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PAPER

Identifying Mathematics Anxiety Through Automated Process (IMATAP): A Web-Based Screening Tool for Teachers

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ABSTRACT

Mathematics anxiety (MA) is considered a potential barrier to success in science, technology, engineering, and mathematics (STEM) careers. A good number of students around the globe are terrified of mathematics. They do whatever they can to avoid math or math-related subjects. Therefore, the early identification of MA and its underlying factors is crucial in initiating timely interventions that can enhance positive attitudes in math, boost math performance, minimize math avoidance, and motivate students to pursue math-related careers. In this paper, we have presented a unique, multifaceted, and complete web-based MA screening tool called identifying mathematics anxiety through an automated process (IMATAP) to assess MA, its severity, and its deficiency. This assessment provides a detailed explanation of developing MA and helps teachers, parents, educators, and researchers design need-based intervention techniques (personalized or cluster-based) to reduce MA, which will ultimately help math-anxious students overcome math fear. Over the past two years (2021–2022), IMATAP has been successfully implemented in nine different primary and secondary level institutions in Bangladesh. Findings revealed that the effectiveness of the IMATAP system has been appreciated and highly accepted by both students and teachers.

KEYWORDS

mathematics anxiety (MA), math performance, mathematics anxiety screening tool, identifying mathematics anxiety through an automated process (IMATAP), technology acceptance model (TAM)

1 INTRODUCTION

Anxiety disorders are pervasive and potentially debilitating conditions that affect a vast number of individuals worldwide. According to the World Health Organization (WHO), as of 2019, over 300 million individuals, including a staggering 58 million

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children and adolescents, were living with anxiety disorders [1]. Among different types of anxiety disorders, mathematics anxiety (MA) has emerged as a prominent psychological phenomenon, especially in educational settings [2]. MA is characterized by feelings of tension, apprehension, and fear when it comes to learning, understanding, applying, or dealing with mathematical concepts or solving math-related problems [3–7]. Even though mathematical activities, such as problem-solving, decision-making, and critical reasoning, have been shown to enhance brain function, many students worldwide still consider mathematics to be a tough and frightening subject [7]. According to the report of the Programme for International Student Assessment (PISA), which analyzed data collected from 39 countries, there is a notable inverse relationship between MA and mathematics performance among students [8]. The report also revealed that countries and economies where students exhibit greater levels of MA tend to record lower performances in mathematics. This is consistent with the majority of recent literature, which also claims that MA harms students' math performance and achievement [9–11]. Moreover, math anxiety is widely considered a potential barrier to success in STEM. Current thinking holds that math anxiety is directly linked to avoidance of and underperformance in STEM domains [12].

Given these findings, early recognition of MA is crucial to prevent students from developing long-term negative effects and an aversion towards mathematics, which can affect their career choices and limit their opportunities. Many intervention techniques, such as mathematical intervention or cognitive intervention, and assessing tools (rating scale-based) have been designed and developed to measure the intensity of MA [11]. One crucial limitation is that most previous studies supporting a connection between math anxiety (MA) and STEM academic outcomes often overlooked the strong association between high math anxiety and poor math ability. Addressing this issue requires a systematic and comprehensive approach to assess both the causes and the severity of math anxiety.Additionally, there was no established dynamic system for systematic record-keeping.

