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Research Article

Comparison of the Reliability and Validity of Math Anxiety Scale with Different Scale Formats

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ABSTRACT

The study compared the reliability and validity of the Math Anxiety Scale (MAS) in different scale formats: 5-point scale, checklist, visual analog scale, and 4-point scale. Specifically, it sought to assess the student's level of math anxiety, determine the reliability coefficients of each scale format, test the concurrent validity against the standardized scale, and compare the extracted factors with the original MAS. The respondents were 67 students, a total enumeration from two sections of a laboratory school in La Trinidad, Benguet. The standardized MAS (5-point scale) was adopted and transformed into a checklist, visual analog scale, and 4-point scale. The tests were administered at three-day intervals. The findings indicated that students experienced a moderate level of math anxiety, with cognitive dimension substantially contributing to their anxiety. The visual analog scale demonstrated the highest reliability coefficient, followed by the 4-point scale, checklist, and 5-point scale, respectively. Concurrent validity analysis revealed that the visual analog scale exhibited the highest concurrent validity, followed by the 4-point scale and checklist, respectively. Based on the results, the majority of the students are experiencing a moderate level of math anxiety. Among the four scale formats, the visual analog scale provides the most reliable and valid responses to be used in measuring math anxiety among junior high school students with ages ranging from 11 to 13 years old.

Keywords: *Math anxiety scale, Reliability, Scale formats, Validity*

Introduction

Math anxiety has been a topic of interest to researchers because of its perceived correlation to math performance (Zhang et al., 2019; Ashcraft and Ridley, 2005). A teacher once referred to it as "mathemaphobia" to describe the remarkable unappealing reaction of students when given mathematical problems (Vargas, 2021). It was in 1957 when Dreger and Aiken coined the term math anxiety to refer to

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the pessimistic reaction toward arithmetic and mathematics. The term was later defined by Richardson and Suinn (1972) as "a feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations."

Math anxiety has been confirmed to be exhibited by people across ages however studies revealed that it usually starts during the late elementary stage and reaches its peak levels at ages 14 to 16 years old (Legg & Locker, 2009; Scarpello, 2007). It has gained attention from the education community because of its negative effects on mathematical achievement and performance in standardized tests (Chang & Beilock, 2016; Rubinstein & Tannock 2010). Cipora and Nuerk (2019) emphasized the importance of assessing individual math anxiety among students. They noted its vital implications for math anxiety research, diagnosis, intervention planning, curriculum development, and policy making. Thus, it is essential to develop instruments measuring math anxiety with satisfactory reliability and validity. Reliability is described as the property of an instrument such that it produces a stable and consistent result (Carmines & Zeller, 1979). According to Huck (2007), reliability is the consistency of the items of the instrument in measuring the same construct. Meanwhile, validity is the property of an instrument to "measure what is intended to be measured" (Field, 2009).

The first tool for assessing numerical anxiety was published by Dreger and Aiken (1957). It is a supplemented version of the Taylor Manifest Anxiety Scale wherein they added three mathematical items to distinguish it from other anxiety scales. Richardson and Suinn (1972) later published the Mathematical Anxiety Rating Scale (MARS) which was the pioneering instrument for assessing anxiety exclusively for mathematics. It is a 98-item questionnaire on a 1 to 5 Likert-type scale that focuses on mathematics in everyday situations and academic settings. Succeeding alternative instruments relied mainly on the MARS. These include the MARS-A for middle and high school students by Suinn and Edwards (1982), and the MARS-E for elementary pupils by Suinn, Taylor, and Edwards (1988). Meanwhile, Plake and Parker (1982) reduced the MARS into 24 items which they named the Abbreviated Mathematical Anxiety Rating Scale (A-MARS). In 1995, the first instrument that caters to younger children was developed by Gierl and Bisanz which they called the Mathematics Anxiety Survey (MAXS). In 2003, Hopko et al. evaluated the psychometric properties of the available survey scales in assessing math anxiety and questioned the limited methodology including sample size and the validity data. They then developed the Abbreviated Math Anxiety Scale (AMAS) consisted of nine items with a high level of psychometric quality. Many other instruments for assessing math anxiety emerged in the following years, some were translations of the existing instruments into another language while the others were revised versions.

