A Weighted Scoring Based Rating Scale to Identify the Severity Level of Mathematics Anxiety in Students

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Abstract—Mathematics Anxiety (MA) is a pessimistic emotional attitude towards math that negatively affects mathematics learning. Due to its adverse impacts on students, assessing Mathematics Anxiety (MA) in early-stage has become a burning need over time. Generally, the existing measures of assessing MA adopt primitive questionnaires, and unweighted rating scale based approaches designed for students' particular age range. As a consequence, this type of scale is not sufficient enough to use widely. To bridge this gap, considering 839 students, the present study has proposed a Weighted Scoring Based Mathematics Anxiety Rating Scale (WSB-MARS). The reliability and validity of the WSB-MARS were ensured by high item-internal consistency, 1-week test-retest reliability, and the expert panel (validity). The study's overall findings suggest that WSB-MARS is a reliable, valid, generalized scale to assess the severity level of mathematics anxiety in students. Besides, the proposed scale could be implemented as a mobile application system that may help teachers/guardians recognize the effective intervention techniques for alleviating mathematics anxiety.

Keywords—Mathematics anxiety, mathematics anxiety rating scale, math learning, assessment

1 Introduction

Mathematics is an essential cognitive skill not only for academic success but also for effective day-to-day functioning. Math is fundamental to a child's development & communication skills in later life. It stimulates the brain and improves analytical and problem-solving abilities. As a consequence, mathematics is considered to be the foundation of science and other academic areas. As well as math is a strong predictor for later academic success in school. Despite having significance, many students show a negative attitude towards math due to Mathematics Anxiety (MA). Mathematics anxiety is a particular form of anxiety disorder that causes reluctance in learning and practicing math. It is a feeling of discomfort, apprehension, or fear that interferes with math performance and achievement [1]. At present, many students worldwide are suffering from MA, which adversely impacts their academic excellence, employability, and career progression. Because of its pandemic nature in students, this issue has received increasing attention from scholars in recent years. Generally, students begin to face an MA at elementary school, which gradually increases to intermediate and tertiary levels. Previous findings revealed that individuals with math anxiety show more brain activation in brain regions involved with negative emotions and less brain activation in brain regions involved with mathematical thinking [2]. These negative emotions create significant fear among students, encouraging them to avoid mathematical activities [3] and math-related careers [4].

On the other hand, this math avoidance leads students to low academic performance [5] and achievements [6]. As a result, MA is considered a substantial barrier to mathematical learning and is thought to hinder students' engagement and proficiency in metacognitive processes [7]. So, academicians are trying to figure out appropriate ways to overcome MA so that students can engage in math, achieve a good learning experience, and pursue a future math-oriented career.

Generally, two types of approaches are followed to overcome MA: (i) preventative control and (ii) detective control. In preventive control, various cognitive tools [8], [9], [10], and effective learning approaches [11-15] are followed that help students to learn Math with fun and realistic experiences rather than only theoretical exercises. These approaches increase students' attention to math and reduce the likelihood of math anxiety. On the other hand, detective controls are designed to identify the intensity of Mathematics Anxiety, and based on the severity; an effective remedial process is provided to overcome it. Several studies were found where scholars proposed various scales to assess and measure the severity level of MA. Among them, 98-items based MARS [16] is considered a very trusted and widely accepted measure for diagnosing MA. The reliability of MARS was ensured by test-retest ($\alpha = 0.85$) and internal consistency reliability ($\alpha = 0.97$). However, the main drawback of the MARS is that it takes a long administrative time to complete.

Consequently, the study [17] proposed a shorter version of MARS with 30-items whose primary purpose was to reduce the administrative time by keeping the validity and reliability the same as the original 98-items MARS. Later, in [18], 9-items based Abbreviated Math Anxiety Scale (AMAS) was introduced, which claimed a more correct and parsimonious approach to assess MA. Because of its fewer items and higher reliability, AMAS has become popular to asses MA based on psychometric properties. At the same time, several translated [19-20], and researchers commonly use modified [21] versions of AMAS. As the majority of measures of MA are designed and implemented for adults and adolescents, in [23], researchers proposed a 19-items based Children's Mathematics Anxiety Scale UK (CMAS-UK), which was specially developed for children (Age range: 4-7) of the UK.

