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Mitigating math anxiety and improving math achievement in K-12 students: an extended literature review

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Abstract. Mathematics anxiety is a widespread issue among K-12 students, often impairing their mathematical performance and long-term academic development. This study aims to explore the inverse relationship between math anxiety and achievement, drawing on nearly a decade of global research. Using thematic analysis and an interpretivist approach, the study reviews key internal factors such as self-efficacy and cognitive load, as well as external influences including parents, teachers, and educational policies. The findings reveal a consistent negative correlation between math anxiety and achievement across diverse cultural contexts. Moreover, countries with supportive educational environments, particularly in parts of Europe, report relatively lower levels of student math anxiety. Based on these insights, the study outlines targeted strategies to alleviate math anxiety, including parental support reforms, teacher training, and policy adjustments. It also discusses the feasibility of adapting successful international approaches to the Chinese educational context. These findings offer practical guidance for educators and policymakers aiming to reduce math anxiety and improve math outcomes in K-12 education systems worldwide.

Keywords: mathematics anxiety, math achievement, K-12 education

1. Introduction

Mathematics is a core component of the K-12 curriculum and is widely regarded as essential for students' future academic and career success [1]. The OECD has identified mathematical literacy as a fundamental competency for students globally, prompting educational systems to focus on enhancing mathematics proficiency [2]. However, many students experience negative emotional responses such as tension, fear, and anxiety during math learning, a phenomenon referred to as mathematics anxiety. This anxiety can manifest in classroom participation, homework completion, and performance on assessments, ultimately affecting students' math achievement [3].

Math achievement is often quantified using students' test scores [4]. Consequently, examining the relationship between math anxiety and achievement holds theoretical and practical significance. Understanding the underlying causes of math anxiety could inform effective interventions and instructional strategies that enhance both emotional well-being and academic outcomes.

Despite growing interest in this area, prior research lacks a systematic and comparative perspective across cultures and educational systems. This thesis aims to address this gap by exploring whether the correlation between math anxiety and math achievement among K-12 students is universally applicable or context-dependent. It adopts a global comparative lens, categorizing the factors influencing anxiety into internal and external domains. The theoretical framework draws on Bandura's (1977) self-efficacy theory and Sweller's (1988) cognitive load theory to interpret internal factors affecting learners [5,6].

The overarching aim of this thesis is to identify key contributors to math anxiety, evaluate strategies for alleviating it, and examine their potential to improve students' mathematical outcomes. This study also explores the transferability of successful strategies across different educational contexts, with implications for practice and policy. The findings aim to provide educators and policymakers with evidence-based recommendations to support K-12 students in reducing anxiety and enhancing mathematical competence.

To guide this inquiry, the following research questions are proposed:

How are the terms "math anxiety" and "math achievement" defined?

What is the relationship between math anxiety and math achievement in K-12 students?

What factors influence math anxiety in K-12 students, and how can targeted strategies mitigate its impact and improve math achievement?

2. Methodology

2.1. Research method and paradigm

This study is an extended literature review based on subject analysis of secondary data. According to Clarke and Braun (2017), topical analysis allows for systematic identification and analysis of data and a flexible summary of the characteristics and implications of secondary literature [7]. This study explores correlations between math anxiety and achievement, the influence of different anxiety types, and mitigation strategies. These features are coded and grouped into themes such as intrinsic and extrinsic factors, and analysed to draw conclusions.

The research adopts an interpretivist epistemological stance to understand phenomena related to math anxiety and achievement. Interpretivism focuses on understanding human experiences [8], allowing for in-depth interpretation of the data and its implications. This approach values the subjective experience of learners and supports analysing internal factors from students' perspectives. It helps summarise influencing factors from different angles and identify effective strategies to alleviate anxiety.

2.2. Literature search procedures

As shown in Table 1, three databases were used: Google Scholar, Scopus, and the University of Glasgow Library. Studies from the last decade were selected to ensure timeliness and reduce outdated information. The focus was on diverse countries and regions to explore the global relevance of the relationship between math anxiety and achievement. Boolean searches were conducted using keywords such as “math anxiety”, “math achievement”, and “K-12”.

