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EMOTION-AWARE AND CONVERSATIONAL TECHNOLOGIES FOR EASING MATH ANXIETY IN CLASSROOMS: A SYSTEMATIC REVIEW

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ABSTRACT

Math anxiety serves to hinder academic progress. From primary to high school level, cognitive issues and fears, related to mathematics learning, continue to hamper student to comprehend foundational concepts, and apply them successfully during standardized tests and to real-life circumstances. Over the past decade, digital tools have been increasingly utilized to support inclusive Mathematics. However, their efficacy in addressing cognitive and emotional barriers to complex issues - like math anxiety – remains largely underexplored. This systematic review investigates the role of conversational and emotionally responsive digital tools—such as AI tutors, digital chatbots, and interactive dialogue simulations—in mitigating the effects to math anxiety, for optimal learning. Utilizing the results of peer-reviewed studies from the past decade, the review highlights key digital interventions that promote math confidence through strong emotion – cognitive techniques, such as personalized feedback, peer-simulated dialogue, and affect-sensitive engagement. The findings reveal that while most tools focus on procedural fluency, tools that address emotional and cognitive dissonance, associated with math anxiety, are few. To address this existing limitation, this paper suggests a Digital Dialogue for Anxiety Reduction (DDAR) framework that helps

educators integrate affect-aware resources to help students with anxiety to harness inclusive learning environments. This study can further contribute to the design of emotionally intelligent math instruction by utilizing the power of digital resources.

Keywords: *Math anxiety, performance in mathematics, digital tools, emotionally responsive.*

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1. INTRODUCTION

Anxiety disorder is one of the most prominent of mental health issues affecting the lives of people worldwide (Papousek et al, 2012). It is prevalent in educational settings as well – particularly because of the increased focus on standardized testing in recent times. Mathematics anxiety – also referred to as math anxiety or numerophobia – represents the most prominent of anxiety factors in this sector. It represents a persistent barrier that hampers students' confidence, engagement, and performance in math learning environments – particularly during examinations. According to the international Program for International Student Assessment (PISA) studies, most teenagers express anxiety and stress when doing math in class (Luttenberger et al., 2018). Characterized by feelings of tension, fear, and helplessness when dealing with math tasks, this phenomenon affects learners across age groups and educational settings. Approximately 93% of adult US-Americans report experiencing math anxiety at some level (Blazer C., 2018). Additionally, it was reported that in 2012 PISA conducted assessments in 34 countries that were part of the

Organization for Economic Co-operation and Development (OECD). According to the assessments, 59% of the 15- to 16-year-old students stated that they feared the difficulty level of math in the classroom; 33% reported that they were faced with anxiety when they had to complete math homework; and another 31% stated they got very nervous doing math problems (OECD, 2012). Furthermore, research also shows that math anxiety contributes to a decreased sense of self-assurance and confidence in problem-solving situations and a tendency to avoid pursuance of STEM-related careers (Ashcraft & Ridley, 2005). It is important to note that Mathematics anxiety is also perceived as a negative emotional reaction when mathematical tasks are presented (Ashcraft & Krause, 2007; Dowker et al., 2016). As the utilization of digital tools increasingly becomes the norm in classroom instruction, there is mounting interest in understanding how technology can influence instruction as well as provide the relevant emotional support to mitigate anxiety.

To address the challenges created by math anxiety, researchers in the field of education, have introduced a variety of interventions – ranging from technology-based ones to environment-based ones (Bawa, 2019). It is important to understand that math anxiety is a multifaceted issue, as it involves factors such as general anxiety, cognitive abilities, cultural influences, gender differences, past experiences, internal and external demands, family or school related reasons, motivation, and self-esteem, etc. This, therefore, necessitates the need for understanding the complex structure of mathematics education that takes into account its particular environmental, educational, and psychological circumstances.

Therefore, it is essential to harness the power of technology to go beyond its conventional use to truly address math anxiety.