2 LITERATURE REVIEW

The effective intervention strategy for individuals experiencing MA depends on accurately identifying the severity level and underlying factors influencing it. Since different individuals develop mathematics anxiety due to different reasons, an ideal screening tool should have the ability to identify the factors fueling MA in different individuals. Currently, the measurement of MA is predominantly conducted through questionnaires and rating-scale-based approaches [11]. One such commonly used tool is the mathematics anxiety rating scale (MARS), developed by Richardson and Suinn (1972) [13]. The MARS is a 98-item scale designed to assess both cognitive and affective dimensions of MA. The scale has shown high internal consistency ($\alpha = 0.97$) and test-retest reliability ($\alpha = 0.85$), making it a useful instrument for measuring MA. Despite the benefits of the MARS, researchers have sought a shorter alternative to reduce the administration time. As such, a 30-item version of the MARS was later introduced [14]. This abbreviated version of the MARS also maintains high internal consistency ($\alpha = 0.96$) and test-retest reliability ($\alpha = 0.90$). Furthermore, the abbreviated math anxiety scale (AMAS) is another widely utilized tool for measuring MA. It is comprised of only nine items but possesses high internal consistency (α = 0.90) and test-retest reliability (r = 0.85) [15]. While the MARS assesses both the cognitive and affective dimensions of MA, the primary focus of the AMAS is on the affective dimension. Due to its versatility and concise number of items, the AMAS is more commonly used and can be administered to both university students and adults in the general population, either as a self-report questionnaire or through an interview. Subsequently, a modified version of the AMAS (mAMAS) was developed to evaluate MA in British children and adolescents [16]. As the majority of the tools are primarily focused on adolescents and adults, the MARS elementary form (MARS-E) was introduced for assessing MA at the elementary level [17]. This self-report questionnaire consists of 26 items and takes approximately 20 minutes to complete. MARS-E has demonstrated high internal consistency and reliability (α = 0.88). In addition, the children's mathematics anxiety scale-UK (CMAS-UK) was developed specifically for children aged 4–7 in the UK [18]. Although the initial version of the scale included 21 items, the final version was refined and consisted of 19 items with high internal consistency (α = 0.88) and item loadings (> 0.45).

Despite the availability of various screening tools to assess MA, several issues are associated with their use. Firstly, the majority of these tools are designed for use by researchers and psychologists in psychotherapy, treatment, or research [13], making them unsuitable for teachers, educators, or the general audience due to their pen-and-paper statistical approach. Furthermore, manually analyzing data can be time-consuming, particularly when dealing with a large number of students. Secondly, cultural and linguistic backgrounds, as well as familiarity with the types of mathematical tasks being assessed, may influence the effectiveness of these tools. For example, the majority of the existing tools were developed in Western cultures and may not consider the specific cultural and social factors that contribute to MA in developing countries like Bangladesh. To address these gaps, this study aims to introduce a web-based and robust screening tool for MA called identifying mathematics anxiety through automated processes (IMATAP). The purpose of IMATAP is to help teachers, researchers, and educators identify students' current level of MA and its underlying factors quickly and comprehensively, in general and particularly in the context of Bangladesh.

3 SYSTEM FRAMEWORK AND IMPLEMENTATION

Figure 1 illustrates the framework of the IMATAP application system, which comprises three distinct phases. In phase 1, students will undergo an initial diagnostic test as well as a MA-level identification test. This assessment is anticipated to uncover both the strengths and weaknesses of students in terms of their overall prerequisite knowledge and skills necessary for individual school curricula. Additionally, the assessment will reveal varying degrees of MA among students, ranging from low to very high levels. However, it should be noted that this phase alone does not identify the underlying factors responsible for fueling students' MA. So, to reveal the factors contributing to their MA, such as mathematical deficiency or poor foundation knowledge, self-belief, low self-esteem, past negative experiences, negative parental attitudes, teachers' negative attitudes, learning environment, low intelligence quotient (IQ), and poor working memory revealed in previous studies [19–24], in phase 2, students have to sit for a series of age-based adaptive tests.

These adaptive tests include a set of subjective tests to assess students' depth of knowledge and areas lacking in arithmetic, geometry, and algebra (see Figure 2). An individual perception and characteristic test will be conducted to better understand students' thoughts, habits, anxiety, and experiences related to the study of math (see Figure 3). A data analysis ability test will be conducted to determine if students have any deficiencies in understanding and interpreting given data (see Figure 4). A numerical skill test will be conducted to determine students' computational and manipulative abilities (see Figure 5). Additionally, a working memory test will be administered to determine students' working memory capacity in areas such as remembering, recognition, visual-spatial, and verbal skills to better understand their problem-solving abilities (see Figure 6). Finally, an IQ test will be conducted to measure students' intellectual abilities and competence in relation to their age group (see Figure 7).

