mathematics was confirmed as first or second-order construct. The study concluded that the 12-item ATMI is a valid tool for measuring ATM in Zimbabwean secondary schools, and recommended that mathematics educators should use it, especially for underachieving students and during educational transitions.

Keywords: Validation, attitude towards mathematics, psychometric properties, western world

Introduction

Globally, reviewed literature shows that, mathematical abilities are generally important for the economic development of any nation (Copur-Gencturk, Lubienski & Thacker, 2020; Kopeika & Zvirgzdina, 2020; Pertiwi, Rohaeti & Hidayat, 2021). The comprehension of science and technology, which has applications in other fields including engineering, pure and applied sciences, arts, and corporate operations, requires mathematic abilities in many different ways (Narh-Kert, Agyeman & Crankson, 2021). However, whether attitude is identified as an aversion to mathematics 'methamaphobia' or 'disaffection', student attitude towards mathematics has been argued to be a problem, especially at secondary school level.

In addition, because attitude is a social construct which depends on learners' individual experiences, significant differences are likely to exist on what constitute attitude and how attitude is measured across cultures (Noyes, 2012; Rosso, 2020).

Since the identification of attitudes towards mathematics as a problem, several research studies have been done globally in order to explain reasons for student attitudes towards learning mathematics. Most of these studies have shown a positive link between ATM and achievement in mathematics (Kiwanuka et al., 2022; Ma & Kishor, 1997; Wangdi & Wangdi, 2022). However, the methods employed to examine student ATM varied from one study to another and were mostly qualitative research designs. These studies relied on consulting university students, teachers and researchers for opinion to ascertain the origins of attitude towards mathematics, ignoring secondary school learners (Bovill, 2020; Karali & Aydemir, 2018). A few quantitative studies have been conducted to understand what constitutes ATM and the effectiveness of the instruments measuring ATM from the secondary school student's perspective, and results indicate no consensus on what constitute ATM. For example, Aiken (1976) developed a five point Likert scale with 23 items and two sub-scales. The two sub-factor scales referred to were named enjoying mathematics and the value of mathematics. In the same year, the Fennema-Sherman mathematics attitude scale was also developed for the same purpose (Fennema & Sherman, 1976). The Fennema and Sherman (1976) attitude scale is a five-point Likert scale with 9 sub-scales made up of 1268 items originally. The psychometric properties of Fennema-Sherman attitude scale have been revised several times, and the most recent was the Short Form Version of 1998 one with 108 items shortened by Mulhern and Rae (1998). Research employing secondary school students as respondents provides a clearer understanding of the underlying factors contributing to ATM. This is why this study focused on Form Three students enrolled in two selected secondary schools in Harare, Zimbabwe. The selection of students from two schools provided an insight of ATM in two similar, but distinct contexts.

Internationally, some studies have shown that positive ATM is not always positively correlated with success in mathematics (Berger, Mackenzie, & Holmes, 2020; Rozgonjuk, Täht, & Vassil, 2021; Zakariya, Barattucci, Fernández-Cézar, & Solano-Pinto, 2022). In Australia, a large percentage of secondary and tertiary students from affluent communities had negative views towards mathematics and perform worse than students from less affluent societies in the subject (Charles, Cech & Hendley, 2014). According to recent research, Huckling, Murcia and Anderson (2014) noted that secondary school students in

Western Australia had negative attitude towards science technical engineering and m (STEM) subjects, and enrolment in mathematics courses in high schools across Australia was declining (Kennedy, Lyons, & Quinne, 2014).

To get an understanding of ATM globally, the Trends in International Mathematics and Science Study (TIMSS) scale is used. The three constructs that make up the TIMSS scale are intrinsic value (interest), utility value, and ability beliefs (confidence). According to the 2011 TIMSS report on ATM in the classroom, pupils who had good attitudes were more likely to succeed academically than those who had negative attitudes, and their attitudes decreased as they aged (Mullis, Martin & Arora, 2012). The study also established a positive link between positive attitudes towards mathematics and higher grade achievement. However, differences were observed across individual countries. For instance, even though Japan is the fifth-ranked country in the world for mathematical achievement, just 9% of eighth-grade students there indicated liking mathematics. According to Skilling, Bobis and Martin (2015), this suggests that higher academic achievement does not always indicate a higher level of academic involvement.

Ngussa and Mbuti (2017), in their Tanzanian study on underachievement in mathematics, attributed the high failure rates to several reasons, but found attitude towards mathematics as the major cause. Similarly, Tshabalala and Ncube (2016) postulated that several cross-factors related to students, schools, teachers, parents, society, personality, interest and intellectual intelligence quotient were indeed predictors of underachievement in mathematics. With regards to student factors, most researchers agree that ATM is the major cause of high failure rates in mathematics (Ngussa & Mbuti, 2017). For example, in Zimbabwe's ZIMSEC O-level examinations, the lowest percentage pass rate has always been in mathematics, despite high pass rates in other non-STEM subjects. For example, ZIMSEC O-level results in 2020 indicated highest failure rate of 81% in mathematics. Similar trends have also been observed in the 2021 results, despite the failure rate dropping to 79% (ZIMSEC, 2022).