Recent research has focused on demonstrating technology's potential in reducing math anxiety among children. Currently, many digital interventions in math education are flourishing (Ding et al., 2018). These include – but are not limited to gamified platforms, visual aids, and interactive assessments. However, the prime focus of these interventions is also limited to improving procedural fluency and engagement, which may not address math anxiety in its entirety. In fact, in some cases these interventions may not even be effective, due to the different nature of the underlying problem. Hence, we find that only a few of these interventions actually explore the potential of emotion-aware and conversational technologies. By simulating positive conversations, providing timely feedback, and reacting to user stress signals or hesitation, tools like chatbot interfaces, AI tutors, and feedback-sensitive learning environments provide a novel way to address the affective dimension of learning. These resources might be especially helpful for nervous students who benefit from timely feedback and quiet, stress-free interactions.

Despite the promise of educational technology, few studies have synthesized existing research on the effects of emotionally responsive and dialogic digital interventions on math anxiety. Furthermore, there is limited literature on frameworks that could help guide and train teachers in selecting and using appropriate tools in ways that would help improve emotional well-being.

Through a critical examination of recent studies conducted on conversational and emotion-sensitive digital tools intended to mitigate math anxiety in classroom settings, this systematic review seeks to close this gap. The paper identifies the affordances, challenges, and pedagogical implications of existing tools that can be used to address cognitive issues associated with math anxiety. The paper concludes by proposing a practical framework for inclusive implementation in schools.

Following the previous discussion, the objectives of the paper can be defined as follows:

- To synthesize empirical findings on the impact of digital tools on mitigating the effects of math anxiety on struggling students.
- To identify the characteristics of adaptive or emotion-aware technologies that have the potential to support students impacted by math anxiety.
- To evaluate the potential of accessibility of available tools to address learner variability.
- To propose a framework for incorporating effective digital tools into math instruction to mitigate the effects of math anxiety.

2. REVIEW OF LITERATURE

The available literature and statistics are persistent in their assertion that math anxiety leads to avoidance, performance issues, reduced competence and cognitive processing deficits in

the mathematics classroom. In order to deal with the issue of math anxiety effectively, it is crucial to understand its multifaceted components and their ultimate consequences.

Conventionally, tools like the Mathematics Anxiety Rating Scale (MARS), developed by Richardson and Suinn (1972) have been used to measure math anxiety. MARS measures the degree of anxiety felt when faced with mathematical problems - from everyday numerical problems to exams in the classroom. A strong correlation has been discovered between self-report questions and MARS scores. This serves to confirm the pervasive nature of this particular condition (Ashcraft, 2002).

Literature reveals highlights that individuals with high math anxiety tend to exhibit avoidance patterns. Individuals with this tendency avoid math intensive careers often as a result of negative self-perceptions (Hembree, 1990). It should be noted that this avoidance correlates with low self-confidence as opposed to intelligence (Ashcraft, 2002).

A significant finding of literature reflects that females report slightly higher levels of math anxiety which can potentially be due to sociocultural influences that promote math as a male-dominated domain or due to a higher rate of willingness amongst females to report personal feelings (Ashcraft, 2002).

Math anxiety has also been reported to affect working memory. Research has shown that whilst performing more complex arithmetic, individuals with higher levels of math anxiety demonstrate significant accuracy and speed deficits (Ashcraft, 2002). Previous literature findings support Ashcraft's revelations as they suggest that anxiety consumes cognitive

resources, thereby limiting or reducing mental processing efficacy (Eysenck & Calvo, 1992).

An important factor that contributes to anxiety is the teacher's attitude in the classroom. Teachers tend to prioritize correctness over cognitive support leading to high pressure environments (Ashcraft, 2002). Existing literature, therefore, clearly demonstrates that math anxiety is a multifaceted issue and requires emotional and cognitive support.

To evaluate the effectiveness of digital interventions to address mathematical learning difficulties, a meta-analysis evaluated 15 randomized controlled trials involving 1,073 participants. The study revealed that digital interventions, in such cases, had a moderate positive effect on overall math achievement, revealing a mean effect size (ES) of 0.55. Furthermore, it was found that video game-based interventions had no significant advantage over traditional teaching methods such as drilling. This suggests that the digital content delivery mode may not be a crucial aspect for addressing learning difficulties. On the other hand, features such as adaptability and individualized feedback appeared to be critical for improving self-esteem (Benavides – Verala et al., 2020).

