BREAKING THE CYCLE: ADDRESSING MATHEMATICS ANXIETY IN EDUCATION WITH GAME-BASED LEARNING

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1 INTRODUCTION

Mathematics anxiety (MA) is a widespread psychological phenomenon that significantly affects students' self-efficacy, confidence, cognitive performance, and attitude toward mathematics. It also has an effect to long-term engagement with STEM disciplines (Dowker et al., 2016). Defined as a feeling of tension, apprehension or fear that interferes with math-related performance, MA can emerge early in childhood and persist into adulthood, leading to avoidance behaviors and a self-perpetuating cycle of poor performance and increased anxiety (Aschcraft 2002; Carey et al., 2017).

Based on prior research, it is well-established that around 20–30% of students experience significant levels of math anxiety, which can negatively impact their academic performance and future career opportunities in math-related fields. (Barroso et al., 2021). Despite its

significant impact on academic and professional outcomes, MA remains an under-addressed issue in elementary and middle school education. Traditional pedagogical approaches often fail to recognize and mitigate the emotional barriers that students face, leaving many without the necessary support (Sanders et al., 2020).

The MathifyMe project (Erasmus+) aims to tackle this challenge by raising awareness and providing innovative solutions to help students and educators manage and overcome MA effectively. This project proposes a game-based learning approach to address MA by making mathematics learning more engaging, motivating, and personalized. The digital game will be designed to adapt to individual learning preferences and cognitive needs using learning analytics, ensuring that each student receives tailored support. Furthermore, it will offer a customizable interface for teachers to adjust content to meet specific classroom requirements, fostering an inclusive educational environment. Importantly, MathifyMe provides a safe, supportive, and interactive space for students to practice mathematical concepts in which they can safely experience failure and overcome their fear of failure. Unlike traditional educational games, MathifyMe integrates mental well-being strategies alongside STEM content, enabling students to develop cognitive and emotional resilience when facing math-related challenges.

Another key aspect of the MathifyMe project is the teachers' professional development, especially from the MA perspective. Increasing the knowledge and skills of math teachers is one of the objectives of teacher professional development in the countries involved. Recognising and positively influencing mathematical anxiety and using the game to be developed in a variety of ways are the objectives set for teacher professional development.

This article provides an overview of the MathifyMe project, its goals, the methodology behind the needs analysis conducted across five participating countries (Finland, Croatia, Portugal, the Netherlands, and Malta), and the expected impact on students, teachers, and other stakeholders.

2 UNDERSTANDING MATHEMATICS ANXIETY (MA)

The effects on MA can be far-reaching, often resulting in avoidance of mathematics courses and activities, which can limit their educational and career opportunities in an increasingly STEM-focused job market (Beilock & Willingham, 2019). Students with high levels of math anxiety often struggle with confidence in mathematics, making it crucial to address math anxiety early to foster a positive attitude and improve overall student self-assurance. Interventions that focus on the emotional aspects of learning, such as the MathifyMe project, are essential for supporting students in managing math anxiety and improving educational outcomes.

One significant contributor to MA is negative past experiences with mathematics. Adverse experiences in early mathematics education – such as receiving low grades, experiencing failure, or receiving negative feedback – can lead to the development of MA (Carey et al., 2017; Dowker et al., 2020). These experiences create a psychological association between mathematics and distress, which can persist and influence future mathematical endeavors.

Societal and cultural perceptions of mathematical ability also play a critical role in the manifestation of MA. Societal narratives often frame mathematics as an inherently difficult subject, contributing to the belief that proficiency in mathematics is a rare skill possessed by only a select few (Gunderson et al., 2018). Such cultural perceptions can exacerbate feelings of inadequacy among students, particularly those who do not conform to the stereotype of a "mathematically gifted" individual.

Additionally, gender-related biases significantly influence the experiences of students in mathematics education. Research indicates that societal beliefs regarding gender roles can lead to differential experiences in mathematics. For instance, girls may internalize the stereotype that boys are naturally better at mathematics, which can diminish their confidence and increase anxiety. This internalized bias may result in reduced participation in math-related activities, ultimately contributing to the underrepresentation of women in STEM fields (Lavy & Megalokonomou, 2019).

Teaching methods that fail to accommodate diverse individual learning preferences further exacerbate MA. Traditional pedagogical approaches often employ methods that prioritize rote memorization and standardized testing. Such approaches may not adequately address the diverse learning styles present within a classroom, leaving some students feeling alienated and overwhelmed. A lack of differentiation in teaching strategies can compound MA, as students may struggle to engage with mathematical content in a manner that resonates with their individual learning preferences.