Although there are several scales outside, no significant structural changes have been observed. All these scales are mainly psychometric measurement of behavioral attitudes where students specify their degree (generally 1 to 5, where one means less math-anxious and five means extremely math-anxious) of agreement or disagreement for a set of statements (items) and then sum up all the values where high scores indicate high Mathematics anxiousness. The key drawback of these existing scales is that the items (factors of MA) are considered equally important to assess MA. However, in reality, each item does not play an equal role in evaluating mathematics anxiety. To bridge this gap, the present study has proposed an effective detective control which identifies the severity level of Mathematics Anxiety of students more accurately. The purpose of the current study can be summarized as follows:

- Identifying the underlying factors of Mathematics Anxiety
- Categorizing the factors according to importance
- Introducing an effective mathematics anxiety rating scale called WSB-MARS
- Ensuring the reliability and validity of WSB-MARS
- Presenting a mobile application wireframe based on WSB-MARS

The rest of the study is arranged in the following way: in section 2, we discussed the methodological part. In section 3, we presented our proposed mathematics anxiety rating scale called WSB-MARS. In section 4, we explained the reliability and validity of WSB-MARS. In section 5, we have introduced a mobile application wireframe based on WSB-MARS. Lastly, in section 6, we discussed the overall study results and concluded with potential future work in this area.

2 Research Methodology

The methodology of the current study is split into several sub-sections for better understanding. In 2.1, we briefly outlined the data collection procedures. In 2.2, we discussed how the data set was pre-processed to eliminate conflicting data, and finally, in 2.3, we showed the reliability of our survey instrument.

2.1 Participants & primary data collection procedures

The present study has followed both qualitative and quantitative approaches to draw a meaningful research conclusion. At the initial stage, significant background work was conducted to identify the critical factors of mathematics anxiety. After finding out the responsible factors, all these factors were grouped into seven categories. Based on those findings, a survey (see Fig.1) was designed and distributed (between December 2019 and February 2020) to different class level students of 13 institutions (Level: primary, secondary & tertiary) in Bangladesh. The survey has consisted of 16 self-constructed questionnaires (16-items) that describe internal, external, and cognitive symptoms related to students' mathematics anxiety (see Fig.1). Among 16 questionnaires/items, the first 15 items are based on a 4-point Likert scale, which is used to identify the severity level of mathematics anxiety of an individual student (Severity Range: 0 to 3), and the 16th item represents whether a student is math-anxious or not (Range: 0 and 1). This 16th item is included only for determining the importance of the other 15 items (see details in section 3). A total of 1500 sampled of survey were distributed online and offline, and 871 responses were gathered (Male = 557 and Female = 314). The sample consisted of 147 primary level students (16.89%), 331 secondary level students (38%), and 393 tertiary level students (45.12%). The age range of the participants was 7 to 25.

Mathematics Anxiety Rating Scale - Survey (MARS - S)

16 questionnaire of 7 categories that describe certain feeling & experiences that students have related to Mathematics Anxiety. Students were requested to carefully go through this questionnaire and rate appropriately.

Level of severity (4 point Likert Scale):	**Never = 0**	**Rarely = 1**	**Sometimes = 2**	**Very often = 3**
Level of severity (2 point Likert Scale):	**No= 0**	**Yes = 1**		

Category 1 : Visible signs of Mathematics Anxiety

- **Item 1 : Do you feel unusual nervousness when doing or thinking about Maths?** (0) (1) (2) (3)
- **Item 2 : Do you feel panic or cold, when calling on to answer Maths related questions?** (0) (1) (2) (3)
- **Item 3 : Do you have visible signs of nervousness (sweaty palms, shaky hands, and so on) ?** (0) (1) (2) (3)

Category 2 : Test anxiety

- **Item 4 : Do you feel unusual nervousness when doing or thinking about Maths?** (0) (1) (2) (3)
- **Item 5 : Do you "fear of missing out" during Math test?** (0) (1) (2) (3)

Category 3 : Defeatism

- **Item 6 : In spite of having good preparation, do you feel lack of confidence in Math?** (0) (1) (2) (3)
- **Item 7 : Do you suffer from fear of failure in Maths subjects?** (0) (1) (2) (3)

Category 4 : Individual perception

- **Item 8 : Do you think your parents/teachers expect a lot from you especially in Maths subject?** (0) (1) (2) (3)
- **Item 9 : Instead of understanding Maths, do you prefer memorizing the process?** (0) (1) (2) (3)
- **Item 10 : Do you practice Maths regularly?** (0) (1) (2) (3)

Category 5 : Sleep disorder

- **Item 11 : Do you have trouble in sleeping at night especially before the day of Maths test?** (0) (1) (2) (3)