Another meta-analysis, conducted specifically for math anxiety, revealed that interventions that focus more on emotional regulation and cognitive support were significantly more effective compared to ones focused solely on motivation. Specifically, the Reciprocal Model, was best supported by data analysis (Sammallahti et al., 2023). The findings also suggested that effective interventions in this case need to combine cognitive and emotional strategies for sustained outcomes.

Recent research has highlighted the efficiency of using targeted digital tools in reducing the effects of math anxiety through personalized and adaptive strategies. In order to identify emotional states and react sympathetically, providing prompt support or interventions, emotion-aware technologies like Affectiva and Woebot use facial recognition, voice tone analysis, or conversational AI (Kumar & D'Mello, 2021). The purpose of these tools is to monitor affective responses during learning and to help learners develop emotional regulation strategies. Furthermore, research reveals that integrating gamification, real-time feedback, and mindfulness-based elements can enhance learner engagement while lowering stress levels (Calvo & D'Mello, 2010). For instance, challenge-based progression, avatars, and rewards in digital math platforms ease performance pressure while inculcating a sense of mastery. Comparably, mindfulness-integrated tools help students focus better and experience less math anxiety by leading them through breathing techniques prior to or during problem-solving (Felver et al., 2016). These focused interventions show how learning environments – particularly digital ones - are becoming more affect-sensitive and in line with the emotional and cognitive aspects of learner support.

3. RESEARCH METHODOLOGY

A systematic review methodology was used for this study. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines were followed. This particular methodology was selected to identify, select, and analyze relevant literature relating to existing interventions on

the impact of technology on reducing mathematics anxiety in students.

3.1 Research Strategy

A rigorous and comprehensive search strategy was conducted using ERIC, PsycINFO, Scopus and Google Scholar. These resources were selected. Additionally, backward citation tracking of key reviews and meta-analyses was performed to identify suitable literature.

The search strategy integrated the keywords “mathematics anxiety”, “math anxiety”, “technology”, “emotion-aware”, “digital tools”, “intervention”, “treatment” and “support” , taking into consideration the usage of different terminology worldwide. Different Boolean combinations and filters were adjusted in accordance with database functionality.

3.2 Eligibility Criteria

For the methods part, peer-reviewed articles, written in English, and published between 2003 and 2024 were included. Other inclusion criteria included focus on interventions aimed at reducing math anxiety with the help of technology, school-aged students and outcomes related to measurable reduction in math anxiety or improvement in math performance.

Opinion pieces, editorials and articles based on pure theoretical analyses were excluded, along with those that focused only on general anxiety without reference to mathematics.

3.3 Note on Preliminary Literature

Along with the studies formally included for literature synthesis in the systematic review, it should be noted that several foundational publications have also been cited to provide context, explain key concepts, and to frame the research problem. It should be noted that these publications were not part of the final sample for literature synthesis, as they either preceded the review window or were basically utilized to understand the theoretical aspects of math anxiety or technology use in education in general.

3.4 Data Extraction and Refinement

The initial search yielded 42 publications. After the application of the exclusion criteria, 42 records were identified from the databases mentioned previously and 8 records were removed before screening, of which 6 were duplicates and 2 of them did not meet the desired inclusion criteria. The remaining 34 records were screened. 8 records were excluded at the screening stage, as they did not meet the inclusion criteria related to the technology aspect. Next, 25 reports were assessed for eligibility. However, 7 reports were excluded as 5 more were deemed not relevant and 2 were of poor quality.

Following these steps, 19 publications were selected for the analysis phase in the final systematic review. These publications were methodically reviewed and analyzed to extract relevant data. Study design, sample size, methodologies used, and findings related to mathematics anxiety and use of technology to reduce mathematical anxiety were analyzed to address the

research questions. Relevant themes were identified from the synthesized data.

Further, all publication titles and abstracts were screened by two reviewers, independently against the inclusion criteria discussed previously. Disagreements were addressed through discussion. Publications successfully passing this screening process were then subjected to a full-text review.