Table 1. Search procedures performed in databases

Database	Search string	Additional information
Google Scholar	("mathematic anxiety" OR "math anxiety" OR "mathematic learning anxiety") AND ("math achievement" OR "mathematic achievement") AND ("k-12" OR "primary and secondary school" OR "high school" OR "teen") Filter used: 2014-2024	-search in the field "Title", "abstract" or "author-specified keywords" -search in all publication dates -77 initial results
Scopus	("mathematic anxiety" OR "math anxiety" OR "mathematic learning anxiety") AND ("math achievement" OR "mathematic achievement") AND ("k-12" OR "primary and secondary school" OR "high school" OR "teen") Filter used: 2014-2024	-search in all fields -search in all publication dates -1233 initial results
University of Glasgow Library	("mathematic anxiety" OR "math anxiety" OR "mathematic learning anxiety") AND ("math achievement" OR "mathematic achievement") AND ("k-12" OR "primary and secondary school" OR "high school" OR "teen") Filter used: 2014-2024	-search in all fields -search in all publication dates -948 initial results

Search strings combined variations of math anxiety, achievement, and K-12-related terms.

The results were screened for eligibility and quality using inclusion/exclusion criteria, as shown in Table 2:

Table 2. Inclusive and exclusive Criteria

Inclusion criteria	Exclusion criteria
Topic involving math anxiety and math achievement	Not involving math anxiety or math achievement
The participants were k-12 or primary or secondary school or high school students	For preschool children, special education, college students, teachers and other adult learners
Peer reviewed	Without peer review
Written in English	Written in other languages

Only peer-reviewed journal articles, meta-analyses, or literature reviews were included. Studies refuted by newer research were excluded to improve reliability. Ultimately, 20 papers were selected.

2.3. Coding process

After selecting the 20 studies, thematic analysis was used to code their content. The first step involved identifying the correlation coefficients reported between math anxiety and achievement. Then, factors contributing to anxiety were coded, including self-efficacy, cognitive load, parental and teacher influence, and policy context. Similarly, mitigation strategies mentioned in each article were also coded.

Codes were grouped into broader themes reflecting different influences, such as intrinsic (e.g., self-efficacy, cognitive load) and extrinsic factors (e.g., parents, teachers, policy). These themes were then reviewed and refined to ensure accurate representation of the literature's core content. The thematic structure helps unpack the complex relationship between math anxiety and achievement and points toward targeted strategies to reduce anxiety and support student progress.

2.4. Ethical considerations

This study adheres strictly to ethical principles. All 20 selected papers are peer-reviewed and publicly published, ensuring the legitimacy of data sources. Academic integrity was maintained throughout the analysis, avoiding plagiarism or data distortion. The researchers remained objective and neutral, ensuring no personal bias influenced the analysis or conclusions. These practices strengthen the credibility and ethical soundness of the study.

Overall, this thesis has adopted a thematic analysis approach to discuss the relationship between math anxiety and math achievement in K-12 students, as well as to analyse the relevant influencing factors and strategies. In this chapter, the quality of the literature is assessed by designing literature search and screening procedures to ensure transparency and integrity of the research. In this study, high quality studies related to mathematics anxiety and achievement were identified and synthesised, and literature that exceeded the target number of studies and did not meet quality criteria was eliminated through precise screening criteria, resulting in a final selection of 20 studies directly related to the research question. The literature review section, which leads into the next chapter, outlines the meaning of the terms mathematics anxiety and mathematics achievement and explores the relevance of mathematics anxiety and achievement for K-12 students in countries and regions around the world.

3. Math anxiety and academic achievement in K-12 students

3.1. The significant of mathematics and its global evaluation

Mathematics plays a foundational role in K-12 education worldwide, especially within STEM disciplines, supporting students' logical reasoning, problem-solving, and future academic and career pathways [1]. Strengthening math proficiency also helps develop sustainability awareness and life-relevant skills [9]. Education systems across the globe prioritize refining K-12 math curricula to foster these outcomes.

Math achievement is commonly evaluated using standardized tests, international assessments, and math competitions. Standardized exams such as China's Gaokao, A-levels, the International Baccalaureate (IB), and AP tests assess math proficiency and guide educational decisions. Comparative assessments like PISA and TIMSS offer cross-national insights and inform educational policies. Competitions like the International Mathematical Olympiad (IMO) also identify talent and motivate student interest.