Category 6 : Cognitive skill (Working memory/short time memory)

- **Item 12 : How often do you forget the lesson which you have just learnt?** (0) (1) (2) (3)
- **Item 13 : Do you make mistakes on easy questions of Maths that you knew very well?** (0) (1) (2) (3)
- **Item 14 : How often do you have trouble finding words when you are talking to?** (0) (1) (2) (3)
- **Item 15 : How often do you need to ask someone for repeating instructions or a story because you can't remember what was said in the first time around?** (0) (1) (2) (3)

Category 7 : Math anxiousness

- **Item 16 : Do you have fear in Maths?** (0) (1)

Fig. 1. Survey details

2.2 Data pre-processing

This primary data in this study was collected through both online and field surveys, which were then combined and used as an aggregate dataset. To get reliable and precise measurement, the aggregated dataset was fully preprocessed. We found 32 abnormal responses where seven records were irrelevant (i.e., responders added information that was not connected to the study), 16 records were incomplete (i.e., responders did not respond to all questionaries), and nine records were inconsistent and redundant (i.e., same responders responded both online and field survey with different answers). So, we have removed all those responses to get a more efficient result. After performing data pre-processing, 839 valid observations were selected for the next procedures.

2.3 Reliability of the survey instrument (MARS-S)

As illustrated above, the present study's observations were collected through a survey called MARS-S (see Fig.1), which consists of 16-items. It needs to be ensured that MARS-S can reliably fulfill the purpose of the study. Consequently, the reliability of the MARS-S was estimated by Cronbach's alpha (α) that measures the internal consistency of a group of items [see equation (i)].

$$\alpha = \frac{N\bar{c}}{\bar{v} + (N-1)\bar{c}} \quad (1)$$

Here, α = Cronbach's alpha, N= number of items, $\bar{c}$ = average inter-item covariance, $\bar{v}$ = average variance.

Findings show that Cronbach's alpha of MARS-S is α = .93, which indicates a high internal consistency of 16-items. The inter-item correlation matrix of MARS-S also shows positive scores, which indicates those 16-items are working as a group to fulfill the goal without any contrast (see Table 1.).

Table 1. Inter-item correlation matrix

	I1	**I2**	**I3**	**I4**	**I5**	**I6**	**I7**	**I8**	**I9**	**I10**	**I11**	**I12**	**I13**	**I14**	**I15**	**I16**
I1	1.00															
I2	.577	1.00														
I3	.299	.207	1.00													
I4	.753	.582	.344	1.00												
I5	.497	.437	.257	.478	1.00											
I6	.636	.532	.367	.681	.511	1.00										
I7	.627	.526	.301	.671	.414	.665	1.00									
I8	.662	.527	.300	.666	.430	.622	.650	1.00								
I9	.424	.354	.223	.483	.374	.469	.409	.421	1.00							
I10	.480	.531	.164	.419	.388	.416	.447	.472	.282	1.00						
I11	.545	.558	.181	.564	.364	.514	.573	.561	.350	.494	1.00					
I12	.360	.435	.114	.306	.329	.354	.359	.345	.304	.473	.392	1.00				
I13	.582	.493	.227	.577	.532	.588	.560	.518	.421	.461	.525	.439	1.00			
I14	.454	.474	.204	.461	.433	.468	.482	.451	.404	.452	.450	.541	.576	1.00		
I15	.454	.503	.206	.468	.387	.482	.488	.450	.453	.483	.452	.545	.503	.635	1.00	
I16	.743	.619	.363	.728	.503	.716	.721	.769	.465	.530	.612	.410	.586	.541	.553	1.0

3 Research Results

The core structure of WSB-MARS is illustrated in this section. In section 3.1, we demonstrated how to determine the items' weight based on their role in creating an MA. Lastly, in section 3.2, we discussed briefly how our proposed scale (WSB-MARS) works.

3.1 Determining the weight of the items based on importance

In MARS-S (see Fig.1), the first 15 items are used to identify the severity level of mathematics anxiety, and the 16th item represents whether a student is math-anxious or not. The primary purpose of the 16th item is to help (as a target variable) identify the importance of the first 15 items in terms of diagnosing mathematics anxiety. In this current study, we used SelectKBest (Python Class) and a function called chisquared to select items according to their highest scores. The column "Importance of Items (IOI)" of table 2 represents the scores of the first 15 items against the target variable (16th item). At the same time, the weighted point of the first 15 items (according to their degree) was calculated in column "Weighted Point (WP) = UP*IOI" (see Table 2).