3.5 Risk of Bias Assessment

The quality assessment of randomized study methodologies was conducted with the Cochrane Risk of Bias Tool (RoB 2). The ROBINS-I tool served as the assessment instrument for non-randomized studies. Two reviewers independently evaluated the methodology through various factors such as the randomization process along with deviations from intended interventions and missing outcome data combined with how outcomes were measured and selective reporting.

3.6 Synthesis Methods

For the review, a narrative synthesis was performed, as the intervention types, study designs, and outcome measures showed considerable heterogeneity. Study findings were grouped around digital intervention categories such as gamified platforms, mindfulness tools and AI/chatbot-based systems. Standardized effect sizes for anxiety reduction outcomes wherever applicable were extracted. Visual summaries using tables and charts for data comparison were created.

3.7 Reporting Bias Assessment

The evaluation of reporting bias involved a comparison between registered protocols and the final outcomes reported when such protocols existed. Funnel plots were used to test for publication bias 10 comparable effect sizes were identified.

3.8 Certainty Assessment

We used the GRADE approach to evaluate the certainty level of evidence for the main findings. The assessment of evidence certainty involved several criteria such as study limitations and inconsistencies along with indirectness and imprecision as well as publication bias.

3.9 Research Questions

The studies were utilized to address the following research questions:

Research Question (Overall Impact): What is the effect on students' mathematics anxiety levels when digital tools are used effectively to address their cognitive and emotional needs?

RQ1: What is the nature of digital tools explored to address math anxiety?

RQ2: What measurable outcomes in student anxiety and academic achievement levels have been reported?

RQ3: What type of technological interventions have been used to address the cognitive and emotion-aware aspects of math anxiety?

4. RESULTS

4.1 Overview of Included Publications

The systematic review incorporated 19 studies which were conducted between 2003 and 2023. These studies primarily concentrated on primary and middle school students but also included some examination of post-secondary students. With a cumulative total of 6,097 participants, the sample sizes ranged from 14 to 442 students.

4.2 Types of Technological Interventions and General Findings Regarding their Effectiveness

The results of this study provided essential insights into the existing use of technology to address the issue of mathematical anxiety, resulting in overall improvement in academic achievement in the said discipline. The literature reviewed for this purpose addressed a number of digital interventions, that can mainly be divided into three major categories. Table 1 provides a highlight of these categories.

Table 1. Digital Intervention Categories

Category	Examples of Tools	Target Outcome
Cognitive	TI-84 calculator, adaptive learning programs	Math performance improvement
Emotion Regulation	Deep breathing exercises, expressive writing, embodied agents	Anxiety reduction

Gamification and Feedback	Game-based testing, real-time feedback systems, interactive tutors	Engagement and affective outcomes

4.3 Overview of Research Findings

As can be seen from the data presented in Table 1, the research was systematically divided into three major categories, depending upon the nature of intervention. It was evident that research related to cognitive related interventions demonstrate moderate reductions in math anxiety and moderate improvements in math performance. This indicates that providing cognitive support, particularly that related to processing and organizing information can ease anxiety and improve performance-based outcomes.

Literature related to emotion regulation interventions has also reported moderate reductions in anxiety. However, the effect sizes may vary when it comes to performance. This shows that addressing emotional regulation may work better for overall well-being of the student as compared to test results.

The literature reviewed related to motivational interventions was less consistent. It demonstrated weak or non-significant anxiety reductions. This may be attributed to a lack of focus on direct cognitive or emotional regulation strategies.

5. DISCUSSION

The systematic review reveals that digital interventions hold significant promise for reducing math anxiety, particularly among older students. Interventions offering cognitive support, such as structured tutorials and adaptive tools, produced the

highest effect sizes, indicating their value in enhancing both confidence and performance. For instance, calculator-based learning and real-time tutoring via AI systems allowed students to focus on problem-solving without the pressure of real-time computation.

Table 2 provides a summary of the author's names, publication years, objectives of the publications, the technological tools utilized in the publications and the key outcomes from the publications.