Most studies have found a positive association between learners' attitudes and academic success in mathematics. Identifying attitude of students towards mathematics through standardised mathematic attitude scales may help reduce underachievement in secondary schools by identifying students with negative attitudes and forming positive attitudes. However, the attitude scales that have been used in some countries in their original form without examining their reliability and validity in the local environment (Bastos, Reichenheim, & Moraes, 2021; Mpofu & Nyanungo, 1998; Reilly, Neumann & Andrews, 2019). Quantitative researchers assert that it is always important to assess the validity and reliability of instruments, especially if the population being studied was not the norm group when the instrument was designed and standardised (Bastos, Reichenheim, & Moraes, 2021; Syyeda, 2021; Herdman, Fox-Rushby, & Badia, 1998). As a result, all instruments used in quantitative studies should be assessed for internal and external validity (Johnson, Adkins, & Chauvin, 2020; Malmqvist et al., 2019). Attitudes as social constructs, change with time and differ according to culture (Syyeda, 2021). While a positive change in attitude can improve students learning outcomes, this is only possible if attitudes are identified with a good instrument with psychometric properties normed on the population understudy (Biencinto et al., 2021; Callahan et al., 2020; Wang, Tan, & Li, 2020). It is against this background that this research sought to validate the Attitude towards Mathematics Instrument (ATMI) in the context of Zimbabwe secondary school learners in Harare.

Statement of the problem

Zimbabwe has made significant progress in ensuring that nearly all secondary school learners have access to mathematics education at 'O' level. This is crucial for the country's innovation and industrialisation agenda, as mathematical skills are essential for economic development. However, despite substantial investments, many learners face challenges in mathematics as they transition from primary to secondary education, often developing negative attitudes toward the subject (Copur-Gencturk, Cimpian, Lubienski & Thacker, 2020; Schult, Mahler, Fauth, & Lindner, 2022). The issue lies in the fact that attitudes are social constructs that cannot be universally measured across different cultures and can change over time, even within the same culture (Siegle, McCoach & Rubenstein, 2021; Varela-Losada et al., 2021). Therefore, the absence of a valid and reliable scale to assess attitudes towards mathematics presents a barrier to addressing the high prevalent mathematics phobia and underachievement among learners in Zimbabwe. Having a valid and reliable scale to test attitude could be the genesis to addressing this mathematics phobia, and the way forward in achieving innovation and industrialisation in Zimbabwe.

Research objectives

This study major objective sought:

To validate the Attitude towards Mathematics Inventory (ATMI) by examining the attitudes of Form Three learners in Harare.

Sub-objectives
The specific objectives were:

- To determine the psychometric properties of ATMI in secondary schools in Harare North District.
- To determine the factor structure of the 15-item ATMI.

Significance of study

This study contributes original insights to the existing literature. There is a gap in the development and validation of attitude measuring instruments in Zimbabwe secondary schools. Additionally, this study offers an alternative approach to intelligence quotient (IQ) testing in explaining underachievement in mathematics. By using a multi-method approach that includes attitudes testing, followed by IQ testing, the risk of wrong diagnosis when underachievement is observed is minimised. Fostering positive attitudes towards mathematics through the approach aligns with the goals of the National Development Strategy One (NDS1) to increase the number of STEM graduates and drive Zimbabwe to towards an upper middle class economy by 2030.

Conceptual framework

ECV conceptual model of ATM

The ECV model of attitude towards mathematics guided this study. Prior to conducting the research, the researchers reviewed the various definitions of ATM particularly the ABC model. The ECV model, which consists of enjoyment (E), self-confidence (C) and value of mathematics (V), emerged as a concise and consistent framework for conceptualising attitudes towards mathematics. These three attributes have been integral to the definition of ATM since the early stages of measurement. This model of ATM posits that attitude is influenced by the interaction of enjoyment, self-confidence, and perceived value of mathematics, excluding motivation.

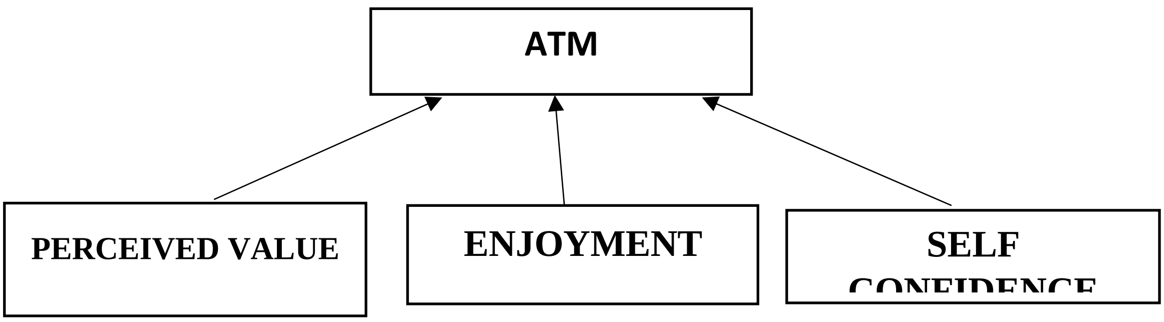

Figure 1: Proposed ECV model of ATMI

Self-confidence in mathematics refers to a learner‘s belief in either their ability to learn and perform well in mathematics. Research has shown that self-confidence significantly impacts on learning outcomes, and achievement in mathematics. Enjoyment of mathematics refers to the extent to which a learner finds enjoyment in studying and learning mathematics. Studies have indicated that students are more likely to excel in mathematics if they find the subject enjoyable and interesting. Perceived usefulness refers to how students view the importance of mathematics in their current and future lives (Soydaş, 2023). Students who recognise the value of mathematics are more motivated to study, practice, and excel in the subject. Therefore, the ECV conceptual framework was deemed appropriate for validating the ATMI among secondary school learners in Harare.