This thesis emphasizes standardized test data for its objectivity. For instance, PISA consistently shows East Asian regions (e.g., Singapore, Japan, China) scoring above global averages, while many Western countries aim to close achievement gaps. Despite these efforts, psychological barriers—particularly math anxiety—continue to hinder student performance [1]. Thus, understanding the importance of mathematics and how it is assessed globally provides essential context for exploring the role of anxiety in student achievement, as discussed in the following sections.

3.2. Anxiety measurement and typology

Anxiety is a persistent emotional state marked by worry, fear, and tension, which can interfere with learning and academic performance [10]. Commonly used tools to measure anxiety include the State-Trait Anxiety Inventory (STAI), the Beck Anxiety Inventory (BAI), and the Hospital Anxiety and Depression Scale (HADS-A), among which the STAI is most suitable for K-12 populations. It contains two subscales assessing state anxiety (temporary, situational) and trait anxiety (a stable predisposition), both via self-report [10].

State anxiety refers to short-term emotional responses triggered by specific stressors like tests or public speaking, often accompanied by restlessness and nervousness. Trait anxiety reflects a long-term tendency to feel anxious across various situations and is considered a personality trait that may impair cognitive function and memory.

Although STAI distinguishes between state and trait anxiety, some researchers argue anxiety is multidimensional, requiring context-specific analysis [11]. Particularly in educational research, it's useful to analyze anxiety in relation to specific subjects

like mathematics.

Studies exploring the relationship between trait anxiety and math anxiety yield mixed results. While some report weak positive correlations [12], others find no significant link, suggesting that math anxiety is a distinct phenomenon influenced by cognitive, emotional, and environmental factors [13].

This complexity highlights the need to examine math anxiety separately from general anxiety, especially given its strong relevance in academic settings. The next section will explore the characteristics, types, and measurements of math-specific anxiety.

3.3. Math anxiety

Math anxiety is defined as an emotional disturbance occurring during math-related tasks, which interferes with cognitive processing and academic performance [14]. Unlike general test anxiety, math anxiety is domain-specific and has distinct effects on learners [15]. It can impact not only math performance but also broader academic choices and future engagement in STEM fields. Scholars typically categorize it into two forms: anxiety during learning and anxiety during evaluation [16].

Two common tools are used to assess math anxiety in K-12 students: the Math Anxiety Rating Scale (MARS) and the Abbreviated Math Anxiety Scale (AMAS). MARS, originally comprising 98 items, offers detailed assessment but can be time-consuming. The AMAS, with just 9 items, is widely used for large-scale studies due to its efficiency and reliability [17,18]. It includes two subscales: one for learning anxiety and another for evaluation anxiety.

Learning-related math anxiety often arises during classroom activities or homework, triggered by unfamiliar concepts or difficult problems. It leads to reduced confidence, lower engagement, and in some cases, avoidance of math-related subjects or careers [3]. Evaluation-related anxiety appears in high-pressure settings like exams and quizzes, often accompanied by physical symptoms such as sweating or rapid heartbeat. Students experiencing this form of anxiety may fear failure or underperform due to stress, although not all perform poorly despite high anxiety [19].

Internationally, math anxiety varies widely across countries. East Asian, South American, and Middle Eastern students often report higher anxiety levels due to intense testing pressures [20]. In contrast, Scandinavian and Western European countries, which emphasize relaxed learning environments, tend to show lower anxiety levels. These differences underscore the role of educational culture and pedagogy in shaping students' emotional responses to math.

Age also plays a role: anxiety tends to increase with grade level. It remains low in primary school, escalates during early secondary years due to increased academic demands, and peaks around grades 9–10 [2,14]. Some students adapt over time, while others experience persistent stress, particularly in highly competitive academic environments.

These findings suggest that math anxiety is both a psychological and educational issue that develops over time and varies significantly across cultural and individual contexts. Understanding its dimensions lays the foundation for examining its impact on academic achievement, which is discussed in the next section.

3.4. The correlation between math anxiety and achievement

The negative correlation between math anxiety and achievement is well-documented. Across 19 studies in the past decade, most report moderate to strong negative correlations, typically ranging from -0.08 to -0.597 [4,21].

In Asian contexts, Al Mutawah (2015) found correlations of -0.30 to -0.50 among Bahraini students, and Mutlu (2019) reported -0.597 in Turkish primary students [22,23]. In China, Yu et al. (2024) observed -0.122 and -0.248 for fourth and eighth graders [24]. Despite this, East Asian students (e.g., Singapore, Japan, China) consistently rank highly in math achievement [20], suggesting a paradox where strong academic performance coexists with high anxiety. Still, within-country studies reveal average correlations around -0.32 [25], indicating a persistent individual-level burden.