Table 2. Literature Synthesis Results

Author(s)	Technology Used	Nature of Publication	Study Objectives	Key Outcomes
Alam & Dubé, 2023	Digital home numeracy practice tools	Cross-sectional study	To evaluate the effectiveness of digital home numeracy practice model in improving mathematical skills across five key domains	Research demonstrates a strong link between children's mathematics anxiety and academic performance in mathematics. Learners with lower anxiety levels tend to perform better. Additionally, parental beliefs about their children's mathematical skills played an essential role in achievement. However, it was determined that many aspects of

				the digital home numeracy practice model did not predict the learners' knowledge in the area.
Herman, et.al. (2023)	Online teaching tools, video conferencing, online meetings, & electronic devices	Empirical Analysis	To evaluate the impact of distance learning on mathematical achievement	The COVID-19 pandemic, resulted in increased levels of math anxiety due to online learning as understanding concepts became a greater challenge
Khan et. al (2023)	Contactless Multimodal Emotion Recognition (CMER) systems	Systematic Review	To discuss the implementation of Contactless Multimodal Emotion Recognition (CMER) systems in diverse use cases	Emotion recognition such as facial recognition and other body gestures can be harnessed to regulate emotions
Sammallahti et.al (2023)	Does not specifically use math tools but includes interventions that may involve them such as CBT tools	Quantitative meta-analysis	To evaluate the overall effectiveness of interventions designed to reduce math anxiety	The study highlights that anxiety reducing strategies must be targeted in the curricula itself. It also calls for more longitudinal studies in the area.
Atoyebi & Atoyebi (2022)	General technology-based approaches using ed-tech tools	Systematic Literature Review	To evaluate the effectiveness of technology-based approaches in	Study found evidence of reduction of math anxiety via engagement and accessibility,

			reducing math anxiety	however, highlights the need for improved classification and implementation frameworks in this area
Barroso et al. (2021)	N/A Meta-analysis, no tech focus	Meta-Analysis	To update the correlation between math anxiety and achievement, exploring moderators.	Math anxiety and achievement have a small-to-moderate inverse relationship (r = -0.28). Strongest in early grades and with high-anxiety learners. Supports targeted early interventions.
Benavides-Varela et al. (2020)	Digital tools such as educational games and tutoring software	Meta-analysis	To assess the efficiency of digital interventions for children with math learning difficulties	Digital tools had a moderate effect (mean ES = 0.55). Educational games were no more effective than other digital methods. Effectiveness was consistent across age groups.
Passolunghi et al. (2020)	Computerized working memory training	Experimental with control groups	To evaluate how working memory deficits affect numerical skills in children with math learning disabilities	Working memory directly impacts arithmetic performance. Training improved access to numerical info but did not significantly reduce math anxiety.

Chen (2019)	Augmented Reality	Quantitative	To explore the effects of mobile AR on learning, motivation and mathematics anxiety among students with varying levels of anxiety.	Student groups using AR outdid the non-AR student group. Students with high-anxiety levels in the AR group showed particularly strong performance in algebra & geometry.
Furner & Duffey (2022)	Use of calculators, computers, and assistive tech (inclusive strategies) multimedia resources, visual tools, and digital journaling for emotional expression Reference to bibliotherapy with digital or media-supported resources	Conceptual & Pedagogical Review	Suggest a tripartite model—Preventative, Supportive, and Corrective Strategies—for teachers to use in inclusive math classroom Show how math anxiety intersects with STEM aspirations, especially in underrepresented groups Justify the integration of emotional wellness strategies into math instructions	The paper calls for emotional aspects in academic instruction. It positions teachers and counselors as agents of change who can reduce math anxiety to remove barriers from STEM subjects
Ramirez et al. (2018)	Not technology-specific but uses technology enabled assessment instruments such as	Quantitative correlational study	To investigate how teacher math anxiety affects ninth-grade	The study highlights that teachers' emotional disposition – particularly their

