Development of Mathematics Anxiety Scale: Factor Analysis as a Determinant of Subcategories

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Abstract

The purpose of this study was to develop an instrument for measuring students' mathematics anxiety scale (MAS) with high psychometric property. A survey research design was used involving 510 students randomly selected from secondary schools. Exploratory factor analysis (EFA) was carried out to determine the number of factors to be retained in the MAS subcategories. The factors were extracted using maximum likelihood method and the pattern matrix was rotated using Oblimin with Kaiser Normalization which converged after 22 iterations. The final 20-item MAS contained two anxiety subcategories: learning mathematics anxiety (Cronbach's alpha = .86) and perception of difficulty and motivation (Cronbach's alpha = .74). The reliability coefficient of the instrument was .90 with sufficient evidence of content and face validity.

1. Introduction

It is a common occurrence in universities to see the sick bay filled up with students battling with "examination fever" when the final exams are approaching. This in no doubt is apparently related to the students' anxiety towards the exams, which have negative effects on students' achievements (Ashcraft & Moore, 2009; Chang & Beilock, 2012; Heydari, Abdi, & Rostami, 2013). Though, some researchers have argued that not all mathematically anxious students performed equally poorly in mathematics (Lyons & Beilock, 2011). Mathematics anxiety had been described long ago by Richardson and Suinn (1972) as "feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations". More recently, Ashcraft (2002) defined mathematics anxiety as a feeling of tension, apprehension, or fear that interferes with mathematics performance. Mathematics anxiety, therefore, can be regarded as negative psychological reactions involving fear, apprehension, lack of confidence and tension towards activities involving numerical manipulations. It has raised concerns for educators because of its negative impacts on mathematical knowledge, math grades, and standardized test scores in young adults (Chang & Beilock, 2012; Rubinsten & Tannock, 2010). This served as the underlying motivation for this study.

The importance of students' anxiety towards mathematics cannot be overemphasized considering the amount of research related to its measurement or its correlation with students' academic achievement and performance. Despite the diverse disparity in the attempts to measure

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students' anxiety, some important common points have also emerged, especially concerning the factor structure of the constructs underlying the anxiety. Several researchers (Mahmood & Khatoon, 2011; Plake & Parker, 1982) have argued that mathematics anxiety instrument should be bi-dimensional and concise contrary to the earlier unidimensional multiple item instruments reported for its measurement (e.g., Richardson & Suinn, 1972). Mathematics anxiety instruments satisfying all these properties are still rare in the literature. Therefore, there is a need to develop a mathematics anxiety instrument that draws upon indigenous data from Nigeria. Hence, this study stemmed from the measurement of students' mathematics anxiety through the development of a concise instrument and having high psychometric properties, specifically item total correlation, internal consistency, reliability and validity.

Research on the correlation between mathematics anxiety and demographic factors, cognitive processing, educational achievement and performance of students abound in the literature. Wood and his/her colleagues, in their 2012 study, reported that mathematics anxiety increased with age among 1st to 6th grade school children with ages ranging from 7 to 12 years, while Mutodi and Ngirande (2014) reported no significant difference between students' levels of mathematics anxiety and language backgrounds. In a study involving 480 high school students Abbasi, Samadzadeh, and Shahbazzadegan (2013) reported a significant negative relationship (r = -.61 and r = -.588 for boys and girls respectively) between mathematics anxiety and self-esteem. This may mean that the higher the anxiety the lower the students' self-esteem and vice versa. There have also been conflicting reports on whether mathematics anxiety affects both males and females equally. Some researchers have reported females having stronger negative affective reactions than males (Mutodi & Ngirande, 2014; Pourmoslemi, Erfani, & Firoozfar, 2013; Wigfield & Meece, 1988) while others have reported no significant difference between males and females with respect to mathematics anxiety (Keshavarzi & Ahmadi, 2013). Moreover, mathematics anxiety had been reported to disrupt cognitive processes by compromising the on-going mental processing during problem solving (Ashcraft, 2002). These divergent implications of mathematics anxiety have added to its extensive study among mathematics educators and psychologists.