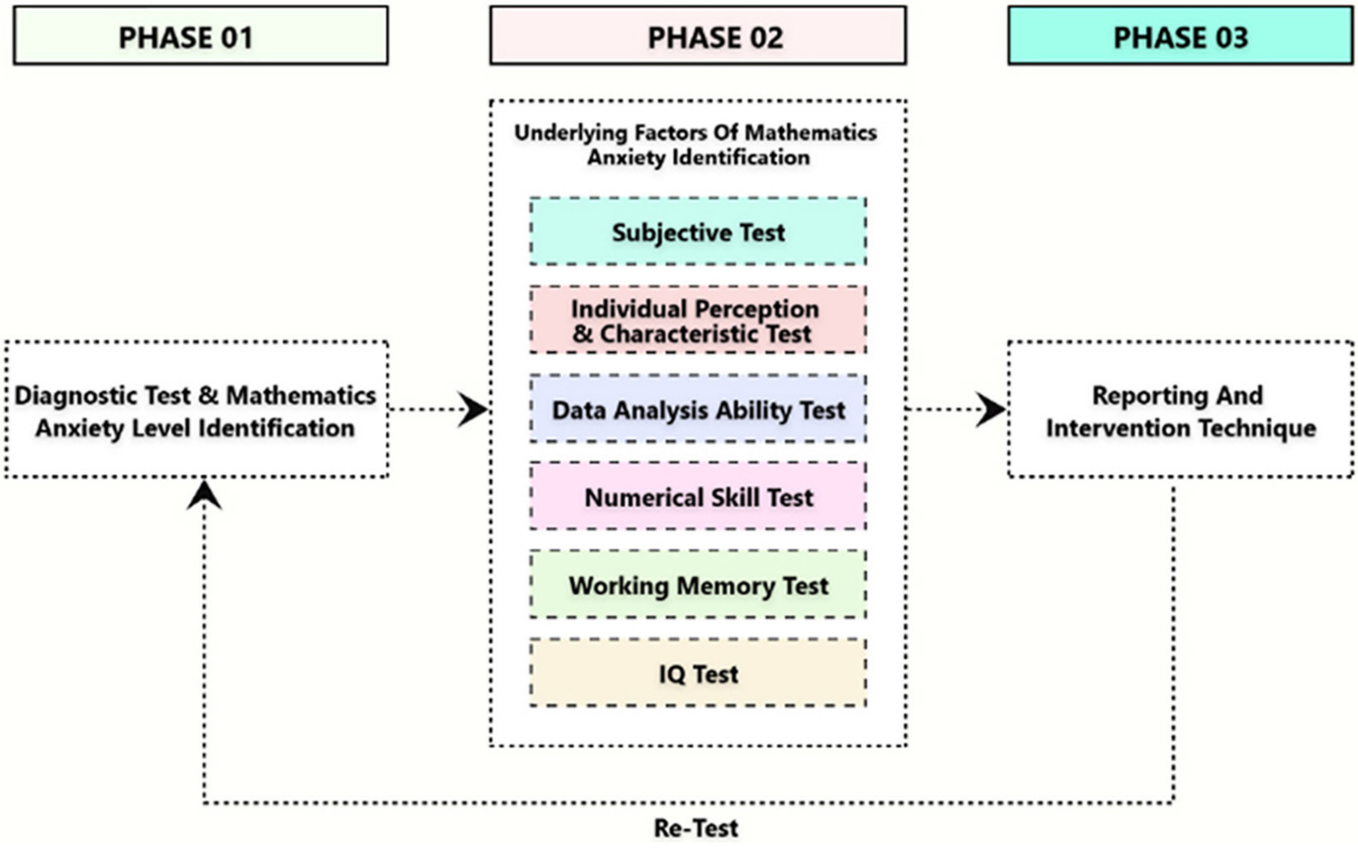

Fig. 1. Framework

Based on the results obtained from these tests, phase 3 generates a comprehensive report detailing the intensity level of each student's mathematics anxiety and the specific underlying factors contributing to it (see Figure 8). This report provides math teachers with valuable insights into each student's individual needs and enables them to design and implement personalized or cluster-based intervention techniques that effectively address the identified issues. Upon applying the intervention techniques, teachers can also retest their students to evaluate the effectiveness of their interventions. If the desired improvement in students' MA is observed, the cycle ends. However, if further improvement is necessary, students will repeat the process until their desired level of progress is achieved.