European research highlights mediating factors. In Germany, teacher sensitivity was linked to reduced anxiety and better outcomes [26], while executive functioning [19], and self-concept [27] also played roles. Longitudinal studies in Poland found bidirectional effects [16], with similar findings in Italy [28].

In North America, research emphasizes cognitive mediators like working memory [29] and broader factors such as emotional environment [29]. Ramirez et al. (2018) offered an explanatory model, though some studies underexplored socio-environmental variables [30].

Cross-national data further supports this global pattern. PISA analyses show consistent negative correlations between math anxiety and performance in 15-year-olds (-0.23 to -0.32) [20], echoed by global meta-analyses [4,25].

Despite cultural variation, the detrimental impact of math anxiety is evident. Effective interventions include teacher training [26], emotional regulation [28], and self-concept enhancement [27], though their long-term and cross-cultural efficacy warrants further study.

4. Factors affecting math anxiety in K-12 students

4.1. Internal factors

Internal psychological mechanisms significantly contribute to students' mathematics anxiety, with self-efficacy and cognitive load being particularly prominent. Bandura's (1977) self-efficacy theory highlights the impact of individuals' beliefs in their capabilities on their actions and emotional responses [5]. Students with high self-efficacy are more likely to persist through challenging mathematical tasks, while those with low self-efficacy are prone to avoidance and anxiety. These students often view mathematical difficulties as threats rather than opportunities to grow, leading to reduced engagement and poorer performance.

Cognitive load theory further explains how mental processing demands can overwhelm students, especially when instructional design is suboptimal [6]. When mathematical content is presented in a fragmented or overly complex way, students may experience excessive cognitive load, impairing working memory and fostering anxiety [31]. This can be particularly problematic for students with underdeveloped mathematical schemas, who lack the cognitive structures needed to simplify and absorb new information.

To alleviate math anxiety rooted in low self-efficacy, several interventions have proven effective. Bandura (1997) suggests that self-efficacy can be enhanced through mastery experiences, social modeling, verbal encouragement, and emotional regulation. For example, small group tutoring allows students to achieve incremental successes in a supportive environment, gradually strengthening their self-perception of competence [28]. Teachers can also foster efficacy by setting achievable goals and providing constructive feedback, reinforcing students' belief in their capabilities.

Reducing cognitive load involves improving how information is presented. Worked examples and scaffolded instruction can ease mental effort, while reducing redundant or extraneous content supports memory retention [6]. Teachers trained to recognise signs of overload can adjust their instruction to maintain optimal cognitive engagement.

In summary, addressing self-efficacy and cognitive load through targeted teaching strategies and supportive learning environments may help reduce anxiety and improve outcomes in mathematics classrooms.

4.2. External factors

Students' math anxiety is significantly shaped by external influences such as parents, teachers, and educational policies. Parents with high levels of math anxiety may unknowingly transmit their fears during interactions like homework assistance, especially in early grades when children are most dependent on parental support [29]. In contrast, parents who demonstrate a calm attitude and avoid pressuring children for high achievement can create a supportive environment that fosters mathematical confidence [24]. Adjusting expectations to a moderate level and offering praise based on actual effort rather than performance has been shown to reduce anxiety and promote sustained motivation. Some interventions also suggest using structured digital tools at home to create low-pressure, engaging learning experiences [30].

Teachers play a similarly influential role. Supportive and emotionally attuned teachers can help students view mistakes as learning opportunities, reducing the fear associated with mathematics [15]. By contrast, harsh discipline, gender stereotypes, or unrealistic academic expectations can intensify anxiety and promote avoidance [21]. Teachers struggling with math anxiety themselves may transfer negative emotions to students, especially when relying on rigid, textbook-based instruction [20]. Training teachers to identify their own anxiety and offering professional development that enhances both content knowledge and emotional awareness can mitigate this cycle. Building an inclusive classroom climate—where encouragement, patience, and error tolerance are the norm—remains essential.

