IJOFE, 2025, 11 (3) 30-43 ISSN: 2149-3030

INTERNATIONAL JOURNAL OF FIELD EDUCATION

Mathematics Anxiety as a Reflection of Self-Regulatory Processes

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ABSTRACT

Mathematics anxiety has long been recognized as a barrier to mathematical performance and engagement. Yet, traditional perspectives have tended to isolate it as an emotional problem rather than viewing it as part of a broader system of learning regulation. This paper reconceptualizes mathematics anxiety as a reflection of self-regulatory processes, emphasizing its dynamic relationships with self-efficacy, task persistence, and contextual influences. Drawing upon evidence from recent empirical and theoretical studies, the paper synthesizes how low perceived control, reduced metacognitive monitoring, and emotional dysregulation jointly sustain the anxiety–achievement cycle. Theoretical frameworks, such as self-efficacy theory, control–value theory, and processing efficiency theory, are integrated to explain the cognitive and motivational mechanisms underlying this phenomenon. In addition, research on classroom climate, technology-supported learning, and socio-emotional interventions is reviewed to show how contextual factors shape self-regulatory functioning. The discussion highlights the need for pedagogical approaches that cultivate metacognitive awareness, emotional regulation, and autonomy-supportive environments, as well as for research designs that capture the dynamic, reciprocal nature of these processes. Conceptualizing mathematics anxiety through the lens of self-regulation not only bridges emotion and cognition but also reframes anxiety as a diagnostic indicator of regulatory imbalance, offering a more comprehensive understanding of how learners can develop adaptive control, persistence, and confidence in mathematics learning.

Key Words: Mathematics anxiety, self-regulation, self-efficacy, emotional regulation, learning environments

ARTICLE INFO

Received: 12.10.2025
Published online: 31.11.2025

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Öz-Düzenleme Süreçlerinin Bir Yansıması Olarak Matematik Kaygısı

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ÖZET

Matematik kaygısı, uzun zamandır öğrencilerin matematik performansını ve derse yönelik katılımını olumsuz etkileyen bir unsur olarak görülmektedir. Ancak geleneksel yaklaşımlar bu olguyu çoğunlukla yalnızca duygusal bir sorun olarak ele almış, öğrenmenin öz-düzenleyici yapısı içindeki yerini yeterince dikkate almamıştır. Bu makale, matematik kaygısını öz-düzenleme süreçlerinin bir yansıması olarak yeniden kavramsallaştırmakta ve bu kavrayışın, öz-yeterlik, göreve bağlılık ve bağlamsal etkenlerle olan dinamik ilişkilerini vurgulamaktadır. Güncel kuramsal ve deneysel araştırmalardan yararlanılarak, düşük algılanan kontrol, azalmış üstbilişsel izleme ve duygusal düzensizliğin matematik kaygısı–başarı döngüsünü birlikte nasıl sürdürdüğü ortaya konulmuştur. Öz-yeterlik kuramı, kontrol-değer kuramı ve işlem verimliliği kuramı gibi temel kuramsal çerçeveler birleştirilerek bu olgunun bilişsel ve güdüsel mekanizmaları açıklanmıştır. Ayrıca, sınıf iklimi, teknoloji destekli öğrenme ve sosyo-duygusal müdahaleler üzerine yapılan araştırmalar, bağlamsal faktörlerin öz-düzenleyici işlevleri nasıl şekillendirdiğini göstermektedir. Tartışma bölümünde, üstbilişsel farkındalık, duygusal düzenleme ve özerklik destekleyici öğrenme ortamlarını geliştirmeye yönelik pedagojik yaklaşımların önemi vurgulanmaktadır. Matematik kaygısının öz-düzenleme perspektifinden ele alınması, duygu ve biliş arasındaki köprüyü güçlendirmekte ve kaygıyı bir başarısızlık göstergesi değil, öz-düzenleme dengesizliğinin tanısal bir göstergesi olarak yeniden konumlandırmaktadır. Bu yaklaşım, öğrencilerin matematik öğreniminde denetim, azim ve özgüven geliştirme yollarına daha bütüncül bir bakış sunmaktadır.

Anahtar Kelimeler: Matematik kaygısı, öz-düzenleme, öz-yeterlik, duygusal düzenleme, öğrenme ortamları

MAKALE BİLGİSİ

Alınma Tarihi:12.10.2025
Çevrimiçi yayınlanma tarihi: 31.11.2025

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Introduction

Mathematics anxiety has long been recognized as a complex emotional phenomenon that negatively affects learners' engagement and performance in mathematics. Traditionally, it has been studied as a dispositional fear or tension that interferes with numerical reasoning and problem solving (Ashcraft, 2002; Dowker et al., 2016). However, recent research suggests that mathematics anxiety cannot be fully understood as a mere emotional reaction; rather, it reflects a broader imbalance within learners' self-regulatory systems (Du et al., 2021; Lau et al., 2024; Pei et al., 2025). When students experience high anxiety, their beliefs about competence, motivation to persist, and ability to regulate cognitive and emotional processes tend to deteriorate. Consequently, mathematics anxiety should be conceptualized not only as an emotional barrier but as a manifestation of self-regulatory breakdown.

