Student mathematics engagement: development and validation of a measurement instrument.

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Abstract

Engagement is an aspect of mathematics affective domain that previous studies had reported could influence learning of the subject. However, most of the tools available to measure this construct were validated using obsolete psychometric methods. This study therefore adopted a survey research design to develop Student Mathematics Engagement Scale (SMES). The sample consisted of four thousand, one hundred and forty-six (4,146) SS3 examinees from 73 schools randomly selected from co-educational public secondary schools in Oyo State, Nigeria. Data were analysed using Exploratory Factor Analysis (EFA), Horn Parallel Analysis (HPA), Confirmatory Factor Analysis (CFA) and Ordinal Alpha Reliability Coefficient. The results showed that the scale was reduced from thirty-three (33) to sixteen (16) items across three (3) components. Final compliance indices were: $\chi^2 = 658.99$, *p = 0.10, RMSEA= 0.04, GFI = 0.98, AGFI = 0.97, TLI = 0.94, NFI = 0.94, SRMR= 0.01, CFI= 0.95 and IFI= 0.95. The ordinal alpha reliability index of the three (3) factors of SMES was 0.87, while the reliability index of each of the subscales of the SMES ranged from 0.76 to 0.87. Mathematics teachers at secondary schools should be encouraged to use the scale for measuring students' level of engagement in mathematics.*

Keywords: *Student Mathematics Engagement Scale, Confirmatory Factor Analysis, Ordinal Alpha Estimation*

Introduction

Mathematics as a school subject has been a compulsory subject in the primary and secondary schools in Nigerian for many years and is a prerequisite subject for students aspiring to study science related courses and humanities in all Nigerian tertiary institutions. In spite of the important role of mathematics in the choice of career and daily living, the present level of achievement of students in mathematics at all levels of education calls for great concern. This is evident in the result of students in the West African Examinations Council for many years. The performance of secondary students in mathematics between 2005 and 2014 is an evidence that there was low level of achievement of Nigerian students in mathematics, since no year recorded 50% credit pass except 2008 throughout the period of ten years. If this problem is not addressed now, it may be difficult for Nigeria to position herself for national, sustainable development in science and technology that will ensure industrialisation by the year 2020. Madu (2011) stated that over the years, the performance of students in mathematics at all levels of education has continued to decline geometrically judging from failure recorded in examinations and the number of students who enrolled for it. However, in spite of concerted efforts by the researchers to solve numerous problems affecting students' performance in the subject, the performance rate is still not improved.

It is very imperative for researchers in the area of mathematics education to intensify their researches and advance other reasons accountable for decline in students' level of performance in Mathematics. In other climes such as United Kingdom, United States of America, Germany etc there is a paradigm shiff of research from government factor, parents factor, student factor, teachers factor and school related factors to student's engagement in Mathematics teaching and learning processes in and out of classroom. Perusal of literature has shown that an examinee features which has a very high likelihood of influencing learning outcomes is known student academic engagement. This was classified into three along a continuum as observed by Fredricks, Blumenfield & Paris (2004) namely; cognitive academic engagement, behavioural academic engagement and emotional academic engagement. Academic engagement could be defined as the interest, the determination, and the passion of students towards learning and teaching. Therefore, academic engagement shows the relationship between non-cognitive factors such as attitude, interest, perseverance, and learning outcomes. It is predicated on the belief that when students are inquisitive, interested, determined, or motivated, learning improves. On the other hand, learning suffers when students are bored, uninterested, restless etc. Academic engagement is making every effort to learn what the teacher teaches. Educators view academic engagement differently. Some define it with reference to observable behaviours, while others define it in terms of internal state, with regard to observable behaviours, academic engagement is the willingness of students to participate in routine school activities such as attending classes, listening attentively, participating in classroom discussion (i.e. asking and responding to questions) and submitting assignments on time.