Methodology

Research design

The objectives of this study were to determine the psychometric properties of the 15-item ATMI and its factor structure by examining the interrelationships of the instrument elements that have been observed in previous studies. To achieve these objectives, the descriptive survey research design and explanatory research design were employed. The descriptive survey design was used to provide descriptive statistics of the demographic characteristics of the respondents. Since the study aimed for objectivity, causality, replicability and generalisability of inferences, the explanatory research design was deemed appropriate to determine the psychometric properties and the factor structure of the ATMI (Cooper & Schindier, 2001; Creswell, 2014; Saunders et al., 2011; Levin, Klein & Wolf, 2009).

Participants

This study employed stratified random sampling approach to select two hundred and eight Form Three students (106 male and 102 female), aged 16 and 17 years from two secondary schools in Harare, Zimbabwe. This sample size of 208 learners was selected from a population of 260 Form Three learners determined by Raosoft Sample Size Calculator at 95% confidence level, 5% standard error and assumed population proportion of 50%. The sample size used in the study robustly supports the results of the confirmatory factor analysis (CFA) analysis. Simulation studies indicate that when indicator variables follow a normal distribution and there is no missing data, a sample size of approximately N = 150 is generally sufficient for a simple confirmatory factor analysis (CFA) model (Muthén & Muthén, 2002; Kline, 2005).

Respondents completed the English version of the 15-item ATMI scale recommended by Lim and Chapman (2015). The Zimbabwean government adheres strictly to standard guidelines to ensure no harm happens to the learner during psychological evaluations. In compliance with this guideline, the researchers obtained permission from the Provincial Educational Director of Harare Province to administer the questionnaire in two secondary schools, one private and one public.

The instrument consists of three subscales: an enjoyment scale, a self-confidence scale and a value of mathematics scale. Each subscales contains five items rated on a 5-point Likert scale ranging from ‘strongly disagree’ to ‘strongly agree.’

Statistical analysis

Item analysis (IA), exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were used to examine the reliability and construct validity of the 15-item ATMI. Item analysis and EFA were performed in SPSS 25, while CFA was conducted in AMOS 22. EFA used principal component analysis with promax rotation to determine the factor structure of the instrument. The maximum likelihood method in CFA was used to test the parameters of the ECV model (Oamen, 2024).

Initially, the goodness-of-fit measurement model was assessed using various fit indices, including the Chi-square goodness-of-fit, Chi-square degrees of freedom ratio (CMIN/DF), comparative fit indices (CFI), root mean square error of approximation (RMSEA), goodness-of-fit indices (GFI), and adjusted goodness-of-fit indices (AGFI). Following the assessment of the goodness-of-fit measurement model the reliability and construct validity of the measurement model were determined by calculating the average extracted variance (AVE) and composite reliability (CR) using standardised regression estimates derived from the CFA measurement model in Excel. Discriminant validity was established by comparing the discriminating value (√AVE=DV) with the correlation between the construct and other latent variables in the model.

Results

This chapter presents the results of the study, which aimed to validate the adapted 15-item Attitude Towards Mathematics Inventory (ATMI) within the context of Form Three learners in Harare. The analysis focused on evaluating the reliability and validity of the instrument in this educational setting. As outlined in the methodology section of this study, the analysis involved three key stages: item analysis (IA), exploratory factor analysis (EFA), and confirmatory factor analysis (CFA). These procedures were conducted to assess the internal consistency of the items, explore the underlying factor structure, and confirm the model's fitness to the data. The results from each stage of analysis are presented in the sections that follow.