Table 2. Scoring of items according to the importance

I. No.	Importance of Items (IOI)	Unweighted Point (UP)				Weighted Point (WP) = UP*IOI			
		Never	*Rarely*	*Sometimes*	*Very often*	*Never*	*Rarely*	*Sometimes*	*Very often*
1	292.19	0	1	2	3	0	292.19	584.38	876.57
2	333.21	0	1	2	3	0	333.21	666.42	999.63
3	71.96	0	1	2	3	0	71.96	143.92	215.88
4	308.57	0	1	2	3	0	308.57	617.14	925.71
5	88.20	0	1	2	3	0	88.2	176.4	264.6
6	313.22	0	1	2	3	0	313.22	626.44	939.66
7	377.84	0	1	2	3	0	377.84	755.68	1133.52
8	443.81	0	1	2	3	0	443.81	887.62	1331.43
9	112.49	0	1	2	3	0	112.49	224.98	337.47
10	187.16	0	1	2	3	0	187.16	374.32	561.48
11	359.94	0	1	2	3	0	359.94	719.88	1079.82
12	110.44	0	1	2	3	0	110.44	220.88	331.32
13	145.89	0	1	2	3	0	145.89	291.78	437.67
14	155.51	0	1	2	3	0	155.51	311.02	466.53
15	193.17	0	1	2	3	0	193.17	386.34	579.51

3.2 Weighted scoring based rating scale

After calculating the Weighted Point (WP) of each item (see Table 2), the cumulative value of all the WPs represents the severity score of the mathematical anxieties of a particular student. (See step 3, Algorithm 1). According to our proposed Weighted Scoring Based Mathematics Anxiety Rating Scale (WSB-MARS), the maximum or highest possible severity score can be 10480.8, and the lowest or minimum possible severity score can be 0. A higher severity score indicates higher mathematics anxiety, and a lower severity score indicates students' lower mathematics anxiety. For better understanding, the overall severity score has been divided into 4 stages e.g., NORMAL (0 <= severity_score <= 2,620), MILD (2,620 < severity_score <= 5,240), MODERATE (5,240 < severity_score <= 7,860) and SEVERE (7,860 < severity_score < 10481) (see step 4, Algorithm 1).

Algorithm 1. Weighted Scoring Based Rating Scale

```
Input: Unweighted Points (UP) & Importance of Items (IOI)
Output: Severity score of Mathematics Anxiety
Step 1: X {1, 2, 3, 4, 5……...15} = Unweighted Points of 15 items
Step 2: Y {1, 2, 3, 4, 5……...15} = Importance of 15 items
Step 3: severity_score = ∑_{i=1}^{n=15} X[i] * Y[i]  [Severity score range: Min: 0 to Max: 10480.8]
Step 4: if (severity_score>= 0 && severity_score<= 2,620)
           Return "Severity Level = NORMAL"
        else if (severity_score>2,620 && severity_score<= 5,240)
           Return "Severity Level = MILD"
        else if (severity_score>5,240 && severity_score<= 7,860)
           Return "Severity Level = MODERATE"
        else if (severity_score>7,860 && severity_score< 10481)
           Return "Severity Level = SEVERE"
```

4 Reliability and Validity of the Proposed Scale (WSB-MARS)

4.1 Reliability

The reliability of our proposed scale WSB-MARS is ensured by the 1-week test-retest reliability coefficient (see Fig.2). It's a measure of the reliability achieved by performing the same test twice in a group of people over a period of time [22]. About 150 students from different schools (primary, secondary, and tertiary) took part in the test twice a week. The mean of the first test result (severity score) was 4921.10 (SD = 2223.5) and the second test result was 4984.37 (SD = 2011.4). Pearson's correlation coefficient (see formula ii) between the two test scores was 0.968. The overall finding confirms that WSB-MARS can reliably measure the Mathematics Anxiety of students.

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \tag{2}$$

Here, r = Pearson's correlation coefficient, x_i = scores of the first test, $\bar{x}$ = mean of the first test scores, y_i = scores of the second test, $\bar{y}$ = mean of the scores of the second test.