More so, it is the degree of attention, curiosity, interest, optimism, and passion that students show in learning as well as the level of motivation with which students learn and make academic progress. Furthermore, academic engagement refers to the extent to which students are connected to what is going on in their classes. Academic engagement according to Deneen (2010) manifests when students take on the academic challenge of directing learning, finding time to study and making effort to understand course content. When students are involved in active and collaborative learning (that is students working in pairs or small groups to discuss school work, there is evidence of academic engagement. Students also show signs of being engaged academically when they are into a cordial relationship with school staff that could help them improve their progress in school. Participating in enriching educational programmes that can complement school learning, such as independent study with use of electronic devise also augments learning. Academic engagement happens too when students maintain a healthy student-teacher relationship; such that there can be a follow up to what was taught in the classroom.

A careful review of literature shows that the construct (academic engagement) is multidimensional in nature and it is an indispensable variable that can influence students' achievement in mathematics. It is very important to understand the construct in-depth. To investigate this construct (student's academic engagement), it is desirable to develop valid and reliable instrument that can be used by the researchers and classroom teachers to observe students in their Mathematics classes and to ascertain any relationships between their levels of engagement and their academic performance in the class. Researchers such as Squire (2009); Deneen (2010) have developed different instruments in the time past to measure academic engagement without using robust statistical tools to establish the psychometric properties of the scale. Therefore, in this study, authors directed energy in the development and validation of measurement instrument for students' mathematics engagement.

Statement of the Problem

Mathematics is a school subject that is compulsory both at the primary and secondary school levels. It is also a pre-requisite for admission for students who aspire to study Science related courses and Humanities in all tertiary institutions. Researchers have been challenged to find ways of improving performance of students in mathematics because the current state of performance is declining. Thus, despite their immeasurable efforts, the performance was not improved. More importantly, researchers in the area of mathematics education should beam their searchlight on other reasons accountable for decline in students' level of performance. In advanced countries, researchers had shifted their attention from government factor, parentsfactor, student factor, teachers factor and school related factors to student's academic engagement in and out of the classroom.It is very essential to develop valid and reliable instrument that can be used by researchers and classroom teachers to observe students during their Mathematics lessons. Though, literatureremarked that researchers had developed and validated instruments over the yearsusing obsolete psychometric methods. This will inherently affect the psychometric properties of the scale adversely. Therefore, in this study, authors directed energy in the development and validation of measurement instrument for students' mathematics engagement using robust statistical tools to establish the psychometric properties of the scale.

Research Questions

Three research questions guided the study. These include:

1. How many dimensions underlie Student Mathematics Engagement Scale (SMES)?
2. Are the fit indices explaining the model of SMES?
3. How reliable are the subscales of SMES?

Methods

Expost-facto research type of non-experimental design was used for the study. The population for the study consisted of Senior Secondary School three (SSS3) students of co-educational private, federal and public schools in Oyo State, Nigeria. Oyo State was stratified along the existing three (3) senatorial districts while purposive sampling method was used to select one (1) rural local government area (LGA) and three (3) urban LGAs was drawn randomly, making four (4) LGAs selected from each district. Six schools were selected randomly from each L.G.A, totalling72 schools. An intact class of science, social-science and humanities of SSS3 were used from each of the selected school, making 4,146 testees. Among the 4,146 sampled participants, 2817 (67.9%) were males and 1329 (32.1%) were females. More importantly, when using maximum likelihood estimation as suggested by Jackson (2003) cited in Kline (2005) that sample size minimum requirement for any Structural Equation Modelling (SEM) family is the proportion of cases (N) to the number of model parameters that require statistical estimates (q). An ideal sample size to parameters ratio would be 20:1. Thus, minimum sample size for this study should be 20*33 = 660.

The authors constructed the instrument used, called Student Mathematics Engagement Scale (SMES). The scale consisted of forty (40) draft items and after review by the expert in scale development. The scale was reduced to thirty-three (33) items with 3-point Likert scale where 3= Always, 2= Sometimes, 1= Never. Scores on negative items were reversed before the analysis. Missing data was established using expectation maximization (EM) method of single imputation technique with Little's missing completely at random (MCAR) test: Chi-Square = 8056.295, df = 6808, Sig. = .000. Since the p-value was significant, this implies that the proportion of missing data is ignorable since it does not exceed 5%. Data was analysed using Exploratory Factor Analysis (EFA), Horn Parallel Analysis (HPA), Confirmatory Factor Analysis (CFA) and Ordinal Alpha Reliability Coefficient.