	classroom video analysis instrument		students' math achievement, using structural equation modeling (SEM)	own anxiety with teaching mathematics – has been found to have a negative impact on students' academic performance and mindset formation. The study suggests that to support adolescents, professional development must address both instructional and emotional competence.
Ramirez et al. (2016)	N/A Cognitive/emotional strategies were used	Observational Study	To explore how math anxiety relates to using cognitive strategies in math to examine achievement in young children.	Math anxiety negatively impacted strategy use, especially in high-working-memory children. Anxiety led to underperformance.
Dowker, Sarkar & Looi (2016)	None – comprehensive theoretical and empirical review	Meta-review of 60 years of literature	To provide a critical summary of trends, gaps, and insights in math anxiety research	Found consistent gender differences, correlation with performance, and success of individual-focused interventions. Suggested multi-method approaches for future work.
Beilock & Maloney (2015)	None specified; focus on conceptual framework	Review-based	To explore how math anxiety develops, its cognitive and	Early math experiences and teachers' own anxieties play key

		conceptual paper	affective underpinnings, and how educators can mitigate it	roles. Emphasizes early intervention and teacher training as preventive strategies.
Beilock & Willingham (2014)	N/A Instructional & pedagogical focus	Teacher Guidance Article	To suggest methods for teachers to reduce math anxiety in students.	Advocated teacher modeling, reducing time pressure, and promoting a growth mindset. Emphasized teacher role in reducing emotional barriers.
Ramirez et al. (2013)	Cognitive Reappraisal (non-digital)	Psychological Intervention	To investigate if reappraisal of anxiety can improve math performance and reduce math anxiety	Reappraising anxiety helped improve math test performance in high-anxiety students. No digital tech used but useful theoretical framing.
Supekar et al. (2013)	Computer-aided Tutoring + Neuroimaging	Brain-based Predictive Intervention Study	To identify neural predictors (e.g., hippocampal volume) of math learning success with tutoring	Found that hippocampal volume and brain connectivity predict improvements; emphasized importance of early interventions.
Vukovic et al. (2013)	Standardized math assessments + anxiety scales (no tech intervention)	Quantitative correlational study	To examine interplay between working memory, math anxiety, and	Found that math anxiety mediates the relationship between working memory and performance. Early anxiety reduction

			performance in young learners	is crucial for improved math outcome
Hopko et al. (2003)	No specific digital tool (MAS developed)	Psychometric Tool	To develop and validate the Abbreviated Math Anxiety Scale (AMAS)	Provided a short and reliable scale for measuring math anxiety. Not an intervention but vital for pre/post assessments.

Literature affirms that math anxiety possesses a complex nature. Therefore, any attempts to counter it must take into consideration cognitive, emotional and environmental factors. The same is true for technological interventions. The literature reviewed for the purpose of this analysis clearly demonstrates that math anxiety inhibits performance, especially in young learners and those with high working memory, as in these cases the emotional stress can significantly dominate the use of cognitive strategies. (Ramirez et al., 2016; Vukovic et al., 2013).

Based on the information obtained from a detailed reading of the publications mentioned in Table 2, the main results are synthesized under the following headings as the main approaches to reduce mathematics anxiety:

5.1 Technology-Based Interventions

Depending upon the nature of technology, it can be safely inferred that it has immense potential if used appropriately. Interventions involving digital games, tutoring software, augmented reality (AR) and online writing platforms have demonstrated varying levels of success. Atoyebi & Atoyebi

(2022) and Benavides-Varela et al. (2020) have highlighted the role of technology in improving engagement and accessibility. Chen (2019) has further discussed the role of immersive technologies – such as AR – in reducing math-anxiety in learners, leading to better performance in abstract domains like algebra and geometry.

On the other hand, studies such as those by Passolunghi et al. (2020) caution that improvements in cognitive domains do not always result in reduced math anxiety. This suggests that strategies that focus on the emotional needs of learners are essential and not just a complementary feature.

Furthermore, findings also reveal that even though online platforms for mathematics learning increase accessibility, they may tend to increase stress and anxiety as they can cause difficulties in understanding of concepts (Alam & Dubé, 2023; Herman et al., 2023). These further stresses the need for the development and implementation of a framework that addressed the emotional aspect of mathematics learning.