Item analysis

Table 1: Inter-item correlation and determinant of 15-item ATMI scale

Inter-Item Correlation Matrix

	EM1	EM2	EM3	EM4	EM5	SC1	SC2	SC3	SC4	SC5	VM1	VM2	VM3	VM4	VM5
EM1	1.00														
EM2	0.52	1.00													
EM3	0.52	0.62	1.00												
EM4	0.34	0.42	0.51	1.00											
EM5	0.48	0.49	0.61	0.54	1.00										
SC1	0.13	0.12	-0.02	-0.07	-0.02	1.00									
SC2	0.01	0.20	0.09	0.04	0.23	0.35	1.00								
SC3	-0.01	0.02	0.09	0.00	0.15	0.18	0.51	1.00							
SC4	-0.06	-0.08	0.01	0.04	0.10	0.20	0.46	0.56	1.00						
SC5	-0.01	-0.02	0.07	-0.10	0.12	0.22	0.53	0.55	0.58	1.00					
VM1	0.06	-0.04	0.13	0.15	0.10	0.16	0.12	0.10	0.21	0.17	1.00				
VM2	0.10	0.21	0.34	0.24	0.21	0.07	0.16	0.12	-0.04	0.08	0.49	1.00			
VM3	0.21	0.25	0.31	0.20	0.30	0.11	0.12	0.15	0.08	0.11	0.47	0.55	1.00		
VM4	-0.08	0.07	0.09	-0.06	0.10	0.14	0.20	0.28	0.20	0.29	0.26	0.31	0.36	1.00	
VM5	-0.01	0.01	-0.02	-0.05	-0.01	0.33	0.31	0.24	0.30	0.31	0.15	0.11	0.11	0.18	1.00

Correlation Matrix[a]

a. Determinant = .006

Table 1 presents the inter-item correlation matrix for the 15-item ATMI scale comprising three subscales: enjoyment of mathematics (EM), self-confidence in mathematics (SC), and value of mathematics (VM), assessed for convergent and discriminant validity. Convergent validity was evidenced by moderate to strong correlations within subscales (e.g., EM1–EM5, r = .34 to .62; SC1–SC5, r = .18 to .58; VM2–VM3, r = .55), indicating internal consistency. Discriminant validity was demonstrated through weak or negative correlations between items from different subscales (e.g., EM3–SC1 = –.02), confirming the distinctiveness of the constructs. The determinant of .006 suggests no multicollinearity concerns, supporting factor analysis suitability and overall validity of the scale. In summary**,** the pattern of correlations supports good construct validity of the 15-item ATMI in this sample of Form Three learners, with strong inter-item consistency within subscales and weak correlations between items across different subscales.

Exploratory factor analysis (EFA)

In order to determine the factorial structure of the ATMI, items were subjected to principal factor analysis using promax rotation as the factorisation method. The factors to retain or discard were based on Kaiser's Eigen value greater-than-one rule, and factor loading of at least .4. Only items with factor loadings> .4 and Eigen value>1 were considered useful and retained.

Table 2: Results of KMO and Bartlett's tests

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.756
Bartlett's Test of Sphericity	Approx. Chi-Square	1051.700
	Df	91
	Sig.	.000

Before the exploratory factor analysis (EFA) was conducted to evaluate the construct validity of the 15-item ATMI, Kaiser-Meyer-Olkin (KMO) coefficient and Bartlett's test results were computed to determine whether the data set was fit for factor analysis. As can be observed in Table 2 below, the KMO measure of sampling adequacy value was 0.756. Since the KMO coefficient was close to 1 (>0.5) and the Bartlett's test was significant (p<0.01), the data set met the requirements to perform factor analysis.

Extraction method: Principal component analysis

Table 3: Principal component matric of ATMI

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	3.63	25.93	25.93	3.63	25.93	25.93	3.14
2	2.93	20.93	46.86	2.93	20.93	46.86	2.98
3	1.69	12.10	58.96	1.69	12.10	58.965	2.70
4	.99	7.07	66.03				
5	.75	5.38	71.41				
6	.66	4.71	76.12				
7	.62	4.43	80.55				
8	.59	4.24	84.80				
9	.47	3.38	88.17				
12	.33	2.34	96.31				
13	.27	1.91	98.21				
15	.25	1.79	100.00				

Table 3 shows the results of a principal component analysis (PCA) on the ATMI, revealing that three components had eigenvalues greater than 1 and together explained approximately 59% of the total variance (25.93%, 20.93%, and 12.10% respectively). This suggests that the ATMI data can be effectively summarised using three principal components, each contributing meaningfully to the overall structure (Hamman, 2023). The scree plot below presents a graphical summary of the extracted components.