Data Analysis

Data analyses were performed to determine the reliability and structural validity of SMES. Exploratory factor analysis (EFA), Horn parallel analysis (HPA), confirmatory factor analysis (CFA) and Ordinal alpha reliability coefficient were performed to ascertain the structural validity of the scale. R- programming version 3.4.0 was used for EFA in order to see interaction between the scale items and their components. The independent model Chi-square analysis was conducted using maximum likelihood estimates which depicts that variables contained in the study were correlated and fit for further analysis. Principal axis factoring extraction method with obliminrotation were used to establish components structure of the scale, and horn parallel analysis was further conducted to verify actual number of scale dimensions. AMOS 2.3.0 package program was used to establish CFA, and substantiate the appropriateness of the model that was built in the EFA. However, in order to assess the stability of this model, values of chi-square ($\chi 2 = 1$), Probability level ($p = 0.05$), degree of freedom($df = 1$), Tucker-Lewis index ($TLI = 0.95$), adjusted goodness of fit index (AGFI ˜ 1), goodness of fit index (GFI < 0.95), Normed fit index (NFI = 0.95), incremental fit index (IFI = 0.90) comparative fit index (CFI = 0.90), Root mean square residual (SRMR = 0.08) and root-mean-square error of approximation (RMSEA = 0.06) were determined (Kline, 2005). Consequently, twenty-six (26) items conclusively formed SMES. Furthermore, internal consistency of the scale and subscales were established using ordinal alpha reliability coefficient.

Results

Research Question One: How many dimensions underlie Student Mathematics Engagement Scale (SMES)?

Exploratory factor analysis using R was carried out on the examinees' responses to the scale items in order to determine structural validity and number of factors underlie the scale. Items less than 0.30 were suppressed totalling the number of items used in the study to be sixteen (16) out of thirty-three (33).The results of the independence model Chi-square analysis using the maximum likelihood estimates indicates that chi-square test statistic was statistically significant ($\chi^2 = 486.72$, df = 75, $p < 0.05$). This depicts that items in the study are correlated and the source data perfectly fits the number of factors specified. Principal axis factoring extraction with oblimin rotation segment of EFA conducted, depicts existence of four factors underlying the scale items. Meanwhile, horn parallel analysis was used to verify the number of factors identified from EFA and this revealed three factors is sufficient for the remaining 16 items. Figure 1.1 and 1.2 presents the parallel analysis scree plot and factor analysis,while Tables 1.3 and 1.4 present horn parallel analysis and factor loading of items that are above the cutoff point of 0.30 respectively.

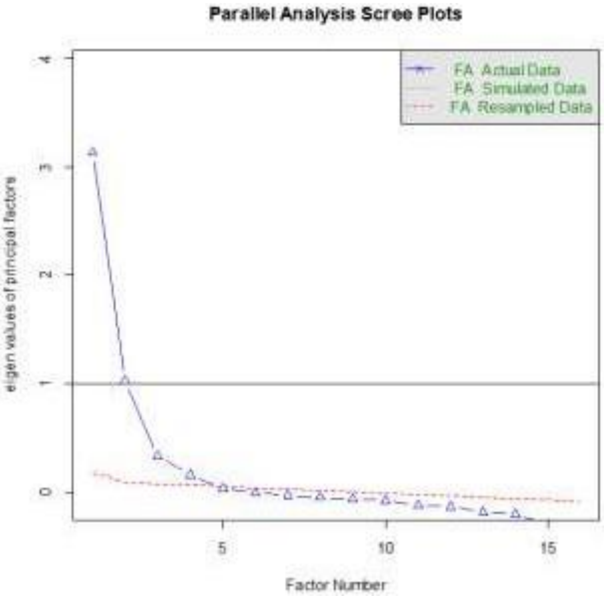


Figure 1.1: Scree Plot Parallel Analysis for Student Mathematics Engagement Scale (SMES)