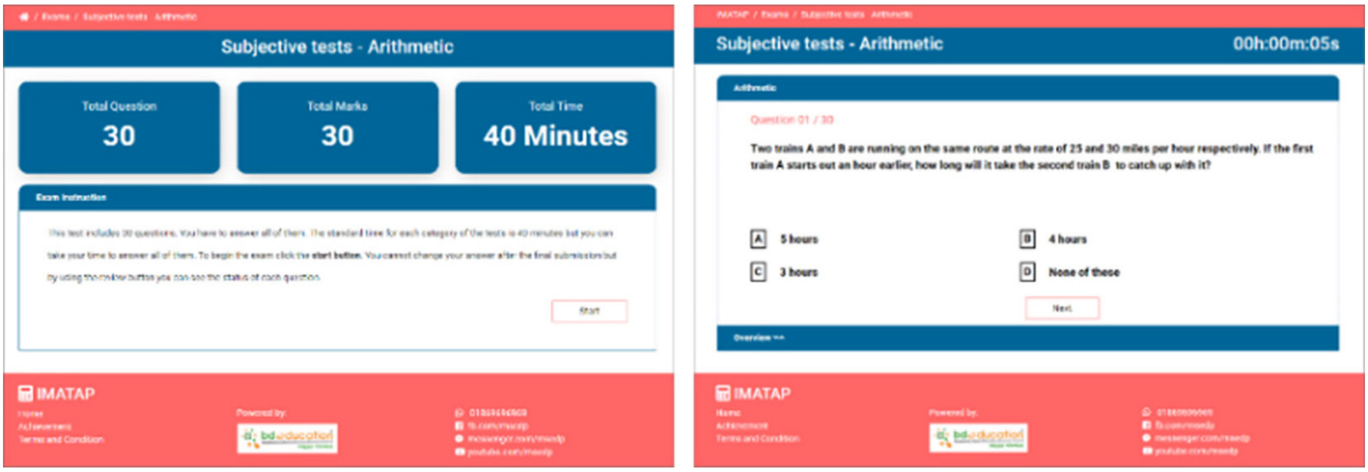

Fig. 2. Subjective test

Fig. 3. Individual perception and characteristic test

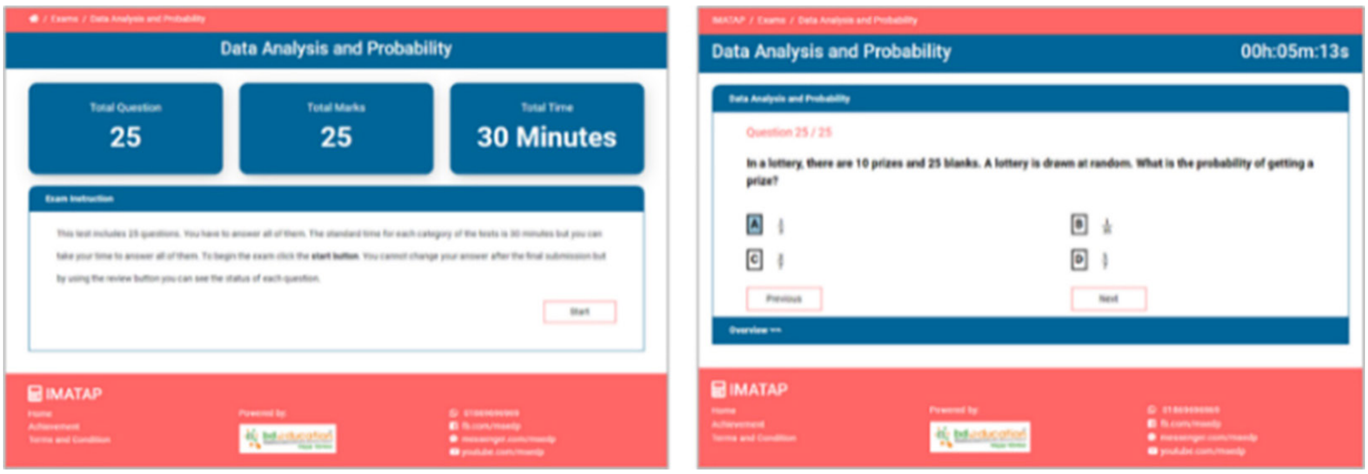

Fig. 4. Data analysis ability test