Addressing MA at an early stage is imperative for cultivating a positive disposition toward mathematics and enhancing students' confidence. Interventions that target the emotional dimensions of learning – such as the implementation of supportive teaching practices, the incorporation of mental well-being strategies, and the use of innovative educational pedagogies like game-based learning – can mitigate the adverse effects of MA. By recognizing and addressing the multifaceted nature of MA, including the influence of gender-related issues, educational stakeholders can foster an environment conducive to positive mathematical engagement and success.

3 FOUNDATIONS FOR GAME DEVELOPMENT AND TEACHER TRAINING

To ensure that the MathifyMe approach and solution is grounded in real educational challenges, the project is conducting a cross-national needs analysis to identify contextual factors contributing to MA and assess the gaps in teacher training and available resources. A comprehensive needs analysis will be conducted across five partner countries: Finland, Croatia, Portugal, the Netherlands, and Malta. The purpose of this analysis is to identify key triggers of math anxiety in students, existing teaching strategies used to address math anxiety, and gaps in teacher training and available resources.

In the needs analysis a mixed-methods approach is used to collect data. The first steps of the needs analysis are based on a literature review and an analysis of the mathematics curricula of the five participating

countries. The literature review will be conducted within the possibilities of an Erasmus + project in a mixed-method style, using supporting tools such as AI-based tools. The main objective is to identify the most relevant issues and practices from a game development and teacher professional development perspective.

A curriculum analysis will be carried out to evaluate the alignment between educational frameworks and the needs of students experiencing math anxiety. The curriculum analysis will be carried out as a comparison, with the aim of identifying similarities and differences in the cornerstones of mathematics education in different countries. This will not only help us to know what kind of game is suitable for each of the five participating countries, but also what needs to be considered in order to use and learn from the game successfully in each of the five countries and in the different school classes.

The study will involve a diverse group of stakeholders. A total of 50 teachers are participating, providing insights into classroom challenges and instructional approaches. Additionally, a minimum of 100 students will share their first-hand experiences of math anxiety, while 20 parents and guardians will contribute their perspectives on home support and expectations.

Questionnaires for teachers, students and parents/guardians are conducted to gather quantitative information on perceptions, attitudes, and experiences related to math anxiety. In addition to this, interviews and focus groups with teachers will provide deeper insights into effective teaching methods and the challenges they face.

4 THE MATHIFYME SOLUTION

The MathifyMe project introduces a game-based learning approach designed to support children with mathematics difficulties and math anxiety. The game developed in the project creates an engaging and personalized learning experience by adapting to individual learning styles and cognitive needs. Through the use of learning analytics, the game dynamically adjusts content difficulty, feedback mechanisms,

and pacing based on students' engagement levels. This personalized approach ensures that each learner progresses at a comfortable and motivating pace.

4.1 Game development

By providing a safe and low-stakes environment, MathifyMe helps reduce the fear of failure – one of the primary contributors to math anxiety (Carey et al., 2017). The game fosters a positive learning atmosphere where students can practice mathematical concepts, build confidence, and develop problem-solving skills without pressure.

In the first stage of the development of the game, we will set up a document containing the game requirements, objectives, genre, storyline and main features. Initial requirements include being customisable as this allows teachers to input different types of maths activities/exercises embedded in the gameplay. The game will also include learning analytics, allowing teachers to get information about the students' performance and carry out formative or even summative assessment. In addition, the game should meet other specific requirements arising from the need analyses with students, teachers and parents as defined in the methodology section.

In the second stage the game will be co-created, tested and improved through iterative design cycles. During this process resources will be developed to support primary/middle school teachers adopting the MathifyMe game and facilitate the implementation of the game in schools.

In the final stage the game will be open to external testing within the schools associated to the project. A MathifyMe Implementation Video-Guide, containing a set of videos with guidelines to implement the game in the classroom and the MathifyMe game will be online available.

4.2 Teacher training

A key feature of MathifyMe is its customizable teacher interface, which allows educators to tailor game content to align with specific classroom needs and instructional objectives. This flexibility ensures that the game

serves as a supplementary educational tool rather than a one-size-fits-all intervention, making it relevant for various learning contexts.

A defining innovation of the MathifyMe project is its holistic integration of mental well-being, STEM education, and game-based learning. Unlike traditional math games that focus solely on skill acquisition, MathifyMe incorporates evidence-based strategies to enhance both cognitive and emotional resilience. The game includes interactive challenges, real-time adaptive feedback, and relaxation techniques to help students manage anxiety while engaging with mathematical content. Through this approach, MathifyMe not only strengthens mathematical skills but also empowers students to develop a positive mindset toward learning, making mathematics more accessible and enjoyable for all learners.

Another big aspect of the MathifyMe project is the teachers' professional development, especially from the MA perspective. Actions to identify math anxiety could be part of every maths teacher's toolkit. Actions to identify math anxiety could be part of every maths teacher's toolkit. At the same time, it would be useful for teachers to identify in their own practice the risk factors that can negatively affect students' attitudes towards learning mathematics, but also good practices that can positively influence students' motivation and enthusiasm for learning mathematics.