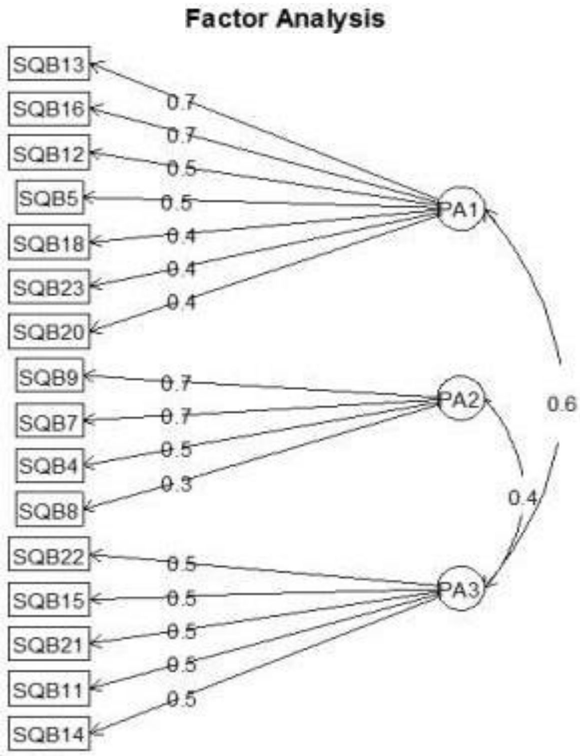


Figure 1.2: Subscales Analysis for Student Mathematics Engagement Scale (SMES)

Table 1.3: Presents Horn's Parallel Analysis for component retention

Factors	Adjusted Eigenvalue	Unadjusted Eigenvalue	Estimated Bias
1	3.81	3.92	0.11
2	1.77	1.85	0.09
3	1.09	1.16	0.07

Table1.4: Presents Factor Loading of the Scale Items

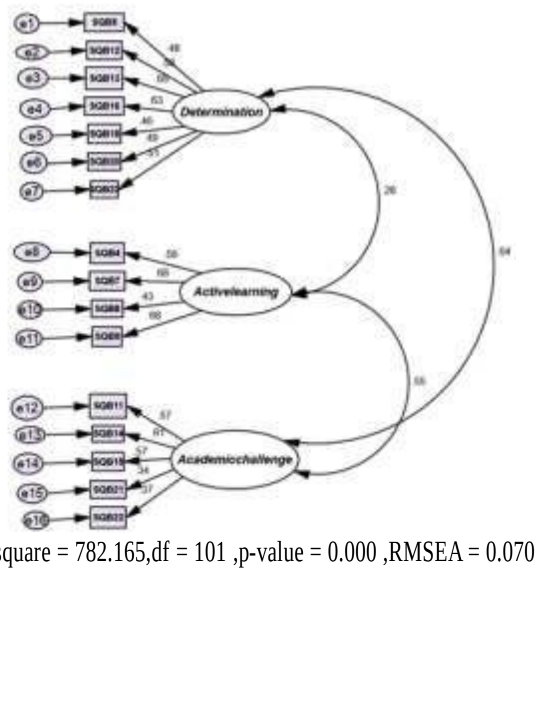
Item Code	Item	PA1	PA2	PA3	u2	h2
SQB4	I prefer sitting at the back of the classroom so that my mathematics teacher will not ask me questions		0.55		0.32	0.68
SQB5	I like to engage in mathematics exercises with my friends during my free period in the school	0.45			0.25	0.75
SQB7	I prefer to postpone my assignment in mathematics until it becomes late		0.68		0.47	0.53
SQB8	When I have any wrong answers in my mathematics assignments, I prefer to do my corrections		0.31		0.20	0.80
SQB9	I don't like to do any mathematics assignment		0.70		0.47	0.53
SQB11	When my score is poor in mathematics, I work harder for better performance			0.46	0.30	0.70
SQB12	I try to practise ahead of mathematics class so as not to miss out during mathematics lesson	0.53			0.33	0.67
SQB13	I like to practise mathematics exercises immediately after the class	0.70			0.45	0.55
SQB14	I work towards getting high marks in mathematics			0.46	0.32	0.68
SQB15	I do my best to gain understanding of the topic I am taught in mathematics			0.47	0.31	0.69
SQB16	I use my free periods in school to practice the topics I'm taught during mathematics lesson	0.67			0.42	0.58
SQB18	I like working out complex mathematics problems	0.44			0.21	0.79
SQB20	I ask my teacher for clarification on mathematics exercises that I find somehow difficult	0.38			0.24	0.76
Item Code	**Item**	**PA1**	**PA2**	**PA3**	**u2**	**h2**
SQB21	When I have difficulties with my mathematics assignment, I ask fellow students around me to help me out			0.46	0.18	0.82
SQB22	I keep company of friends who can assist me in mathematics topics			0.49	0.20	0.80
SQB23	I practise exercises from other mathematics textbooks apart from the recommended text	0.38			0.26	0.74
	Sum Square (SS) loadings	**2.08**	**1.53**	**1.30**	**4.91**	
	% Variance	**31.00**	**23.00**	**13.00**	**67.00**	