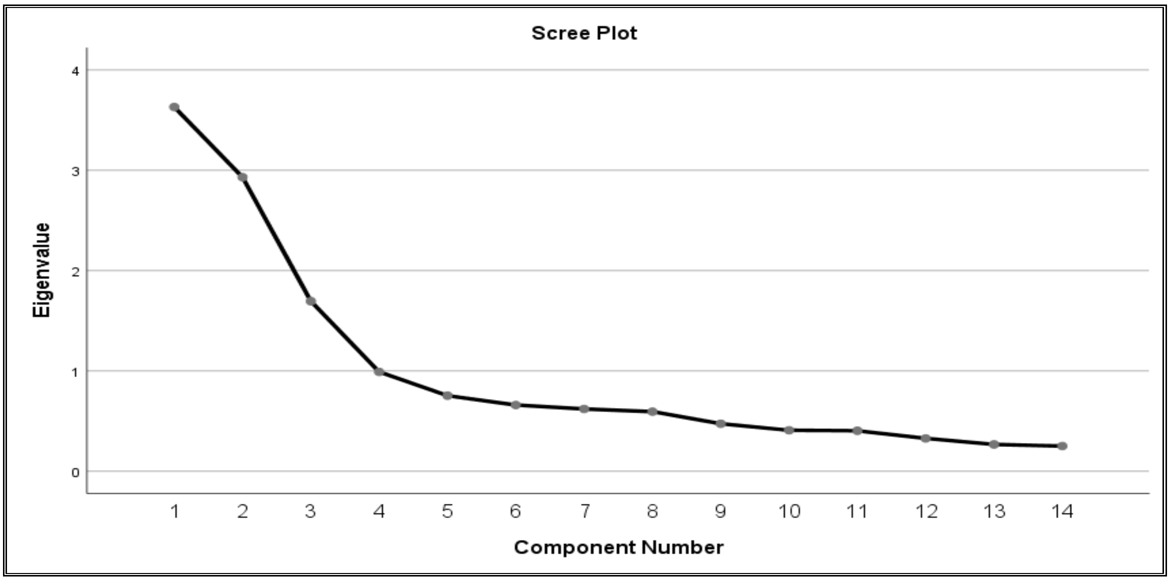

Figure 2: The Scree-Plot for the factors of learners ATMI

Table 4: Rotated Component Matric for ATMI

Variable	Component		
	1	2	3
EM1	.753		
EM2	.800		
EM3	.691		
EM4	.754		
EM5	.802		
SC2		.802	
SC3		.817	
SC4		.784	
SC5		.724	
VM3			.616
VM4			.659
VM5			.751

Extraction Method: Principal Component Analysis.
Rotation Method: Promax with Kaiser Normalisation.
a. Rotation converged in 5 iterations.

Exploratory factor analysis using principal component analysis with promax rotation reveal a clear three-factor structure for the Attitudes Toward Mathematics Inventory (ATMI), as shown in Table 4. Five items related to enjoyment of mathematics (EM1–EM5) loaded strongly on factor 1 (factor loadings = .691 to.802), four items related to self-confidence (SC2–SC5) loaded on factor 2 (loadings = .724 to .817), and three items assessing value of mathematics (VM3–VM5) loaded on factor 3 (loadings = .616 to .751). Items SC1, VM1, and VM2 were removed due to loadings below .40, indicating poor convergence validity. No cross-loadings were observed, and factor loadings across retained items ranged from .62 to .82, supporting the scale's convergent and discriminant validity. EFA results confirm the three-factor structure of the ATMI scale with 12 items. Such relationships indicate that the 12-item ATMI has good convergent and discriminant validity.

Confirmatory factor analysis (CFA)

The structural validity of the three-factor structure of the 12-item ATMI derived from the EFA was examined using CFA. Table 4 and Figure 2 depict the results.

Table 5: CFA model-fit-indices of Zimbabwean version of ATMI

Fit Index	Recommended value (Hair, 2010)	Survey value	Conclusion
Chi-square (X^2)	p>0.05	X^2(62)=145.16,p= 0.000 < 0.001	No model fit
Chi-square (X^2)/df	<5 preferably <3	2.341	Model fit
Adjusted Goodness of Fit Index (AGFI)	<0.8	0.865>0.08	
Goodness of Fit Index (AGF)	<0.8	0.908>0.08	Model fit
Comparative Fit Index (CFI)	>0.9	0.914	Model fit
Root Mean Square Error of Approximation (RMSEA)	<0.08 preferably <0.05	0.049	Model fit

Confirmatory factor analysis (CFA) was conducted to validate the three-factor structure of the 12-item ATMI derived from the exploratory factor analysis. As shown in Table 5, model fit indices demonstrated an acceptable fit between the proposed model and the data: χ^2/df = 2.341, AGFI = .865, GFI = .908, CFI = .914, and RMSEA = .049, all meeting or exceeding recommended thresholds. Although the Chi-square test was significant, $\chi^2(62) = 145.16$, $p < .001$, this is a common occurrence in CFA due to the test's sensitivity to sample size (Hair et al., 2010). Overall, the results support the structural validity of the three-factor ATMI model in the Zimbabwean secondary schools context.