The effects of Mathematics Anxiety (MA) on students' achievement and performance have commonly been studied in the literature. This is evident in the large amount of research in this area (Karimi & Venkatesan, 2009; Lim & Seng, 2015; Lyons & Beilock, 2011; Siebers, 2015). Some researchers have looked at the relationship between MA and performance and found that MA is an important predictor of performance (with a negative correlation) (Beilock & Maloney, 2015; Joseph, 2005; Karimi & Venkatesan, 2009). Others have only characterized its negative impact on students' achievement and performance and proffered possible remediation (Lim & Seng, 2015; Sherman & Post, 2003; Zakaria & Nordin, 2008). Vukovic, Kieffer, Bailey, and Harari (2013) reported both concurrent and longitudinal associations between mathematics anxiety and academic performance among 113 children from second to third grade levels in the United States. Their findings revealed that mathematics anxiety formed a unique source of individual differences in children's calculations and applications of mathematics but not in their geometric reasoning. Furthermore, it was found that higher mathematics anxiety predicted lower academic achievement in mathematics which corroborated the findings of Ramirez, Gunderson, Levine, and Beilock (2013).

Several studies have been reported on mathematics anxiety and its relationship with students' performance, working memory and achievements. Research still lacks the development of concise instruments with adequate evidence of reliability and validity. The historic 98 – item mathematics anxiety rating scale (MARS) of Richardson and Suinn (1972) had been described as pioneering in the literature (Derek, Mahadevan, Bare, & Hunt, 2003). This instrument had been widely adopted, adapted and even translated from its original English language to Turkish (Baloğlu & Balgalmiş, 2010) and Polish (Cipora, Szczygieł, Willmes, & Nuerk, 2015) for intensive application. Despite the relevance of MARS and its wide acceptance among educators, it has also been criticized for its numerous items, unidimensionality and lack of some psychometric properties, which have prompted some authors to develop its abbreviated versions (Derek et al., 2003; Plake & Parker, 1982). Plake and Parker (1982) developed a 24-item revised MARS that measures students' anxiety in mathematics related situations. The reliability coefficient alpha of their instrument is .98 with a correlation of .97 with the original MARS construct.

In 2003, Derek et al. developed an Abbreviated Math Anxiety Scale (AMAS) using a sample of 1,239 undergraduate students with an average age of 19.6 years. Employing exploratory factor analysis, the final version of AMAS contained nine items and two subcategories; learning math anxiety (LMA) and math evaluation anxiety (MEA). The psychometric properties of AMAS were excellent with Cronbach's alpha of .90 as evidence of internal consistency and two-week test re-test reliability coefficient of .85. A confirmatory factor analysis of AMAS was later studied and reported by Vahedi and Farrokhi (2011) with again two-factor solution and invariant of sex using 298 undergraduate students. Another 14-item mathematics anxiety scale (MAS) was also reported by Mahmood and Khatoon in 2011. The bi-dimensionality MAS has Cronbach's alpha of .87 and split-half reliability coefficient of .89 using 250 secondary school students. More recently, psychometric properties of a bi-dimensional mathematics anxiety scale adapted into the Persian language was reported by Seyed, Mohammad, and Habibollah (2014). Both convergent and divergent validity of the instrument were reported with Cronbach's alpha of .86 for internal consistency and test re-test reliability coefficient of .83.

However, an extensive search of the literature revealed that no single instrument for measuring students' anxiety towards mathematics had been developed using data from Nigeria. Perhaps, some had been developed but were nowhere to be found. Researchers in Nigeria have been dependent on the adoption and adaption of foreign instruments to measure students' anxiety (see Adebule & Aborisade, 2014). It is, therefore, pertinent to develop an instrument using indigenous data generated from our students and sophisticated statistics to determine the categories that constitute students mathematics anxiety. Our review of some of the existing literature on mathematics anxiety instruments clearly calls for a concise instrument that could capture latent construct(s) of math anxiety. In addition, for an instrument to have adequate measurement efficiency, its length (or the time it takes to complete) must be whilst maintaining adequate psychometric qualities. Therefore, the purpose of this study is to develop an instrument for measuring students' mathematics anxiety with high psychometric properties, specifically item total correlation, internal consistency, reliability and validity.