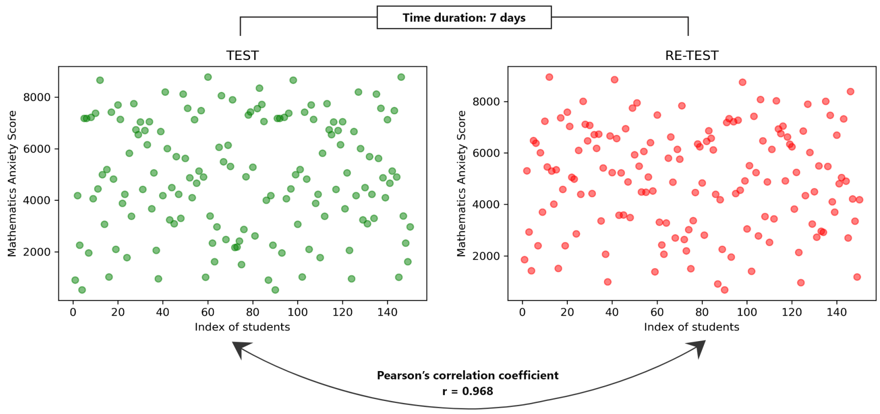

Fig. 2. Test-Retest reliability of WSB-MARS

4.2 Validity

The validity of the proposed scale (WSB-MARS) was ensured by the consultancy of the expert panel (n = 6) based on the following metrics: (i) Reliability of the survey instrument, (ii) Quality of the factors of mathematics anxiety, (iii) The ability of WSB-MARS to measure the severity level of mathematics anxiety (iv) Simplicity and (v) Administrative time to take a test. Table 3 provides the validity details of WSB-MARS. Findings indicate that WSB-MARS is considered a valid instrument to assess MA.

Table 3. Validity test details

Expert	**Metric (i)**			**Metric (ii)**			**Metric (iii)**			**Metric (iv)**			**Metric (v)**		
	Good	***Ok***	***poor***	***Good***	***Ok***	***Poor***	***Good***	***Ok***	***Poor***	***Good***	***Ok***	***Poor***	***Good***	***Ok***	***Poor***
1	✓				✓		✓			✓			✓		
2		✓		✓			✓				✓		✓		
3	✓			✓			✓				✓		✓		
4	✓			✓				✓		✓				✓	
5		✓		✓			✓			✓			✓		
6	✓				✓			✓			✓		✓		

5 A Mobile Application Framework Based on WSB-MARS

Generally, existing mathematics anxiety (MA) measures are used in education, research, psychology, clinical studies, etc., where researchers and academicians perform all the tasks manually rather than using an automated process. Consequently, it takes much time, effort, and money to complete the whole procedure. To overcome this gap, our proposed scale could be used as a mobile app to help teachers measure the severity level more quickly and take appropriate steps to reduce it. Fig. 3 represents the proposed mobile application wireframe, which highlights the functionalities and vital steps. Through this application, a teacher can efficiently perform several activities. Initially, a teacher needs to register himself/ herself with the necessary information to get into the apps. After successful registration, he/she will be able to log in and begin the next steps. After a successful login, he/she will be able to create a new test, set questions with additional information (options, default values, time limits, etc.), and assign the test to the target students. By default, there will be 15 questions from MARS-S. The teacher will determine the weight of each question, generate the rest report, and recommend an effective remedial program for a particular student. At the same time, a teacher will warn the students' guardians about their child's condition. On the other hand, students can also do different things, including self-registration, performing the assigned test, taking notes, checking remedial programs via this application.