It is noteworthy that the enumerated instruments all employed a 5-point Likert-type scale. Math anxiety instruments in literature dominantly use a 5-point Likert-type scale. Some of the rare scales that utilized other scale formats are the Pictorial Test for Early Signs of Math Anxiety (Aarnos & Perkkila, 2012) which uses photographs and graphical illustrations, and the Single-Item Math Anxiety Scale (SIMA) by Nuñez-Peña et al. (2014) which uses a 10-point scale.

The Likert scale is most commonly used because it is easy to use and easier to manipulate for data analysis. However, the literature and methodology studies do not provide specific suggestions on the proper selection of rating scales for research studies (Taherdoost, 2016). This was the underlying motivation of the researchers in conducting this study. This study aimed to compare the reliability and validity of the scale formats: checklist, visual analog scale, 4-point scale, and 5-point scale in assessing math anxiety among junior high school students. Specifically, it looked into the level of math anxiety of the students; determined the reliability coefficients of the different scale formats; tested the concurrent validity of the different scale formats to the standardized scale; and, compared the extracted factors in the different scale formats to the extracted factors in the original Math Anxiety Scale.

Methods

The study employed a within-subjects experiment design where all respondents were tested in all the different scale formats. The researcher adopted a standardized scale from the Mathematics Anxiety Scale (MAS) by Zakariya (2018). It has an internal reliability coefficient of 0.90 with sufficient evidence of face and content validity. It contains 20 items on a 5-point Likert scale. It is bidimensional encompassing the cognitive and affective dimensions of math anxiety. This standardized scale was transformed into checklist, visual analog scale, and 4-point scale. The researchers sought advice from an expert on assessment and evaluation for the face validity of the transformed scales prior to their administration. To minimize the carry-over effect of answering the same questions repeatedly, the tests were administered at three-day intervals. They were also administered following the same time and room as when the standardized test was conducted to minimize the threat to internal validity.

The respondents were a total enumeration of the grade 7 students enrolled in a laboratory school at La Trinidad, Benguet for the school year 2022-2023. There were 67 respondents with ages ranging from 11 to 13 years old.

Data analysis commenced by reverse scoring the reverse-coded items. The level of math anxiety of the respondents was analyzed using weighted mean and standard deviation, and was interpreted using the corresponding descriptive equivalent:

4.50 – 5.00	Very high level of math anxiety
3.50 – 4.49	High level of math anxiety
2.50 – 3.49	Moderate level of math anxiety
1.50 – 2.49	Low level of math anxiety
1.00 – 1.49	Very low level of math anxiety

The internal reliability of each scale was calculated through Cronbach's Alpha. To find the concurrent validity of the transformed scales, the mean of the scores of the respondents on each scale was computed. Scatterplots were used as evidence of concurrent validity and the Pearson correlation coefficient was also computed to determine the correlation of the mean scores in the transformed scales to their mean scores in the standardized scale.

Furthermore, Exploratory Factor Analysis was executed to extract and analyze the factors in the transformed scale. Prior to the conduct of Exploratory Factor Analysis, the adequacy of sample data was confirmed by means of the Kaiser-Meyer-Olkin (KMO) index and Barlett's Test of Sphericity. The KMO index of all the survey scales ranges from 0.727–0.888 so it qualified for the 0.7 cut-off value and Barlett's Test of Sphericity was significant ($p = 0.000$) at a 1% level of significance. Hence, the sample size is adequate and multicollinearity was not a problem to run Exploratory Factor Analysis. The researchers replicated the extraction and rotation method executed in the original Math Anxiety Scale, in which Maximum Likelihood and oblique rotation (Oblimin with Kaiser Normalization) were employed.