2. Method

2.1. Item Development

The development of items of the MAS required drawing from the reviewed literature in Section 1. The initial MAS contains 23 items including two biodata items (I) gender, (II) age in years, and 21 items on students' anxiety towards mathematics. The 21 MAS items are bi–dimensional (having two subcategories): learning mathematics anxiety (LMA) and perception of difficulty and motivation (PDM). Both LMA and PDM were derived by considering items that measure the relevant constructs. The distributions of the items into these subcategories are shown in Table 1. Five-point Likert scale format was used in which respondents selected the most appropriate answer from response options ranging from (5) Strongly agree, (4) Agree, (3) Neither agree nor disagree, (2) Disagree, and (1) Strongly disagree. The respondents were urged to complete the inventory with utmost sincerity. The content and face validity of MAS was assessed by two professors of mathematics education in the Department of Science Education, Ahmadu Bello University, and they gave satisfactory comments and provided guidance for both lexical and construct modifications of some items.

Table 1
Initial MAS Item Distribution

SN	Attitude subscale	Item number	Total
1	Learning mathematics anxiety	2, 4, 6, 8, 10, 12, 14, 16, 18, 20 and 21	11
2	Perception of difficulty and motivation	1, 3, 5, 7, 9, 11, 13, 15, 17, and 19	10

2.2. Research Design

Certain characteristics, including the adaptability of the research design with respect to the type of study, variables under consideration, the number of respondents and phenomenon to be studied, were considered carefully, and a one-shot survey design was selected as an appropriate research design. According to Jansen (2010) one-shot survey involves only one empirical cycle (research question—data collection—analysis—report) in parallel to the typical case of a statistical survey. The factors (students' anxiety towards mathematics) were studied in their natural form without the researcher manipulating any of the variables. The researchers simply collected the data using the MAS and analyzed it to provide an objective description of the phenomenon.

2.3. Participants

The sample for this study involved 510 senior secondary school II (students in the second year of senior secondary schools) students drawn from the target population of 5,403 senior secondary schools students in the area. A total of 11 classes constituted this sample with an average class size of 50 students. This sample is representative enough as suggested by Krejcie and Morgan (1970) who recommended including 361 participants in such studies on average. Five government public secondary schools in the local government were randomly selected out of a total eleven public schools in the area. One of the sampled schools was all-girls while the remaining four schools were co-educational. These students consisted of 228 (45%) males and 279 (55%) females, and had an average age of 17 years old with the youngest student participant aged 12 and the oldest aged 25. Three students did not indicate their sex and so were excluded in calculating the percentage by gender.

2.4. Procedure

The MAS was administered initially to 530 secondary school II students with the help of five research assistants. The exercise took 2 days as permissions were sought from the school principals the first day before distribution of the questionnaires on the second day. The subjects completed the questionnaires before the first period in the morning and took an average of 10 minutes to complete. A total of 20 questionnaires were not included in the analysis as a result of improper completion of some items like multiple responses on a single item and missing biodata. The remaining 510 were analyzed using statistical package for social sciences (SPSS) version 20.0.

3. Results and Discussion

3.1. Exploratory Factor Analysis

Exploratory factor analysis (EFA) was carried out to determine the number of factors to be retained in the MAS subcategories. Prior to the conduct of the EFA, adequacy of the input data was confirmed by means of Bartlett's sphericity test (BST), the Kaiser- Meyer-Olkin (KMO) index, and the matrix determinant. The test was significant at $p < 0.01$ with KMO index of .93 and correlation matrix determinant of 0.005 which is greater than the necessary value of 0.00001 (Field, 2009). Hence, the data was adequate for the EFA and multicollinearity was not a problem for this data as approximate chi-square ($\chi^2 = 2518.45, \text{df} = 210$) was statistically significant at $p < 0.01$.