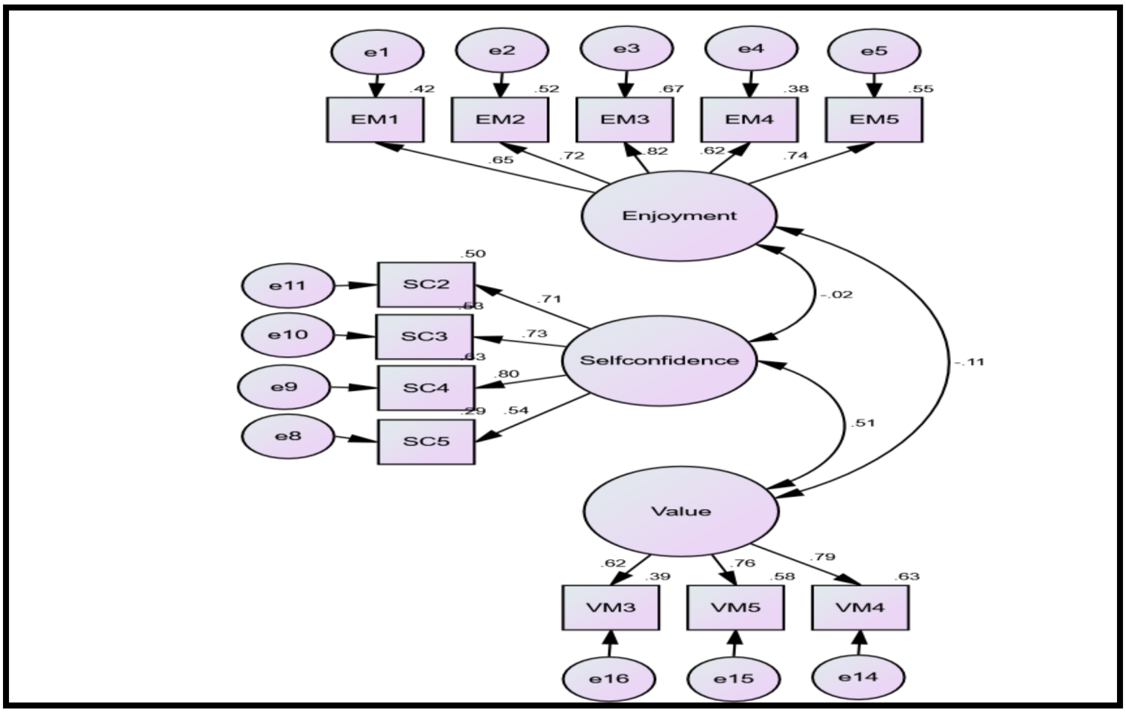

Figure 3: Path diagram for Students' ATM Measurement Model (First order construct)

Model fit results confirm the three-factor structure of the Zimbabwean 12-ATMI scale (5-enjoyment of mathematics items, 4-self-confidence in mathematics and 3-value of mathematics items). Findings suggest that attitudes towards mathematics is a first order construct, which is a product of the interaction between enjoyment of mathematics, value of mathematics and self confidence in mathematics. The next section examines the ATMI's reliability and construct validity.

Table 6: ATMI Zimbabwean version subscale Cronbach's coefficient alpha, AVE, DV and CR values

ATM category	Code	Factor loading	Cronbach alpha	AVE	DV	CR
Enjoyment	EM1	0.651	.833	.508	.82	0.816
	EM2	0.717				
	EM3	0.817				
	EM4	0.615				
	EM5	0.746				
Self-confidence	SC2	0.805	.782	.503	.78	0.780
	SC3	0.725				
	SC4	0.723				
	SC5	0.643				
Value	VM1	0.773	.731	0.527	.75	0.750
	VM2	0.768				
	VM3	0.627				

$CR = (\sum Bi)^2/(\sum Bi)^2 + \sum ME)$ and $AVE = (\sum B_i^2)/N$

Table 6 depicts information about the reliability and construct validity of the 12-item ATMI. The Cronbach's alpha value ranges from .731 to .822 indicating internal consistency of the 12-item ATMI. The composite reliability or construct reliability (CR) values of the items range from .750 to .816, which is a strong indicator that all the items in the model consistently measure the same construct. The AVE values of the three constructs are greater than 0.5, indicating that at least 50.2% of the total variance in the observed construct (learners' attitudes towards mathematics) is explained by the latent variables enjoyment of mathematics, self-confidence in mathematics and value of mathematics. AVE values above 50% indicate internal consistency of a measuring instrument.

Table 6 shows that the discriminant validity (DV) of each construct is greater than the correlation the construct has with other constructs in the model. The results illustrate that all the 12 items in the ATMI model are unrelated to items measuring other constructs in the model, which theoretically should not be associated with each other. This finding illustrates that constructs of the ATMI are distinct from each other, thus confirming the discriminant validity of the model.