Result and Discussion

Level of Math Anxiety

Table 1. Level of Math Anxiety of the Students According to its Subcategories

Factor	Mean	Standard Deviation	Descriptive Equivalent
LMA	2.957	0.590	Moderate Level
PDM	2.838	0.778	Moderate Level
MAS	2.903	0.647	Moderate Level

Table 1 presents the mean scores of the students on the Math Anxiety Scale (MAS) as well as its subcategories: Learning Mathematics Anxiety (LMA) and Perception of Difficulty and Motivation (PDM). In general, the students rated the level of their math anxiety and its subcategories as moderate (2.838 – 2.957). The result implies that the students are experiencing a moderate level of anxiety toward mathematics. This suggests that students experience moderate feelings of tension and anxiety interfering with their manipulation of numbers and in solving problems in a variety of ordinary and academic situations.

Considering the two subcategories of the MAS, LMA has a higher mean (2.957) and lower standard deviation (0.590) in comparison to the PDM ($\bar{x} = 2.838$ and $s = 0.778$). The result implies that the math anxiety felt by the majority of the students is more linked to LMA than to PDM. The LMA refers to anxiety when studying for math tests and when being evaluated in math. Meanwhile, PDM is the emotional component of math anxiety which involves feelings of nervousness and other unpleasant physiological reactions when dealing with math. The result confirms the study of Plake and Parker (1982) specifying that LMA contributes heavier weight to math anxiety. This finding is also supported by the study of Udil et al. (2017) who reported that math anxiety increases during mathematics tests. However, Pizzie (2021) stated that the cognitive and affective components of math anxiety are indistinguishably related.

Results may be attributed to the increasing cognitive demands in mathematics as the grade level increases. The design of the mathematics curriculum in the basic education of the Philippines follows a spiral progression. The complexity level of the topics increases from one grade level to another. Consequently, the students might be overwhelmed by the complexity of the math lessons in junior high school as compared to their elementary math causing them to be anxious. This is supported by the study of Furner and Higgins (2019) where they found out that, in general, junior high school students have a higher level of math anxiety than primary and elementary pupils.

Reliability of the Different Scale Formats

Table 2. Reliability Coefficient of the Different Scale Formats

Scale Format	Cronbach's α	Descriptive Equivalent
Standardized	0.886	Good
Checklist	0.897	Good
VAS	0.953	Excellent
4-Point	0.947	Excellent

Legend:

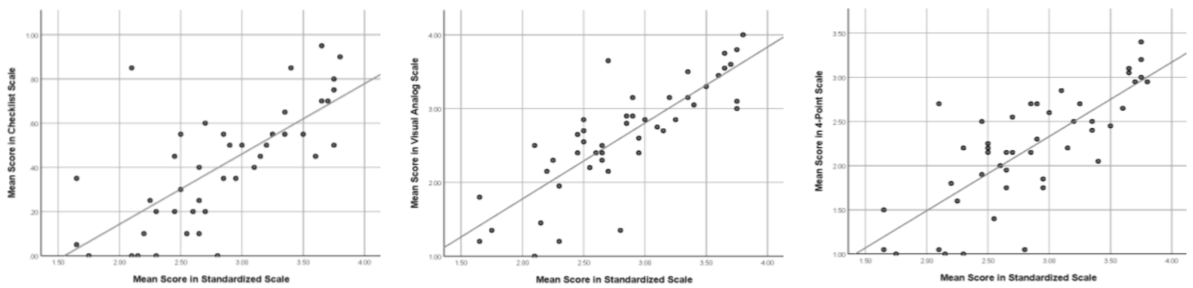
$\alpha \geq 90$	*Excellent*
$0.8 \leq \alpha < 0.9$	*Good*
$0.7 \leq \alpha < 0.8$	*Acceptable*
$0.6 \leq \alpha < 0.7$	*Questionable*
$0.5 \leq \alpha < 0.6$	*Poor*
$\alpha < 0.5$	*Unacceptable*

Table 2 shows the reliability coefficients of the survey scales and their corresponding qualitative description. The visual analog scale (VAS) has the highest reliability coefficient (0.953) followed by 4-point scale (0.947), checklist (0.897), and the standardized which used a 5-point scale (0.886), respectively. The results imply that both the visual analog scale and 4-point scale have excellent reliability while the standardized (5-point) scale and checklist have good reliability. This further implies the adequate reliability of the four scale formats when used in measuring math anxiety among junior high school students. These findings confirm the study of Jacoby and Matell (1971) claiming that the reliability of survey scales is independent of the number of scale options. Hence, tests with established reliability will likely produce reliable results even when the number of scale alternatives or scale format is changed. However, this is contrary to the study of Alwin, D. F., Baumgartner, E. M., & Beattie, B. A. (2018) where they concluded that reliability declines as the number of responses increases. They also stated that there is a strong indication of how middle categories in response formats especially 3-category scales tend to result in measurement error.