Furthermore, the Maximum Likelihood Method (MLM) was used in extracting the factors to be retained based on the assumption of an oblique interaction between factors. A total of three factors were identified with factor 1 explaining 30.01% of the total variance, factor 2 explaining 6.30% and factor 3 explaining only 5.97% of the total variance. Table 2 shows the eigenvalues associated with each identified factor before extraction, after extraction and after rotation as contained in the total variance explained in the SPSS output.

Table 2
Total Variance Explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Var.	Cum. %	Total	% of Var.	Cum. %	Total
1	6.303	30.012	30.012	5.659	26.950	26.950	4.785
2	1.324	6.304	36.316	.623	2.968	29.918	4.454
3	1.254	5.972	42.288	.550	2.618	32.536	1.338
4	.982	4.675	46.963				
5	.899	4.282	51.245				
6	.876	4.172	55.417				
7	.831	3.955	59.372				
8	.794	3.781	63.153				
9	.781	3.720	66.872				
10	.761	3.624	70.496				
11	.747	3.556	74.052				
12	.680	3.237	77.289				
13	.631	3.005	80.293				
14	.606	2.884	83.178				
15	.584	2.781	85.958				
16	.553	2.631	88.589				
17	.539	2.568	91.158				
18	.503	2.396	93.554				
19	.476	2.264	95.819				
20	.451	2.149	97.968				
21	.427	2.032	100.000				

Extraction Method: Maximum Likelihood.
a. When factors are correlated, sums of squared loadings cannot be added to obtain a total variance.

In order to improve the interpretability of the extracted factors Oblimin rotation with Kaiser Normalization was performed. The Oblimin rotation converged after 18 iterations as described in pattern matrix (Table 3). The communalities of each item before and after extraction were also included and small coefficients with absolute values less than 0.1 were supressed for convenience interpretation.

Table 3
Pattern Matrix and Item Communality

SN	Item Description	Factor			Communality	
		1	2	3	Initial	Final
1	I feel more nervous in maths than most of other students		.320	.196	.128	.144
2	I can become a good student of mathematics	.336	.288	-.135	.363	.372
3	Math is hard for me.		.149	-.453	.137	.236
4	Math confuse me	.371	.186	-.241	.344	.376
5	In maths, it's hard for me to decide what I have to do		.568	-.268	.336	.398
6	I have always had trouble with maths	.378	.244	-.110	.354	.360
7	Usually I feel unable to solve mathematical problems		.467	-.156	.284	.291
8	No matter what I do, I always get low grades in math	.240	.281		.213	.213
9	I'm not the type to do well in math.	.132	.324	.101	.161	.167
10	Usually I have difficulty with mathematics	.423	.229	-.216	.426	.462
11	I do not know how to study math		.601		.265	.325
12	Math is one of the most boring subjects	.623			.313	.361
13	I don't think I could handle more difficult math.	.125	.396		.225	.237
14	I will always have difficulty on learning math	.315	.289		.306	.310
15	I'm one of those people who were not born to learn math	.256	.418	-.113	.403	.420
16	I know I can do well in math.	.594			.370	.413
17	I don't feel comfortable studying math like I feel with other subjects		.497	-.104	.299	.335
18	I hate studying maths, even the easiest parts	.520	.176		.392	.414
19	Except for a few cases, no matter how much effort I put out, I cannot understand math	.226	-.106	-.454	.156	.264
20	I am always under a terrible strain in a math class.	.692			.399	.480
21	I am afraid to ask questions in math class	.530			.247	.254
	Extraction Method: Maximum Likelihood					
	Rotation Method: Oblimin with Kaiser Normalization.					
	a. Rotation converged in 18 iterations.					

An investigation into the item communality (Table 3) revealed that the average communality after the extraction which is got by adding up all the final communalities and dividing by 21 gave 0.33. Since our sample is more than 300 and the average communality is less than 0.6 the Kaiser criterion for correctly retaining the extracted factors has been violated. Hence, all three factors with eigenvalues greater 1.0 cannot be retained. A bail out of this problem is to look at the scree plot (Figure 1) as suggested in the literature (Field, 2009).