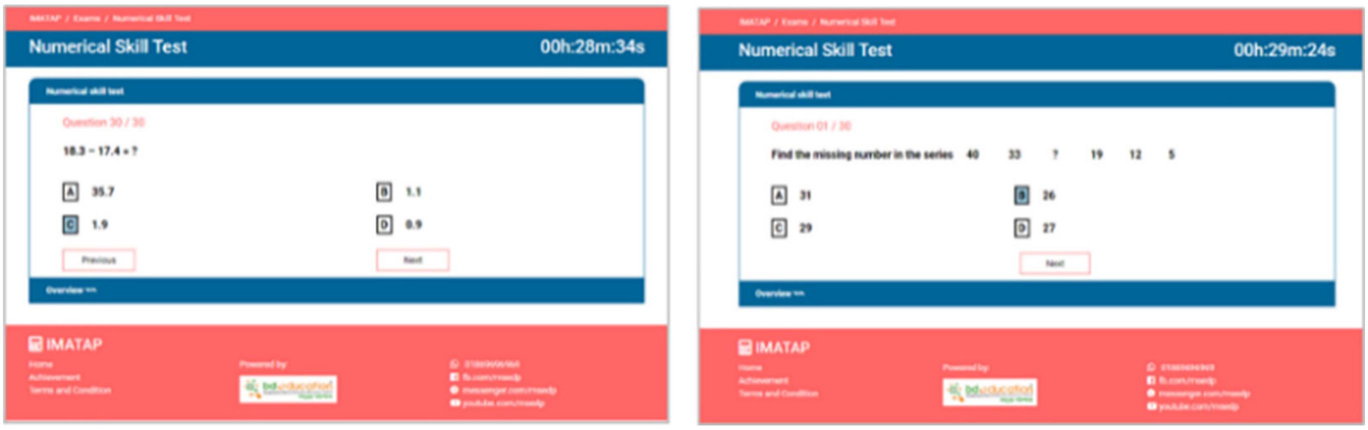

Fig. 5. Numerical skill test

Fig. 6. Working memory test

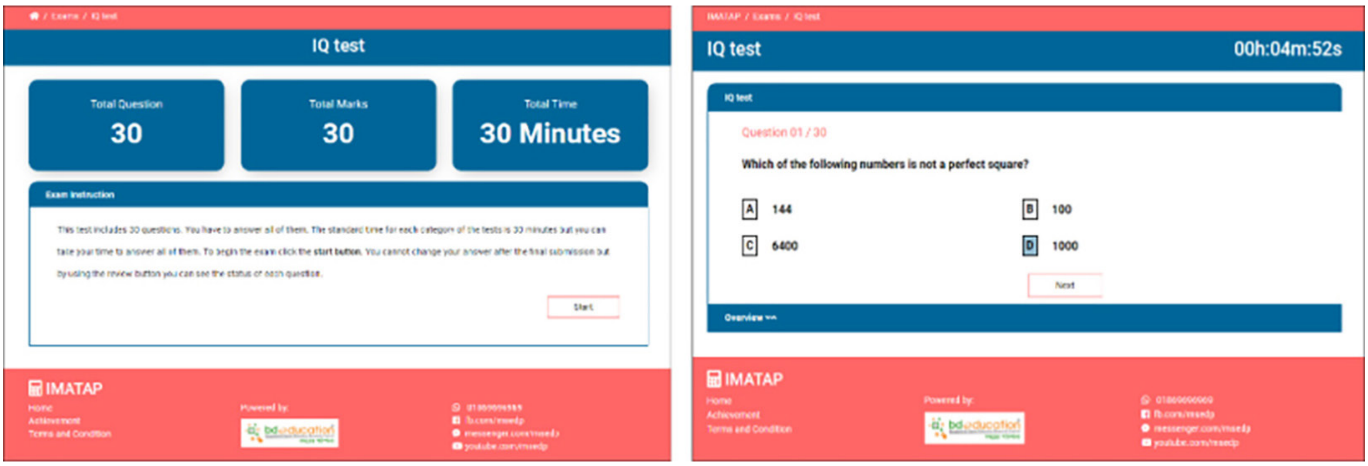

Fig. 7. IQ test

Identifying Mathematics Anxiety Through Automated Process (IMATAP)