Findings suggest that the visual analog scale is the most reliable as compared to the other scale formats. This is supported by the study of Kuhlmann et al. (2017) stating that visual analog scales show superior measurement qualities in comparison to traditional Likert-type scales. This also confirms the study of Shahid et al. (2011) where they presented in their psychometric evaluation of the visual analog scale that it has excellent reliability when used in survey scales. Clarke (1964) suggested that aside from being reliable a visual analog scale is also a sensible response option. Ahearn (1997) also commended the conceptual simplicity, brevity of administration, and minimal intrusiveness of visual analog scales. The result can be attributed to the learning style of the students, in which most people are visual learners. The statistics findings of Bradford (2004) suggest that 65% of the population are visual learners. It is easier for people to recognize and discriminate visual imagery as compared to abstract ideas like numbers. This is backed by the dual coding theory of Paivio (1986) stating that recalling or recognition is enhanced when information is both presented in visual and verbal form.

Furthermore, the result shows that the 4-point scale has comparable reliability to the visual analog scale, unlike the checklist and 5-point scale which have slightly lower reliability coefficients. This implies that a 4-point scale provides more reliable results as compared to a checklist and a 5-point scale. This result may be attributed to the number of responses in the survey scales. Rezende & Medeiros (2022) found in their study that fewer response options tend to obtain higher values. In addition, people are more likely to be perplexed when they are given many options. Jacoby and Matell (1971) stated that too few response options of rating scales result in a "loss of discriminative power" of the rater but too many response options "go beyond the limited powers of discrimination" of the rater. This suggests that two choices may not be enough to express the level of agreement with a statement. Two choices might not be able to capture the true feelings of the respondents. However, the respondents might also fail to differentiate their level of agreement when given five choices as compared to when given four options.

Concurrent Validity of the Different Scale Formats



2.a. Standardized and Checklist *2.b Standardized and VAS* *2.c. Standardized and 4-point scale*

Figure 1. Scatterplots of the Standardized Scale and the Different Scale Formats

Figure 1 presents the scatterplots of the mean scores of the students in the standardized scale against their mean scores in the different scale formats. In general, the three scatterplots show that the mean scores in the different scale formats against the standardized scale follow a positive linear relationship. This implies that a higher level of anxiety when measured by the standardized scale also means a higher level of anxiety when measured by the different scale formats. The figure also shows that the trendlines of the three scatterplots have comparable slopes. The similarity of the slopes of the trendline further implies that the strength of association of the mean scores in the different scale formats to the mean scores in the standardized scale is comparable.

Table 3. Concurrent Validity of the Different Scale Formats

Scale Format	Pearson's r	p-value	Descriptive Equivalent
Checklist	0.714**	0.000	High Positive Correlation
VAS	0.823**	0.000	High Positive Correlation
4-Point	0.770**	0.000	High Positive Correlation

*** Correlation is significant at the 0.01 level (2-tailed)*

Table 3 presents the correlation coefficient of the mean scores in the standardized scale against the mean scores in the different scale formats. In general, the checklist, visual analog scale, and 4-point scale exhibited a high positive correlation to the standardized scale. The correlations are also significant at a 1% level of significance. This implies that an increase or decrease in the mean score in the standardized scale is significantly associated with an increase or decrease in the mean score in the different scale formats. Findings further imply that the three different scale formats have high concurrent validity to the standardized scale. This confirms the study of Jacoby and Matell (1971) claiming that the validity of a scale is independent of the number of alternatives in the scale. Since the standard scale has sufficient evidence of face and content validity, changing the number of response options or scale formats will likely provide a valid result. Moreover, previous studies have revealed that checklist (Ilgen et al., 2015), visual analog scale (Hasson & Arnetz, 2005; Vickers, 1999), and 4-point scale (Osteras, et al., 2008) have acceptable validity when used in survey scales.