It can be inferred from the Figure 1 (as indicated by the arrows) that we have two options of either retaining 2 factors or 3 factors. Due to the aforementioned low average communality and the large sample (above 300) involved, the default recommendation of EFA (to retain all factors with eigenvalues greater than or equal to 1) was disregarded. Hence, only two factors were retained. By implication, we did run the EFA again by fixing 2 factors to be extracted and the pattern matrix was displayed in Table 4.

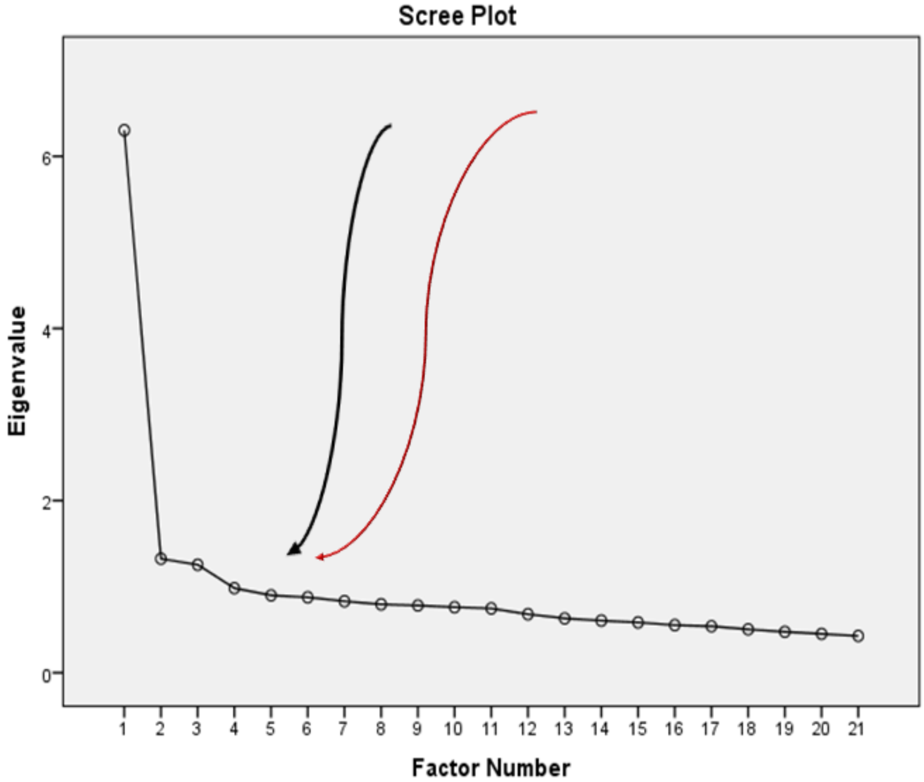

Figure 1. Scree plot ındicating number of retained factors

However, the direct Oblimin rotation failed to converge after 25 iterations. This phenomenon prompted us to look at the item communality once again and delete the item with minimum communality. Item 1 was therefore deleted. We ran the EFA once again and the rotation converged after 22 iterations (Table 4). Factor 1 containing items 2, 4, 6, 8, 10, 12, 14, 16, 18, 20 and 21 was identified as learning mathematics anxiety (LMA) and factor 2 containing items 3, 5, 7, 9, 11, 13, 15, 17 and 19 was identified as perception of difficulty and motivation (PDM).