Student name: Khalid Bin Ali
Student ID: 32443246634
Class: V
Section: B
School Name: Mahmuda Khanam Memorial Academy

Summary Report

#	Exam Title	Catagory	Difficulty Level	Marks Obtained (%)	Date and Time Taken
1	Diagnostic Test	Diagnostic test	Intermediate	40	17/01/2022 56 m
	Comment: Very poor performance. Have deficiency in basic knowledge and understanding.				
2	Individual Perception and Characteristic Test	Maths Anxiety symptoms (Internal and External)	Standard	42	17/01/2022 9 m
	Comment: Exhibit a severe and unhealthy level of nervousness or tension which sometimes stem from very poor preparation/huge lack of basic knowledge/ tremendous pressure doing good which is not justified.				
3	Individual Perception and Characteristic Test	Past Experience	Standard	36	17/01/2022 12 m
	Comment: Severely affected by external factors. Has high level of discomfort towards Mathematical learning that stemmed either from unpleasant past experience or from poor teaching Methodology and negative life experience associated with learning mathematics.				
4	Individual Perception and Characteristic Test	Learning Habit	Standard	43	17/01/2022 16 m
	Comment: Very low confidence. Also shows significant level of over reliance on others and have wrong perceptions and bad learning habit.				
5	Individual Perception and Characteristic Test	Productive / Mathematical Disposition	Standard	43	17/01/2022 9 m
	Comment: Has positive disposition and shown excellent ability to set goals and achieve them.				
6	IQ Test	IQ test	Foundation	28	17/01/2022 25 m
	Comment: Extremely Low				
7	Subjective tests	Arithmetic	Foundation	28.57	18/01/2022 37 m
	Comment: Very poor! Do not have required basic knowledge in mathematical operations.				
8	Subjective tests	Geometry	Foundation	24	18/01/2022 42 m
	Comment: Very poor! Have basic problem in geometrical literacy and application.				
9	Data analysis	Data Analysis and Probability	Foundation	40	18/01/2022 29 m
	Comment: Shows poor capacity of interpreting data.				
10	Working memory test	Remembering and Recognition	Foundation	26	18/01/2022 13 m
	Comment: Has very low capacity to recall events, facts or processes.				
11	Working memory test	Visual spatial & Verbal	Foundation	33.33	18/01/2022 9 m
	Comment: Has very low capacity to recall events, facts or processes.				

* **Has Maths Anxiety** ☑ Yes ☐ No

* **Level Of Anxiety** ☑ Severe ☐ Mediocore ☐ Normal

Expert / Teacher Comment: Based on the assessment, it is observed that the student exhibits a severe level of Maths anxiety. Moreover he has high level of maths deficiency that most likely derived from negative perception about math learning and basic weakness in arithmetic and geometry. He needs counseling to have a positive disposition about maths learning and proper guidance to improve his skills in arithmetic and geometry. He must start from a level where he finds confidence in learning maths irrespective of his grade or age.

IMATAP
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Fig. 8. Summary report

4 EFFECTIVENESS OF EVALUATION

4.1 Participants, material, and evaluation metrics

To comprehensively assess the effectiveness of the IMATAP application, a survey was conducted across nine educational institutions in Bangladesh, where IMATAP was utilized for 2 years (2021–2022). The evaluation included 26 math teachers and 476 students from classes 3 to 10, representing a diverse set of schools spanning six different districts. Utilizing a quantitative research methodology, the primary aim of this evaluation was to investigate the IMATAP's ability to identify the severity level of mathematics anxiety and its underlying factors, as well as to evaluate students' acceptance and usage of the tool. Hence, two data collection instruments were employed, one for teachers and the other for students, which were designed by quantitative research experts. To measure the students' perceived usefulness and perceived ease of use of the IMATAP application, the technology acceptance model (TAM), one of the most tested, prominent, and influential models of technology adoption, was utilized [25–26]. Meanwhile, teachers' perceptions were evaluated based on the following 5 metrics: (i) the reliability of the test; (ii) The quality of the factors of mathematics anxiety (MA); (iii) the ability of IMATAP to measure the level of mathematics anxiety; (iv) the simplicity of the tool; and (v) the time required to analyze the test result.