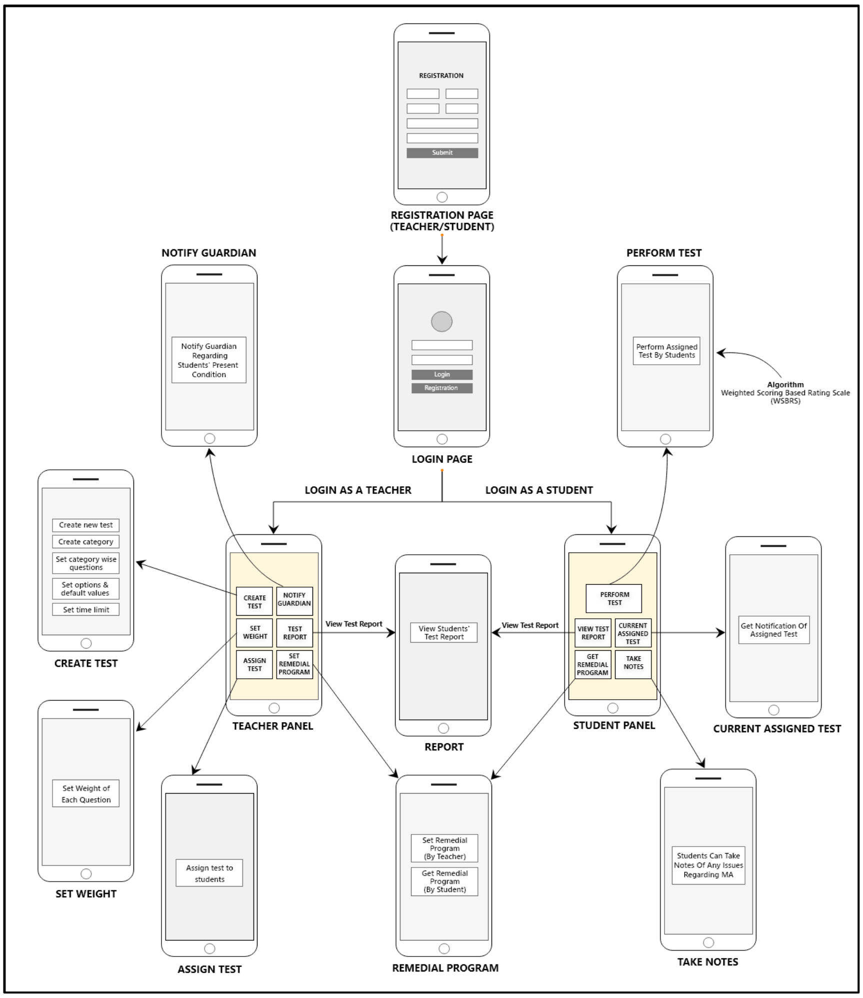

Fig. 3. Mobile application wireframe

6 Discussion and Conclusion

Mathematics Anxiety (MA) has become a global concern nowadays. Early identification of the severity level of MA can reduce its negative impacts to a certain degree. Generally, two approaches are followed to alleviate Mathematics Anxiety: (i) preventative approach and (ii) detective approach. In this study, we introduced a detective instrument called Weighted Scoring Based Mathematics Anxiety Rating Scale (WSB-MARS) that can assess the severity level of Mathematics Anxiety among students. The reliability and validity of the proposed WSB-MARS were ensured by item-internal consistency (Cronbach's alpha: α =.93), test-retest reliability: r = .968, and consultancy of an expert panel, respectively. Since WSB-MARS has 15 items, it takes a short administrative time to complete a test. This makes WSB-MARS easy to use compared to existing scales. Table 4 represents a comparative analysis between our proposed scale and the existing scales. Findings show that existing scales were designed for a particular age range of students. On the other hand, WSB-MARS is constructed based on primary, secondary & tertiary level students.

Table 4. Comparative discussion

Scale	Total Items	Targeted Students/Age	Reliability Score	Sample Size (N)	Ref.
MARS	98	Tertiary Level	0.85 (test-retest)	397 (80% Female, 20% Male)	[12]
MARS (Short Version)	30	Age range: 17 -26	0.90 (test -retest)	124 (63 Females, 61 Males)	[13]
AMAS	9	Ave. age: 19.6	0.85 (test-retest)	1,239 (729 Females, 510 Males)	[14]
AMAS (Italian Version)	9	Primary Level	0.83 (test - retest)	1013 (51% Male, 49% Female)	[15]
AMAS-G	9	Age range: 18 - 35	0.82 (test -retest)	221 (221 Females, 0 Male)	[16]
mAMAS	9	Age range: 8 - 13	0.85 (test-retest)	1746 (882 Males, 864 Females)	[17]
CMAS - UK	19	Age range: 4 - 7	N/A	163 (90 Males, 73 females)	[22]
WSB -MARS	15	Age range: 7 - 25 (primary, secondary & tertiary)	0.968 (test - retest)	871 (557 Males, 314 Females).	Our Proposed Scale

The proposed scale (WSB-MARS) could be implemented as a mobile application that may help teachers/guardians find out the root of students' mathematics anxiety and its level of severity. As WSB-MARS is a reliable, valid, and new approach to assess the severity level of mathematics anxiety in students, it can be useful in the research and education field [24]. However, some limitations are still observed, like less primary data and preliminary validity tests. On the other hand, WSB-MARS is solely based on information from Bangladeshi students. As a consequence, effectiveness may vary outside Bangladesh. So, in the future, we expect to eliminate the above limitations and increase its effectiveness.

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