5.2 Cognitive and Emotional Approaches

The synthesis of relevant literature demonstrates that strategies that directly focus on affective components such as expressive writing (Ramirez et al., 2018) can lead to improved academic performance. These interventions assist students in regulating and reframing their emotional responses to mathematics, resulting in reduction of avoidance behaviors. Teacher modeling of mathematical problems and placing less emphasis on time also leads to reduced stress and anxiety levels.

The role of the teacher has been consistently identified as being critical throughout literature, as a model as well as an agent of emotional support. For example, Beilock & Maloney (2015) and Barroso et al. (2021) claim that developing early positive math experiences are preventive strategies that can curb the development of math anxiety from a young age.

Chen (2019) investigated the role of game-based learning in mathematics. The study reveals that this approach can be effective in reducing anxiety levels as game-based learning improves motivation and reduces anxiety. The game-based learning approach addresses the cognitive aspect of mathematics learning in an environment where students feel less threatened. However, it should be noted that these environments may not be available to students during standardized assessments, leading to heightened anxiety levels. This further strengthens our notion that we need to utilize technology in a way that would help students regulate emotions in all circumstances.

5.3 Assessment Tools and Meta-Insights

The Abbreviated Math Anxiety Scale (AMAS) (Hopko et al., 2003) serves as a valid tool for evaluating the results of interventions. Studies and meta-analyses (Dowker, Sarkar & Looi, 2016; Barroso et al., 2021) show strong evidence that math anxiety negatively affects performance which highlights the need for timely and individual support strategies.

5.4 Emotion-Aware and Conversational Tools

Studies utilizing emotion-aware technologies were reviewed as well. Findings provided insights into how contactless multimodal emotional recognition can be used to potentially tackle math anxiety. This is substantiated by research that reveals that facial expression recognition is a popular choice for determining behavior cues. This can be complemented by the inclusion of body gestures, audio features, textual analysis, and even contactless physiological signals which enhance emotion recognition capabilities by providing additional, contextually rich data (Khan et.al, 2023).

5.5 Mindfulness and Socio-Emotional Interventions

Literature reveals that mindfulness tools such as Headspace integrations tend to reduce avoidance behavior in math classes. However, they require teacher reinforcement and interaction to sustain impact (Jansen & Lee, 2019).

5.6 Proposed Framework: Digital Dialogue for Anxiety Reduction (DDAR)

The DDAR Framework proposes that emotion-aware and conversational technologies can be instrumental in reducing math anxiety by creating personalized, empathetic, and engaging learning environments. It integrates affective computing, gamification, and teacher facilitation for a holistic approach to emotional well-being in digital learning. Table 3 reflects the key components of the proposed DDAR framework.

Table 3. Key Components of the DDAR Framework

Feature	Description & Purpose
Emotion-aware system	Provide real-time detection of anxiety, confusion, and frustration using facial recognition, voice tone, or input behavior such as the use of the keyboard to enter responses. Provides adaptive responses such as calming prompts, encouragement, or content simplification.
Conversational agents (e.g. chatbots)	Conversational dialogue that simulates teacher responses or peer to peer learning. Ensures emotional well-being and encourages students to articulate challenges.
Gamification	Encourages intrinsic motivation through gamification elements. Reduces performance anxiety and builds confidence through gradual scaffolding.
Mindfulness Tools and Socio-Emotional Learning	Embedded exercises for breathing, reflection, and emotional regulation when hesitancy is detected. Helps students self-identify stress triggers and assist them in building coping mechanisms
Teacher Training & Curriculum Requirements	Teachers are trained to use these tools in blended classrooms. Aligns tech tools with socio-emotional learning (SEL) goals and curriculum needs.

A conceptual flow reflecting an integration of the features is shown in Figure 1.