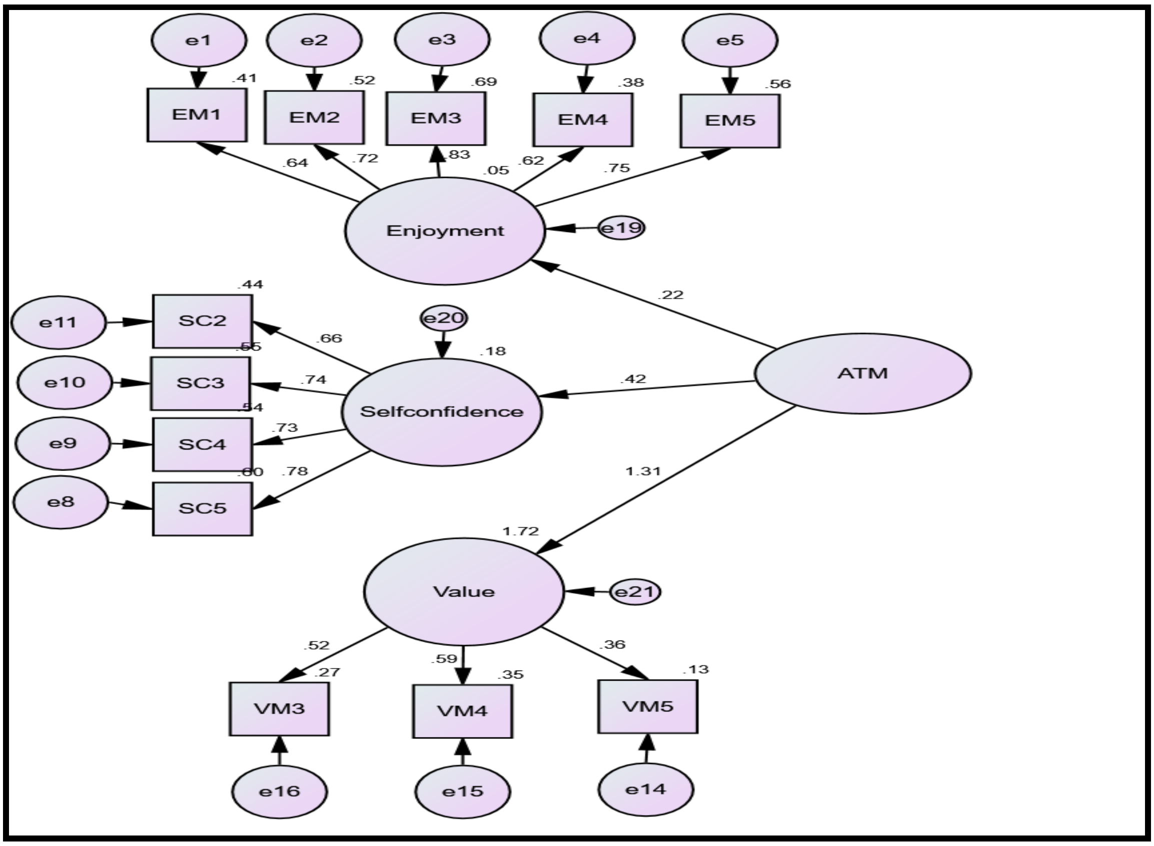

Figure 4: Path diagram for students' ATM measurement model (second order construct)

Figure 4 shows that student ATM can be a second order construct determined by three independent latent variables: enjoyment of mathematics (E), self-confidence in mathematics (S) and value of mathematics (V). CFA results provided in Figure 5 indicate a positive significant relationship between E, S and V with ATM, with the association between value of mathematics and learners ATM having the greatest influence. When ATM increases by I standard deviation it significantly increases value of mathematics by 1.31($p<0.01$) standard deviation, while self-confidence in mathematics goes by .422 ($p<0.01$) standard deviation and enjoyment goes up by 0.223 ($p<0.01$) standard deviations. Furthermore, the results indicate significant positive relationship between items and constructs. Standardised regression estimates for most of the relationships of at least, B>0.62, except for VM5 (B=0.36) suggest good discriminating value of items in the model.

Results imply that attitude can be conceptualised as ether enjoyment in mathematics or self-confidence in mathematics or value of mathematics, without them interacting.

Table 7: Model-fit-indices of second order ATM model

Fit Index	Recommended value (Hair, 2010)	Survey value	Conclusion
Chi-square (X^2)	p>0.05	X^2(51)=121.008,p= 0.000 < 0.001	No model fit
Chi-square (X^2)/df	<5 preferably <3	2.373	Model fit
Adjusted Goodness of Fit Index (AGFI)	<0.8	0.873>0.08	
Goodness of Fit Index (AGF)	<0.9	0.917>0.08	Model fit
Comparative Fit Index (CFI)	>0.9	0.919	Model fit
Root Mean Square Error of Approximation (RMSEA)	<0.08 preferably <0.05	0.069<0.08	Model fit

Table 7 presents the results of the second-order measurement model fit for the ECV model of students' attitudes toward mathematics. The Chi-square (X^2)/df value of 2.373, RMSEA of 0.069, CFI of 0.919, GFI of 0.908, and AGFI of 0.873 all fall within acceptable thresholds, indicating a good fit between the survey data and the proposed model. These findings support the idea that ATM is a second-order construct comprising enjoyment, self-confidence, and value of mathematics, and that it can be effectively assessed using the validated 12-item ATMI.

The CFA results indicate that ATM may be conceptualised as either a first- or second-order construct consisting of three factors: enjoyment, self-confidence, and importance of mathematics. Additionally, the confirmed validity and reliability of the 12-item ATMI support its use in measuring attitudes toward mathematics among secondary school learners in Harare.

Table 8: Discriminant validity of ATMI

	Enjoyment	Self-confidence	Value
Enjoyment	**.82**		
Self-confidence	.196	**.78**	
Value	.245	.486	**.75**

The Cronbach's alpha CR and AVE coefficients provide evidence of the reliability, while DV values confirm discriminant validity of the Zimbabwean 12-item ATMI scale. The next section discusses findings of the validated 12-item Zimbabwean ATMI scale.

Discussion

The primary aim of this study was to examine the psychometric properties of the three-factor model of the ATMI in the context of Form Three learners in Harare. Results from both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) confirmed the three-factor structure of the ATMI, comprising five items on enjoyment, four on self-confidence, and three on the value of mathematics. The validated 12-item ATMI proved to be a reliable and valid instrument for assessing attitudes toward mathematics in this context. Fit indices, including χ^2/df, RMSEA, CFI, GFI, and AGFI, confirmed strong model fit. These findings are consistent with recent international studies validating the ATMI structure across various populations and cultural contexts (Brown, 2015; Kline, 2016; Taber, 2018; dos Santos & Cirillo, 2021).