Furthermore, the results show that the visual analog scale has the highest correlation coefficient (0.823) followed by 4-point (0.770) and checklist (0.714). This implies that the responses in the visual analog scale are more consistent with the result of the standardized scale as compared to the checklist and 4-point scale. However, the result can be attributed to the number of scale options, in which the standardized scale used a 5-point scale and the visual scale also has five response alternatives. Hence, the responses in the visual analog scale were expected to be highly correlated to the standardized scale.

Extracted Factors in the Different Scale Formats

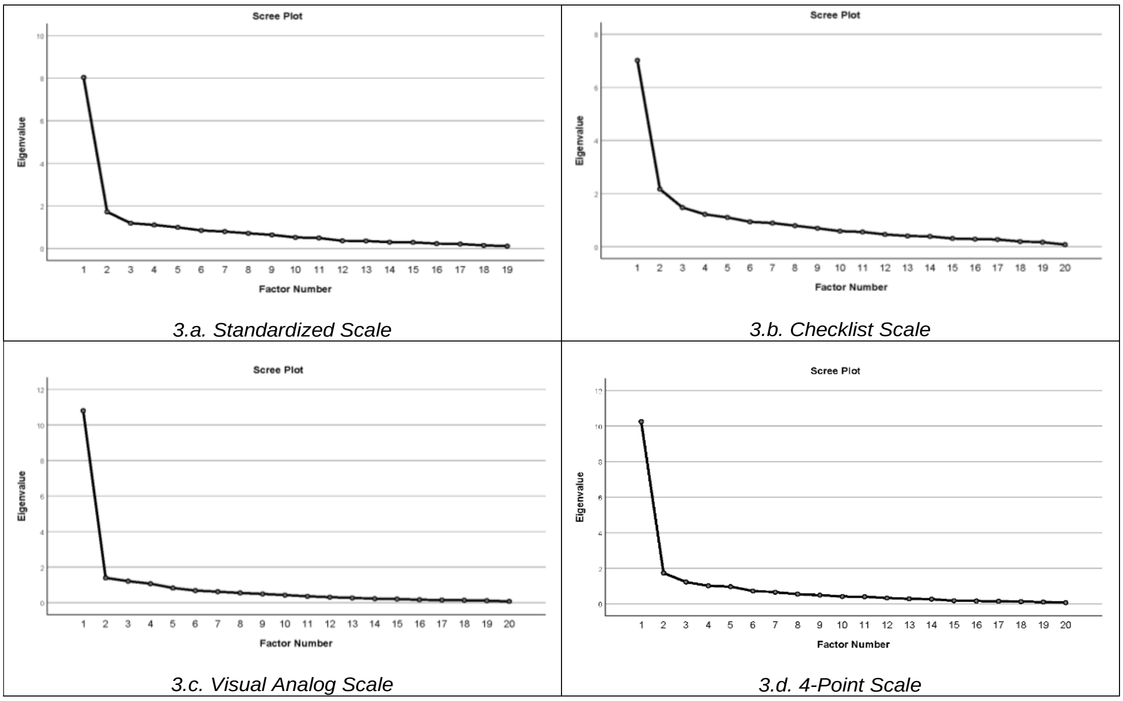


Figure 2. Scree Plots of the Different Scale Formats

Figure 2 presents the scree plots of the different scale formats. Generally, the scree plots of the standardized scale, checklist, and 4-point scale have a point of inflection at factor number 3. This implies that two factors should be retained. This confirms the result of the original Math Anxiety Scale by Zakariya (2018) which has specified two factors namely: Learning Mathematics Anxiety (LMA) and Perception of Difficulty and Motivation (PDM).

In the case of the visual analog scale, the point of inflection is at factor number 2 which suggests that there is only one factor to be retained. However, factor selection can also be based on Kaiser's criterion (1960) which states that all factors with eigenvalues greater than 1 can be retained. The scree plot shows that four have eigenvalues that are greater than one. However, the researchers extracted two factors in the visual analog scale for meaningful comparison with the other scale formats.