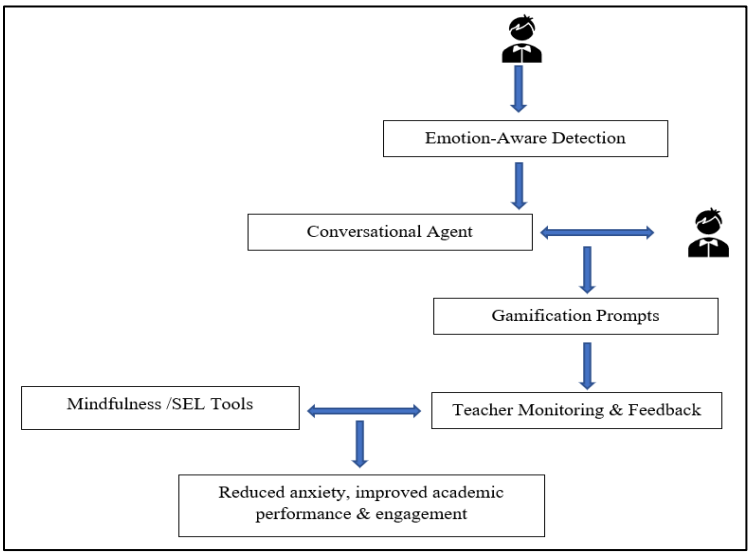

Figure 1. Conceptual Flow of the DDAR Framework

The flow begins by facilitating the student to start interacting with a mathematics learning platform embedded with emotion-detection capabilities. Using AI powered tools, such as facial expression and voice tone analysis and keyboard behavior, the emotion-detection system identifies signs of anxiety, frustration, confusion or confidence. For example, if a student consistently displays self-correction patterns or signs of hesitancy, the system detects it and flags it as possible distress. The conversational agent – a chatbot – then initiates

a supportive conversation. For example, it might suggest taking deep breaths and then to try to attempt the problem again. The purpose of the conversational agent is to simulate empathetic teacher responses and peer-to-peer interaction to potentially reduce the chances of feeling isolated and the fear of failure, which may lead to an increase in anxiety levels. Gamification elements are introduced at the next level. These would include badges, points, level progression. Socio-emotional prompts, allowing students to complete a mindfulness task would appear next, guided by teacher intervention when necessary. The teacher, at this point, receives alerts about the learners' emotional states while attempting certain questions as well as their engagement patterns. This can also help them to adjust or plan their future lessons accordingly. This would be facilitated with the help of a real-time dashboard. As the system is conceived to adapt to learner's patterns – both emotional and performance based - the potential outcome of this framework would be to help students feel more confident and to become more persistent leading to reduction in anxiety and overall improvement in academics and approach towards mathematics learning.

The suggested framework is theoretically grounded in Affective Computing (Picard, 1997) and utilizes the concept of Vygotsky's Zone of Proximal Development. This achieved by providing the required emotional scaffolding, which may potentially help students to achieve better results.

It must be highlighted that whereas emotion-aware tools offer the desired personalized support to the issue at hand, they may also raise substantial ethical questions regarding data privacy, informed consent, and algorithmic bias, which must be taken into consideration when implementing the framework.

6. CONCLUSION AND IMPLICATIONS

Literature synthesis emphasizes the transformative potential of digital tools and provides guidance for further research in exploring tools grounded in emotion-aware and conversational technologies. The DDAR framework has been proposed keeping in view the potential of the tools not yet been explored to their full potential. It utilizes evolving research on affective computing and gamified approach to learning, offering a structured approach to digital dialogue that would potentially reduce math anxiety, thereby improving student academic performance.

Current research findings reveal the power of gamification. However, it is to be noted that gamification combined with emotion-detection systems would potentially offer a more responsive system which would cater to the gaps in current research. Nevertheless, it is essential to equip educators with the pedagogical knowledge to appropriately implement these technologies. Hence, teacher training has been highlighted as an essential feature of the framework.

Furthermore, the ethical scope of emotional data use must be taken into consideration to ensure responsible data practices. It

should also be noted that future research in this area must adopt address longitudinal approaches and explore the results of the implementation of the DDAR framework in diverse educational contexts, thereby leading to the refinement of the framework. It is expected that a well-designed and properly integrated emotional and conversational ecosystem could mark an important shift in supporting learning in this era of technology.

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