4.2 Results and discussion

To evaluate the effectiveness, initially, students' acceptability of the IMATAP web application was measured by the TAM [25–26]. Table 1 presents the responses of students related to the perceived usefulness, perceived ease of use, and acceptance of IMATAP. In terms of perceived usefulness, a vast majority of respondents (82%) either agreed or strongly agreed that the system could enhance math performance. Moreover, over 90% of respondents believed that the system was helpful and effective. The mean value for perceived usefulness exhibited a favorable response, with 45% of respondents agreeing and 44% strongly agreeing that IMATAP was useful. Regarding the perceived ease of use, the results were mixed. While more than half of respondents (56%) found IMATAP easy to use, only 23% found it easy to learn. However, a significant proportion of users (84%) agreed or strongly agreed that the system could be controlled easily, and 79% of users found it clear and understandable. Nevertheless, 22% of respondents agreed that the system was easy to be skilled in, and less than a third (30%) found it flexible. The mean value for perceived ease of use demonstrated a positive response, with 30% of respondents agreeing and 45% strongly agreeing that IMATAP was easy to use. Finally, the acceptance of IMATAP by students was generally positive, with more than three-quarters (79%) of respondents either agreeing or strongly agreeing that they accepted the system. The mean value for acceptance was positive, with 35% of respondents strongly agreeing and 44% agreeing that they accepted identifying mathematics anxiety through an automated process (IMATAP).

Table 1. Results of the TAM

Items	Questions	Percentage of Responses				
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Perceived usefulness	Improve math performance	36%	46%	16%	2%	0%
	Effective	54%	37%	4%	4%	1%
	Helpful	45%	49%	5%	0%	1%
	Average	**45.0%**	**44.0%**	**8.3%**	**2.0%**	**0.7%**
Perceived Ease of Use	Easy to learn	23%	37%	33%	3%	4%
	Can be controlled easily	38%	46%	13%	2%	1%
	Clear and understandable	23%	56%	14%	5%	2%
	Flexible	13%	65%	16%	5%	1%
	Easy to use	56%	22%	21%	1%	0%
	Easy to be skilled	22%	37%	21%	12%	8%
	Average	**30.40%**	**45.20%**	**17.00%**	**5.00%**	**2.40%**
Acceptance of IMATAP		**35.04%**	**44.02%**	**15.30%**	**3.73%**	**1.92%**

After evaluating students' acceptability of IMATAP, teachers' perceptions about its effectiveness were also evaluated in five different metrics: reliability of the test, ability to measure the level of MA, ability to measure the factors of MA, simplicity of the tool, and administrative time required to take the test (see Figure 9). In terms of the reliability of the test, 46.2% of teachers reported being highly satisfied, 38.5% reported being satisfied, and no teachers reported being dissatisfied. Similarly, for the ability to measure the level of MA, 46.2% of teachers reported being highly satisfied, 50% reported being satisfied, and no teachers reported being dissatisfied. For the ability to measure the factors of MA, however, only 38.5% of teachers reported being highly satisfied, while 3.8% reported being highly dissatisfied. 50% of teachers reported being satisfied, and 7.7% were neutral. Regarding the simplicity of the tool, 65.4% of teachers reported being highly satisfied, 15.4% reported being satisfied, and no teachers reported being dissatisfied or highly dissatisfied. Finally, for the time required to analyze the test result, 57.7% of teachers reported being highly satisfied, 38.5% reported being satisfied, and no teachers reported being neutral, dissatisfied, or highly dissatisfied.

Overall findings indicate that most of the students perceived the system as useful and effective. Furthermore, the majority of students found it clear and understandable, and overall perceived ease of use demonstrated a positive response. On the other hand, teachers also reported positive perceptions of the tool's effectiveness in measuring the level of math ability, its reliability, simplicity, and the administrative time required to take the test. Thus, this application can help them to continually improve their teaching skills, provide customized support needed for each student, and indicate a potential tool for enhancing math performance.