In the study of Zakariya (2018), he identified two factors in the Math Anxiety Scale. Items number 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, and 20 loaded at factor 1 while items number 2, 4, 6, 8, 10, 12, 14, 16, and 18 at factor 2. The author specified factor 1 as Learning Mathematics Anxiety (LMA) and factor 2 as Perception of Difficulty and Motivation (PDM).

Table 4 presents the pattern matrix of the different scale formats used in this study. The researchers executed exploratory factor analysis using maximum likelihood. The factors were rotated to an oblique simple structure using Oblimin with Kaiser Normalization and the rotation converged after 7 iterations. Moreover, factor loadings with an absolute value of less than 0.3 were suppressed in the factor solution. In general, many items loaded to a factor different from where they were expected to load as specified by the original MAS. Only items 3, 5, 9, 13, and 19 are parallel to the result of the original MAS, in which they consistently loaded to Factor 1 (LMA) in the four different scale formats. Meanwhile, the other items loaded to a factor different from where they were expected as stipulated in the original MAS. This implies that some of the items were not suitable indicators for the specified factors in the original MAS. The result can be attributed to the different populations used in the original MAS (secondary students in Nigeria) and in this study (junior high school students in La Trinidad, Benguet, Philippines). Child (1975) stressed one of the limitations of factor analysis is the effect of sample selection. Factors that are specific to a population may become obscured when applied to another population. Gaskin et al. (2017) affirmed that different populations can generate different factor solutions, both in terms of the number of factors extracted and factor structures.

Table 4. Pattern Matrix of the Different Scale Formats

Item No.	Standardized		Checklist		VAS		4-Point	
	Factors		Factors		Factors		Factors	
	1	2	1	2	1	2	1	2
1		.617		.488	.619			.985
2	.603		.611		.878		.681	
3	.744		.697		.795		.823	
4	.547		.525		.811		.721	
5	.939		.480		.753		.697	
6	.790		.387		.517		.858	
7	.426	-.312		.496	.541		.779	
8	.363	-.553	.496		.722		.764	
9	.608		.828		.842		.764	
10	.401	-.323		.489	.503	-.326	.705	
11		-.783		.699		-.696	.541	
12	.357	-.417		.557	.440	-.431	.791	
13	.301	-.356	.551	.314	.758		.811	
14	.335		.633		.605		.626	
15		.480		.676	.691			.745

Item No.	Standardized		Checklist		VAS		4-Point	
	Factors		Factors		Factors		Factors	
	1	2	1	2	1	2	1	2
16		-.327		.694		-.439	.786	
17		-.715		.539		-1.012	.517	
18	.413	-.512	.309	.589	.622		.828	
19	.470	-.453	.563		.778		.735	
20		-.457	.415		.546		.591	

Extraction Method: Maximum Likelihood.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 7 iterations.

The adequate reliability coefficient and high concurrent validity of the four scale formats, when administered to the respondents of this study, are evidence that the scale is measuring the actual construct which is math anxiety. The difference in the derived factor solution in the four scale formats from the factor structure of the original MAS may only suggest that some of the items are not appropriate indicators of the subconstruct of math anxiety (LMA and PDM) when applied to the population of this study. The researchers then analyzed the factor solutions of the four scale formats to identify what items are good indicators of LMA and PDM when used in the population of this study.

Table 5 presents the summary of the items that are more suitable indicators of the factors of math anxiety based on the analysis of the factor solutions in Table 4. In general, fourteen items are identified as suitable indicators of the factor Learning Mathematics Anxiety and six items for the factor Perception of Difficulty and Motivation. Table 6 presents that items 2, 3, 4, 5, 6, 8, 9, 13, 14, 18, and 19 loaded to Factor 1 in all four scale formats. Item 7 loaded thrice in Factor 1 loadings ranging from .426 to .779 and twice in Factor 2 with factor loadings of -.312 and .496. Item 20 also loaded thrice in Factor 1 with factor loadings ranging from .415 to .591 and once in Factor 2 with a factor loading of -.457. Hence, items 7 and 20 are more suitable indicators of Factor 1. This implies that items 2, 3, 4, 5, 6, 7, 8, 9, 13, 14, 18, 19, and 20 are more likely to be appropriate indicators of Learning Mathematics Anxiety. Learning Mathematics Anxiety is concerned with activities related to studying for mathematics tests and being evaluated in mathematics (Zakariya, 2018).