***Extraction Method: Principal Axis Factoring.**
***Rotation Method: Oblimin.**

Table 1.4 depicts that 16 Items contained in the SMES loaded across three dimensions. The first dimension consists of seven (7) indicators(SQB5, SQB12, SQB13, SQB16, SQB18, SQB20, SQB23) measuring a construct called *“DETERMINATION”*. The second consists of four (4) indicators (SQB4, SQB7, SQB8, SQB9) measuring a construct called *“ACTIVE LEARNING”*. And the third consists of five (5) indicators (SQB11, SQB14, SQB15, SQB21, SQB22) measuring a construct called *“ACADEMIC CHALLENGE”*.Perusel of EFA revealed that first-factor loading ranges between 0.38 and 0.70 explaining 31.0% of the total variance, the loading values of the second factor ranges between 0.31 and 0.70 explaining 23.0% of the total variance and the third factor loading values ranges between 0.46 and 0.49 explaining 13.0% of the total variance. In all, 67.0% of the total variance jointly explained the three dimensions. Also, column 6 gave value for uniqueness (u2). These values are secondary information and shows the percentage of the statistical variance for each original item that isn't explained by the factors. A large uniqueness value indicates that none of the latent factors captures a variable well, so smaller values are better. More so, column 7 gave value for communality (h2). Values here described percentage of each variable's variance that can be explained by the factors.

Research Question 2: Are the fit indices explaining the model of SMES?

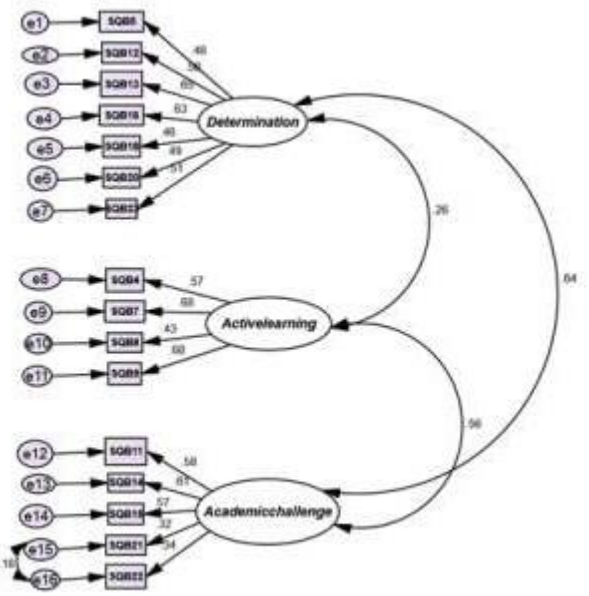
Confirmatory factor analysis (CFA) implemented in AMOS was used to further test result obtained from EFA. Figure 2.1 presents the outline factor distributions and loading values for the CFA.