Table 4
Pattern Matrix of the Modified MAS

SN	Statement on Anxiety	Factors	
		1	2
2	I can become a good student of mathematics	.363	
3	Math is hard for me.		.382
4	Math confuse me	.373	
5	In maths, it’s hard for me to decide what I have to do		.671
6	I have always had trouble with maths	.406	
7	Usually I feel unable to solve mathematical problems		.506
8	No matter what I do, I always get low grades in math	.395	
9	I'm not the type to do well in math.		.501
10	Usually I have difficulty with mathematics	.436	
11	I do not know how to study math		.433
12	Math is one of the most boring subjects	.624	
13	I don’t think I could handle more difficult math.		.333
14	I will always have difficulty on learning math	.624	

Table 4 continued

15	I'm one of those people who were not born to learn math		.405
16	I know I can do well in math.	.604	
17	I don't feel comfortable studying math like I feel with other subjects		.473
18	I hate studying maths, even the easiest parts	.570	
19	Except for a few cases, no matter how much effort I put out, I cannot understand math		.479
20	I am always under a terrible strain in a math class.	.745	
21	I am afraid to ask questions in math class	.554	

Extraction Method: Maximum Likelihood.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 22 iterations.

3.2. Evidence of Reliability

Cronbach's alpha was computed to estimate the internal consistency of the two MAS subcategories as well the reliability of the instrument as reported in Table 5.

Table 5
Cronbach's Alpha on Standardized Items of MAS subcategories

Factor	Mean	Variance	*SD*	N of Items	α
LMA	30.91	97.78	9.89	11	.86
PDM	24.86	44.96	6.70	9	.74
MAS	55.46	232.82	15.26	20	.90

Learning mathematics anxiety factor contains 11 items with a mean of 30.91 (SD = 9.89). It is characterized by students' anxiety towards the learning of mathematics items. The scores for these items had a Cronbach's alpha value of .86 which shows high level of internal consistency among them (Field, 2009). Perception of difficulty and motivation factor contains 9 items with a mean of 24.86 (SD = 6.7). It is characterized by items describing students' perception of difficulty and their motivation for studying mathematics. These items produced a Cronbach's alpha value of .74 which shows again a high level of internal consistency (Field, 2009). The reliability coefficient of the 20-item MAS is .90 which is considered very high in the literature (Field, 2009). Hence, MAS has a high internal consistency and very high reliability. Table 6 presents sample items on the final MAS with the two subcategories the full version is available upon request from the corresponding author of this article.

Table 6
Sample Items on the Final MAS

Factor	Sample Item
I – Learning Mathematics Anxiety	4. I do not know how to study math 14. I don't feel comfortable studying math like I feel with other subjects 18. Except for a few cases, no matter how much effort I put out, I cannot understand math
II – Perception of Difficulty and Motivation	3. I can become a good student of math 5. Math is hard for me. 13. Usually I have difficulty with mathematics

4. Conclusion

This study was aimed at the development of a concise instrument for measuring mathematics anxiety among secondary students using indigenous data from the country in lieu of making generalization. A sample of 510 respondents were used in the study which is higher than the samples of some earlier reported instruments (e.g., Baloğlu & Balgalmiş, 2010; Mahmood & Khatoon, 2011; Vahedi & Farrokhi, 2011). The adequacy of this sample was also confirmed for the EFA using KMO index and Bartlett's sphericity test that proved significant at $p < 0.01$ with .93 index (Table 2). The reliability coefficient of our instrument was .90 (Table 5) which can be considered very high (Field, 2009). This coefficient is higher than the ones reported in the following studies (Cipora et al., 2015; Mahmood & Khatoon, 2011; Vahedi & Farrokhi, 2011) which proved the superiority of MAS over others at least in terms of consistency and stability in the anxiety measured. Even though the Cronbach's alpha is less than that reported by Richardson and Suinn (1972) and Plake and Parker (1982), the discrepancy can be ascribed to the larger samples involved in both studies. MAS is better than the formal instrument in terms of its number of items and psychometric properties and the later in terms of its number of items.

Finally, we have developed a new instrument for measuring students' mathematics anxiety with 20 items and two subcategories having adequate psychometric properties and concise enough. The instrument will be useful for school psychologists, mathematics educators, school counsellors and other stakeholders in the teaching of mathematics at secondary school levels. Though the data for this study had been drawn from the northern part of the country, its findings can be generalized to other parts of the country and beyond. We, therefore, recommend this instrument for use to measure students' anxiety levels in secondary schools in Nigeria. The final 20-item mathematics anxiety scale is available upon request from the corresponding author of this article.

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