Table 5. Good Indicators of the Subconstructs of Math Anxiety

Factor	Item	
Learning Mathematics Anxiety	2.	Math is hard for me.
	3.	Math confuses me.
	4.	In maths, it’s hard for me to decide what I have to do.
	5.	I have always had trouble with maths.
	6.	Usually, I feel unable to solve mathematical problems.
	7.	I’m not the type to do well in math.
	8.	Usually, I have difficulty with mathematics.
	9.	I will always have difficulty learning math.
	10.	I do not know how to study math.
	13.	I’m not one of those people who were born to learn math.
	14.	Except for a few cases, no matter how much effort I put out, I cannot understand math.
	18.	Except for a few cases, no matter how much effort I put out, I cannot understand math.
	19.	I am always under a terrible strain in math class.
	20.	I am afraid to ask questions in math class.

Factor	Item	
Perception of Difficulty and Motivation	1.	I can become a good student of mathematics.
	11.	Math is one of the most boring subjects.
	12.	I don't think I could handle more difficult math.
	15.	I know I can do well in math.
	16.	I don't feel comfortable studying math like I feel with other subjects.
	17.	I hate studying maths, even the easiest parts.

In the previous table (Table 4), it was shown that items 1, 11, 15, 16, and 17 loaded thrice in Factor 2 and only once in Factor 1. This implies that these items are more likely suitable as indicators of Perception of Difficulty and Motivation. This means that these items are associated with the affective aspect of math anxiety or the emotional component of math anxiety concerning feelings of nervousness and other unpleasant physiological reactions to mathematics (Zakariya, 2018). In the case of items 10 and 12, both items loaded three times in both factors. The researchers compared the factor loading values and referred to the literature to decide which factor these items are more likely to measure. The factor loadings of item 10 in Factor 1 range from .401 to .705 and Factor 2 ranges from -.323 to .489. The statement is also more related to the definition of LMA (Factor 1), in which LMA is concerned with activities related to studying for mathematics tests and being evaluated in mathematics. Hence, item 10 is more likely an indicator of Factor 1. Meanwhile, the factor loadings of item 12 in Factor 1 range from .357 to .791, and Factor 2 ranges from -.491 to .551. The minimum and maximum factor loading values are comparable. However, the researchers analyzed the idea of item 12 and they noted that it hints feeling of nervousness when dealing with more difficult math. Item 12 is more concerned with the emotional component of math anxiety hence it is more suitable as an indicator Factor 2 (PDM).

Conclusion

Based on the results, the majority of the students are experiencing a moderate level of math anxiety. Their anxiety is substantially caused by the cognitive dimension of math anxiety. Among the four scale formats, the visual analog scale provides the most reliable result to be used in measuring math anxiety among junior high school students followed by 4-point scale, checklist, and 5-point scale, respectively. The extracted factors also confirmed that math anxiety is bidimensional having cognitive and affective components. However, the factor structure of the Math Anxiety Scale derived from this study with respondents from La Trinidad, Benguet, Philippines is different from the factor structure specified in the study involving secondary students in Nigeria.

Recommendations

Curriculum developers are encouraged to incorporate math anxiety intervention strategies into the curriculum materials. Teachers are also advised to implement classroom practices that have been found effective in reducing students' math anxiety. Furthermore, for studies involving junior high school students, the utilization of a visual analog scale is highly recommended. It is also suggested that they opt for a 4-point scale in comparison to a checklist or a 5-point scale. In addition, future researchers may examine the pros and cons of the different scale formats when applied to different age groups of respondents. They may also consider conducting a follow-up study and performing confirmatory factor analysis to assess the accuracy of the item assignment to the factors of math anxiety. It is also highly encouraged to develop a survey scale specifically designed to measure math anxiety among Filipino junior high school students.

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