Moreover, factor loadings and standardised regression weights exceeding 0.5, alongside Cronbach's alpha values above 0.7, indicate strong reliability and convergent validity across all three subscales. The inter-item correlation matrix further supported discriminant validity. These outcomes are consistent with findings from multiple psychometric studies, which affirm that factor loadings above 0.5 and Cronbach's alpha above 0.7 indicate acceptable measurement of reliability and validity (Hair et al., 2019; Durak et al., 2010; Fornell & Larcker, 1981). The ATMI's construct validity was confirmed through discriminant validity, as each latent variable's AVE was higher than its squared correlations with other variables, consistent with best practice in scale validation (Henseler, Ringle, & Sarstedt, 2015; Hair et al., 2019).

Additionally, AVE values greater than 0.5 and composite reliability (CR) values above 0.7 provided further evidence of internal consistency and measurement reliability (Cronbach, 1951; dos Santos & Cirillo, 2021). The present study's results align with previous research that has explored alternative ATMI factor structures in different cultural contexts. Tran (2022), for example, identified a four-factor, 32-item model in Vietnam, while Lim and Chapman (2013) validated a similar four-factor model but recommended the three-factor ECV model due to high collinearity between motivation and enjoyment. Similarly, this study identified three redundant items, resulting in a concise 12-item scale adapted for use in Zimbabwean schools.

Research by Varela-Losada et al. (2021) suggested that attitude constructs are socially influenced and culturally bound, supporting the need for localised validation. Consistent with this, the findings of the current study concur with the 2021 Trends in International Mathematics and Science Study (TIMSS), which also identifies mathematics attitudes along three primary dimensions: intrinsic value, utility value, and belief in ability (Mullis, Martin, Foy, & Arora, 2021).

The reliability and validity of this 12-item, three-factor ATMI support the continued relevance of this structure, which has underpinned attitudinal measurement since the early days of educational psychology. More importantly, the findings reinforce the theoretical foundations of the enjoyment, confidence and value (ECV) framework, as posited by Lim and Chapman (2013), and support the global applicability of this tripartite model. As Breckler (1984) noted, this model also aligns with the classical tripartite view of attitudes in social psychology, integrating affective, cognitive, and behavioural components into a cohesive structure for understanding students' attitudes toward mathematics.

Limitations and recommendations for further study

This study focused on Form Three learners from only two secondary schools in Harare, limiting the broader applicability of the findings. To improve generalisability, future research should expand to a national scale, incorporating a wider range of schools across diverse regions. A broader and more varied sample would enhance the robustness of the psychometric evaluation of the ATMI and offer policymakers more reliable data to guide its implementation in different educational settings throughout Zimbabwe.

Furthermore, the current study relied solely on a quantitative design and gathered data exclusively from students, offering a limited view of attitudes toward mathematics. Future investigations should employ a mixed methods approach that includes perspectives from various stakeholders, such as teachers, school leaders, and parents. Combining qualitative and quantitative methods would yield a more comprehensive understanding of the dynamics influencing students' attitudes and capture contextual and pedagogical factors more effectively.

Finally, the study has shown that the 12-item ATMI is a reliable and valid tool for assessing attitudes toward mathematics among secondary learners in Harare. It is therefore recommended that mathematics educators use this instrument to evaluate learners' attitudes, particularly when underperformance has been observed or during key transition phases like from primary to secondary school. Recognising and understanding students' attitudes can help educators design targeted strategies to enhance motivation, confidence, and engagement in mathematics learning.

Contribution of the study

The findings of this study significantly contribute to mathematics education literature, particularly in understanding attitudes toward mathematics among secondary school learners in Harare. The research addresses a gap in the development and validation of attitude measurement tools within the Zimbabwean context, where few studies have used advanced multivariate statistical methods. The validated 12-item ATMI appears to be the first in Zimbabwean secondary education to apply both exploratory and confirmatory factor analysis to confirm the three-factor model of enjoyment, self-confidence, and value. This approach improves upon earlier studies that relied on less rigorous item analysis techniques, offering a more credible and practical instrument. Additionally, the study provides a useful framework for exploring causes of mathematics underachievement beyond IQ, highlighting the importance of affective factors in shaping learners' attitudes and informing effective educational interventions.

Conclusion

The study aimed to validate the 15-item ATMI scale in the Zimbabwean secondary schools' context in Harare. Based on the observed results, from a conceptual framework perspective, findings provide evidence of the applicability of the ECV in determining the psychometric properties of the ATMI in Harare. The three factor 12-item ATMI scale has demonstrated sufficient evidence of reliability and validity. The evidence is supported by the fact that results emanated from an adequate and representative sample of Form Three learners in the two secondary schools, thus guaranteeing statistical power and a low level of measurement error.

On this basis, the study concluded that the validated 12-item ATMI composed of 5 enjoyment items, 4 self-confidence items and 3 value items is a valid and reliable instrument that can be used to investigate learners' attitudes towards mathematics in this context, despite the highlighted limitations.

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