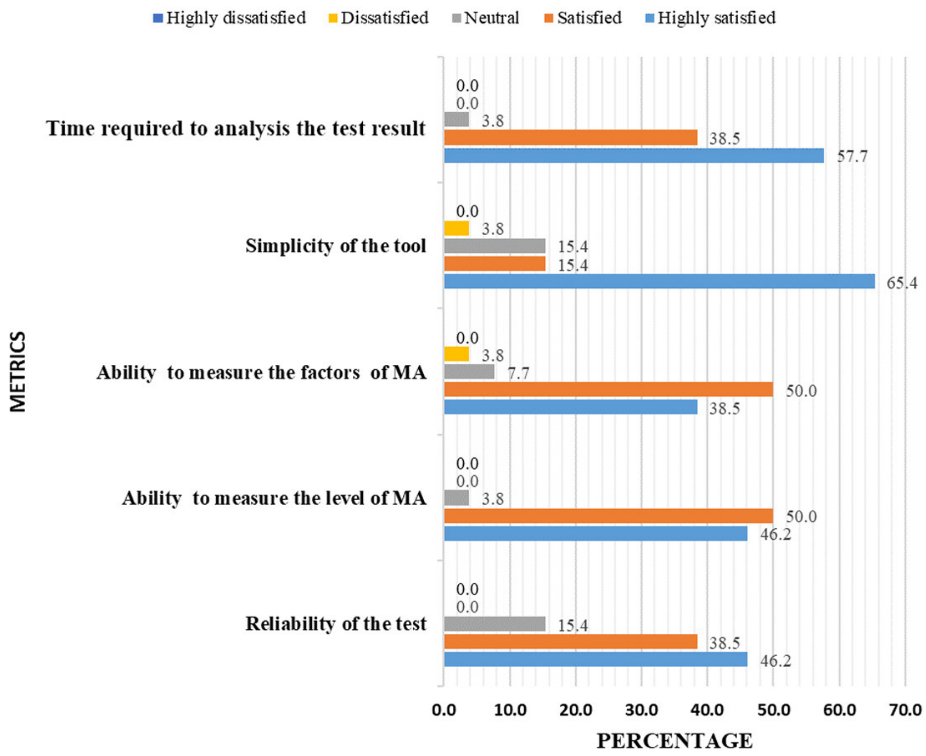

Fig. 9. Teacher's perception of IMATAP

5 CONCLUSION

Mathematics anxiety (MA) is a well-known form of anxiety disorder that hinders math learning and evokes negative emotional reactions toward mathematics. Despite the prevalence of the term MA over an extended period, it has gained growing concern in recent years due to its pandemic nature. The detection of the severity of MA and its underlying factors through an automated system is still unclear. This study aimed to address this gap by presenting a user-friendly web-based application called IMATAP. The study revealed that IMATAP was highly acceptable to both teachers and students. IMATAP effectively identifies the severity level of MA and its underlying factors, enabling teachers to design effective intervention techniques that are personalized or cluster-based for students with MA. Moreover, the findings highlighted the importance of early identification of MA and the significance of technological screen tools like IMATAP in promoting effective math education.

6 LIMITATIONS AND FUTURE DIRECTIONS

Despite its effectiveness and widespread acceptance, IMATAP also has a few limitations. Firstly, completing the series of age-based adaptive tests in IMATAP requires a significant amount of administrative time, typically lasting two to three hours. Consequently, students, particularly those in lower grade levels, may feel impatient and inadvertently rush through the multiple-choice questions to finish the tests quickly. Secondly, while IMATAP is user-friendly, teachers need additional training to effectively utilize the tool, comprehend its various aspects, provide insightful feedback, and develop appropriate remedial programs for students. Therefore, attaining proficiency in operating IMATAP for optimal results requires a considerable investment of time. To address these limitations, further and future directions regarding optimizing the test structure and providing comprehensive resources and training programs for educators could be included. Moreover, there is scope for research to validate and refine the IMATAP model further, to make it fit for diverse cultural contexts and educational settings, and to improve its effectiveness.

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