Chi-square = 782.165,df = 101 ,p-value = 0.000 ,RMSEA = 0.070

Figure 2.1: Factor distribution and CFA values

It can be observed from Figure 2.1 that correlation coefficient values between the components and related items varied between 0.34 and 0.68. The first factor and the second factor covariance was 0.26, covariance between the first factor and the third factor was 0.64 and the covariance between the second factor and the third factor was 0.55. These values show that the items in the scale are appropriate to represent the hypothesised structure. In addition, the chi-square, degree of freedom and compliance index values of this model were calculated as follows: $\chi 2 = 782.17$, $p = 0.00$, RMSEA = 0.07, SRMR= 0.01, GFI = 0.97, AGFI = 0.96, TLI= 0.92, NFI = 0.93, CFI = 0.94 and IFI= 0.94. Examining index values obtained from the above model (figure 2.1), it can be concluded that the proposed model is not in agreement with the observed data. More importantly, modification indices need to be assessed to know which of the items with error of variance had outlier values so, as to release them from the model. Therefore, this was done to some of the items in order to take into account the level of relationship between item errors and the hypothesised model. The relationship between items 21 and 22were released. After these corrections, the model in Figure 2.2 was obtained as follows



Chi-square = 658.994,df = 101 ,

p-value = 0.010 ,RMSEA = 0.037

Figure 2.2: CFA values after items modification

Appraisal of figure 2.2 depicts that model obtained after items modification was in congruent to the observed data. Thus, the final compliance index values obtained were as follows: $\chi 2$ = 658.994, p = 0.010, RMSEA = 0.037, SRMR= 0.013, GFI = 0.981, AGFI = 0.974, TLI= 0.941, NFI = 0.943, CFI = 0.951 and IFI= 0.951. Furthermore, when the covariance between the factors was assessed, the first factor had 0.26 relationship with the second factor, the relationship between the first factor and the third factor was 0.64 and the relationship between the second factor and the third factor was 0.56.

Research Question 3: How reliable are the sub-scales of SMES?

Ordinal reliability in R-programmingwas used to establish ordinal alpha reliability coefficient of SMES. Though Cronbach's alpha (Cronbach, 1951) remains the most widely used method of estimate reliability index, it is still characterized by many shortcomings as observed by Cronbach (2004). The lacuna between the two methods is that ordinal alpha is based on the polychoric correlation matrix, compared to Cronbach alpha which is based on Pearson covariance matrix (Gadermann, Guhn & Zumbo, 2012). Thus, ordinal alpha estimates more accurately for measurements containing ordinal data like the current study. The ordinal alpha coefficient for the scale items was 0.87, and the first sub-scale was 0.82, the second sub-scale was 0.80, and the third sub-scale was 0.76. Based on the alpha values for the three sub-scales, it can be concluded that both the scale and sub-scales were very reliable and valid.

Discussions

One of the cardinal segments in the domain of learning is called affective. This domain is an important area (such as academic engagement); mathematics teachers need to pay careful attention to. It is very imperative to develop scale for measuring academic engagement precisely. The results of exploratory factor analysis and parallel analysis for structural validity shows evidence of three dimensions underlying the scale. About 67% of the total variance accounted for the observed three-factors scale. Also, confirmatory factor analysis was conducted to test earlier result gotten from EFA. Thus, review of EFA and CFA analyses brings to the conclusion that the three factors scale is tenable and valid.Nevertheless, ordinal alpha reliability coefficient displayed high degree of reliability of SMES consisting of 16 items and their sub-scales. Results from structural validity and reliability of the SMES can be used by the mathematics teachers in secondary schools to measure examinees' level of engagement in the subject.

Conclusion and Recommendations

Results from structural validity and reliability of the SMES can be used by the mathematics teachers in secondary schools to measure examinees' level of engagement in the subject. Also, it can be recommended that teachers should be encouraged to use the scale to measure examinees level of mathematics engagement.

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