5 EXPECTED OUTCOMES AND CONCLUSION

The MathifyMe project aims to provide an innovative, evidence-based solution to address mathematics anxiety (MA) by integrating game-based learning with mental well-being strategies. By creating a personalized, adaptive, and engaging digital environment, the game is expected to significantly reduce students' fear of failure, enhance their confidence in mathematical abilities, and foster a more positive attitude toward learning.

One of the primary expected outcomes is an increase in student engagement and motivation in mathematics. The game's adaptive learning analytics will ensure that content difficulty and pacing are tailored to individual needs, allowing students to experience a sense of progress and mastery. This approach is expected "to break the cycle", in

other words, to disrupt the pattern of avoidance and anxiety, which is often linked to mathematics, encouraging students to approach mathematical challenges with greater resilience.

Additionally, MathifyMe game's customizable teacher interface will provide educators with a valuable tool for differentiating instruction and aligning game content with specific classroom objectives. By incorporating the game as a supplementary instructional resource, teachers will be better equipped to address diverse learning needs and integrate more student-centered teaching approaches. The insights gained from the game's analytics can further support educators in identifying students who may require additional interventions.

Through teachers' professional development, the project will provide teachers with new tools to identify and manage maths anxiety. The TPD trainings with teachers focus on how teachers can identify and positively influence students' mathematics anxiety to improve their motivation and enthusiasm to learn mathematics. At the same time, the trainings will provide a practical introduction to using the MathifyMe game with different types of students and how teachers can create a wide variety of learning tasks based on the individual needs of the students.

Beyond its impact on students and teachers, the project is expected to contribute to the broader field of STEM education by demonstrating how holistic, technology-enhanced learning can address emotional barriers to academic success. By integrating mental well-being strategies with mathematical skill development, MathifyMe offers a comprehensive and scalable approach to improving learning outcomes.

In conclusion, the MathifyMe project represents a significant step forward in addressing mathematics anxiety in education. By leveraging the potential of game-based learning and personalized adaptive technologies, the project aims to transform the way mathematics is taught and experienced, ensuring that students not only develop mathematical competencies but also build the confidence and emotional resilience necessary for long-term success in STEM disciplines. The findings from this initiative will contribute to ongoing discussions on the role of educational technology in reducing learning-related anxieties and fostering inclusive, engaging, and effective mathematics education.

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REFERENCES

Ashcraft, M. H. (2002). Math anxiety: Personal, educational, and cognitive consequences. *Current Directions in Psychological Science, 11*(5), 181–185.

Barroso, C., Ganley, C. M., McGraw, A. L., Geer, E. A., Hart, S. A., & Daucourt, M. C. (2021). A meta-analysis of the relation between math anxiety and math achievement. *Psychological Bulletin, 147*(2), 134–168. https://doi.org/10.1037/bul0000307

Beilock, S. L., & Willingham, D. T. (2014). Math anxiety: Can teachers help students reduce it? *American Educator, 38*(2), 28–32.

Beilock, S. L., & Willingham, D. T. (2019). Math anxiety: Can teachers help students reduce it? *American Educator, 43*(2), 28–33.

Carey, E., Hill, F., Devine, A., & Szucs, D. (2017). The relationship between mathematics anxiety and performance: A meta-analysis. *Psychological Bulletin, 143*(6), 696–727. https://doi.org/10.1037/bul0000091

Dowker, A., Sarkar, A., & Looi, C. Y. (2020). Mathematics anxiety: What works? *Frontiers in Psychology, 11*, 1088. https://doi.org/10.3389/fpsyg.2020.01088

Else-Quest, N. M., Hyde, J. S., & Linn, M. C. (2010). Cross-national patterns of gender differences in mathematics: A meta-analysis. *Psychological Bulletin, 136*(1), 103–127. https://doi.org/10.1037/a0018053

Gunderson, E. A., Ramirez, G., & Beilock, S. L. (2018). The role of parents in the development of children's math anxiety. *Journal of Developmental Psychology, 54*(4), 655–661. https://doi.org/10.1037/dev0000462

Lavy, V., & Megalokonomou, R. (2019). *Persistency in teachers' grading bias and effects on longer-term outcomes: University admissions exams and choice of field of study* (NBER Working Paper w26021). https://doi.org/10.3386/W26021

Ramirez, G., & Beilock, S. L. (2011). Writing about testing worries improves exam performance in the classroom. *Science, 331*(6014), 211–213. https://doi.org/10.1126/science.1199427

Sanders, M. T., Bierman, K. L., Heinrichs, B. S. (2020). Longitudinal associations linking elementary and middle school contexts with student aggression in early adolescence. *Journal of Abnormal Child Psychology, 48*(12),1569–1580. doi: 10.1007/s10802-020-00697-6.