At the policy level, highly competitive educational systems and high-stakes assessments, particularly prevalent in East Asian contexts, are linked to increased anxiety among K-12 students [25]. In contrast, countries like Austria and Sweden have adopted flexible curricula and reduced testing pressure to support students' wellbeing alongside academic performance [15]. Policy reforms that incorporate insights from math anxiety research—such as diversifying assessment formats, encouraging home-school collaboration, and promoting early psychological support—may help establish a more balanced learning environment.

5. Mitigating K-12 math anxiety and improving math achievement: what China can learn from other countries

5.1. China's context

China's K-12 education is shaped by high-stakes exams such as Zhongkao and Gaokao, which create academic pressure and elevate math anxiety [32]. Parents and teachers often equate academic success with future stability, further increasing stress levels [24]. Urban students benefit from more resources, while rural students face greater anxiety due to limited support [33].

To address this, China introduced the "Double Reduction" policy to lessen homework and off-campus tutoring [34]. While it eased workloads for some, the absence of consistent support mechanisms led to mixed outcomes [35,36]. After-school services

were introduced to fill this gap, but varying quality has left many students still seeking external tutoring, often under new names like “thinking training”. The 2024 statement by the State Council suggests a potential softening of this policy.

5.2. International experiences and feasibility

European countries offer valuable practices. Sweden and Austria reformed their systems to include inclusive education, which provides psychological support and diversified assessments that reduce reliance on one-off exams [15,37]. In Sweden, digital math tests and project-based tasks help mitigate anxiety and provide a more holistic measure of learning [2]. While China’s exam-centric culture poses challenges, gradually diversifying assessments and building mental health support within schools is feasible [33].

Japan’s “relaxed education” (yutori kyoiku) once reduced content and pressure but led to concerns over declining academic ability and was revised [38]. Later reforms introduced balanced curriculum and peer support systems that helped ease math anxiety [39]. These approaches show that reducing academic burden, while fostering autonomy, may help students manage anxiety more effectively.

South Korea’s “No make-up class” policy banned cram schools to reduce pressure, but failed due to unchanged university entrance systems and persistent demand for tutoring. The underground tutoring market thrived, maintaining student anxiety [40]. This mirrors the limitations of China’s Double Reduction policy—without broader exam reform and systemic support, restrictive measures may have limited effect.

5.3. Integrated reflections

China can learn from Europe’s inclusive models by promoting assessment diversity and expanding in-school mental health services [33]. Regular mental health checks and trained counsellors could help students face math with more confidence.

Japan’s focus on student autonomy suggests that curriculum reform and encouraging cooperative learning could foster long-term academic growth and lower anxiety [41]. Meanwhile, Korea’s failure warns against relying solely on bans—China’s reforms need to consider exam restructuring and increased academic support within schools to gain social acceptance and effectiveness.

In the future, fostering home-school collaboration, expanding psychological support, and offering flexible, equitable evaluation methods may better address student anxiety. Though limited resources and large class sizes remain challenges, demographic shifts could make small-class teaching more attainable, enhancing individual attention and student wellbeing [33].

6. Conclusion

This thesis explored the relationship between math anxiety and academic performance in K-12 students from a cross-cultural perspective. By introducing refined measures such as the MARS and AMAS scales, it addressed limitations in general anxiety tools like the STAI, offering a more situational understanding of math anxiety [17]. The findings revealed a broadly negative correlation between anxiety and achievement across countries [4], suggesting the issue is both widespread and complex.

To analyse this complexity, the thesis categorised influencing factors as internal (e.g., self-efficacy, cognitive load) or external (e.g., parenting, teaching, policy), aiming to construct a comprehensive framework [26]. It also compared East Asian and European systems, showing how cultural and institutional differences shape anxiety and its consequences. European inclusive policies have shown potential in reducing anxiety, while exam-focused approaches in some East Asian contexts may exacerbate it [42]. These insights may inform future policy considerations in China and similar contexts.

However, the study did not fully examine how individual differences such as gender or socio-economic background influence anxiety. It also lacked empirical data and long-term evaluation of mitigation strategies, which may affect the reliability and applicability of the conclusions. Future research could address these gaps by collecting first-hand data, designing longitudinal studies, and evaluating the implementation challenges of proposed interventions.

Despite these constraints, the thesis offers a structured overview of the mechanisms and consequences of math anxiety and proposes adaptive strategies that consider global experiences. It contributes to the ongoing dialogue on improving educational practice and supporting student wellbeing in mathematics education.

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