Historically, research on mathematics anxiety has evolved through several phases. Early work in the 1950s and 1960s emphasized the physiological and affective symptoms associated with math-related fear (Suárez-Pellicioni et al., 2016). The cognitive revolution of the 1980s and 1990s reframed anxiety as a factor interfering with working memory and attentional control (Ashcraft & Krause, 2007; Eysenck & Calvo, 1992). More recently, the focus has shifted toward understanding how motivational, cognitive, and emotional regulation processes interact in shaping students' mathematical experiences (Pekrun, 2006; Ramirez et al., 2018). This transition marks a paradigm shift: mathematics anxiety is no longer viewed merely as a symptom of poor performance, but as an indicator of disrupted self-regulation across cognitive and emotional dimensions.

A growing body of empirical evidence supports the view that mathematics anxiety functions as an indicator of disrupted self-regulation rather than a simple emotional reaction. Du et al. (2021) demonstrated reciprocal relations between mathematics interest, self-efficacy, anxiety, and achievement among secondary school students. Similarly, Pei et al. (2025) found that the influence of anxiety on mathematics performance was mediated by students' engagement, suggesting that anxiety undermines motivation and self-regulatory persistence rather than directly impairing competence. Longitudinal and meta-analytic studies (e.g., Namkung et al., 2019; Zhang et al., 2019) consistently reveal that self-efficacy and task persistence buffer the negative effects of anxiety, while low perceived control exacerbates it.

Despite these findings, most educational interventions still approach mathematics anxiety as an emotional symptom to be reduced, rather than a signal of regulatory imbalance to be addressed. This paper argues that such an understanding limits both theoretical insight and pedagogical effectiveness. By situating mathematics anxiety within self-regulation theory (Schunk & Ertmer, 2000; Zimmerman, 2000) and control–value theory (Pekrun, 2006), it becomes possible to explain how students' beliefs, goals, and emotional control strategies jointly shape their affective responses to mathematics. Moreover, the self-regulation perspective provides a bridge between individual and contextual factors. The classroom climate, teacher support, and technological learning environments can all strengthen or weaken students' regulatory capacities (Ersozlu, 2024; O'Hara et al., 2022; Wang & Wei, 2025). Understanding anxiety as a reflection of these interacting systems allows researchers and educators to move beyond reductionist explanations and toward more integrative models of learning and emotion.

Accordingly, this paper aims to reconceptualize mathematics anxiety as a reflection of self-regulatory processes. Drawing upon recent empirical and theoretical developments, it examines (a) the major theoretical frameworks linking anxiety and regulation, (b) reciprocal relations between mathematics anxiety, self-efficacy, and task persistence, (c) educational contexts that shape self-regulatory responses, and (d) the implications of this integrated view for future research and classroom practice.

Theoretical Perspectives on Mathematics Anxiety and Self-Regulation

Understanding mathematics anxiety through the lens of self-regulation requires a synthesis of theories that connect affective, cognitive, and motivational processes. Three frameworks are particularly relevant: Self-Efficacy Theory (Bandura, 1997), Control–Value Theory of Achievement Emotions (Pekrun, 2006), and Processing Efficiency Theory (Eysenck & Calvo, 1992). Together, these perspectives reveal that anxiety is not a static emotion but a dynamic outcome of how learners monitor, evaluate, and control their own learning processes.

According to Bandura's (1997) Self-Efficacy Theory, individuals' beliefs about their capacity to perform a task influence not only their performance but also their emotional experiences. Low self-efficacy in mathematics amplifies sensitivity to failure, leading to heightened anxiety and avoidance behavior (Pajares & Miller, 1994). Du et al. (2021) provided empirical evidence for this mechanism by showing reciprocal effects among self-efficacy, interest, anxiety, and achievement. Even minor fluctuations in perceived efficacy can significantly alter students' emotional responses and their capacity to self-regulate. Self-efficacy is also a key determinant of how students select, sustain, and monitor learning strategies (Schunk & Ertmer, 2000; Zimmerman, 2000). Within this framework, mathematics anxiety can be interpreted as a signal of self-regulatory breakdown: heightened anxiety reduces perceived control, which in turn further intensifies anxiety. This cyclical relationship is especially pronounced among students with lower achievement or fragile confidence (Lau et al., 2024; Pei et al., 2025).

Pekrun's (2006) Control–Value Theory extends this view by explaining how students' emotions emerge from their appraisals of control and value. When learners perceive low control over mathematical tasks and low personal value in success, negative emotions such as anxiety and hopelessness are likely to arise. These emotions, in turn, consume cognitive resources and narrow attention, thereby undermining self-regulation (Pekrun et al., 2017).

Smith et al. (2025) further demonstrated that decreases in mathematics confidence predict increases in anxiety over time, confirming the reciprocal nature of these processes.

At the cognitive level, Eysenck and Calvo's (1992) Processing Efficiency Theory offers a complementary explanation. It posits that anxiety depletes working memory and attentional control, leading to lower processing efficiency. Neuroimaging studies by Ashcraft and Krause (2007) and Suárez-Pellicioni et al. (2016) revealed that individuals with high mathematics anxiety exhibit increased amygdala activation and reduced prefrontal engagement during problem solving. This neural pattern suggests that emotional arousal interferes with cognitive control, disrupting self-regulation even at the neurophysiological level. These three frameworks collectively indicate that mathematics anxiety functions as both a cause and consequence of dysregulated learning. Bandura's emphasis on perceived competence aligns with Pekrun's focus on control and value, while Eysenck's cognitive model clarifies how emotional arousal constrains working memory. Recent empirical findings reinforce these interconnections: Pei et al. (2025) and Kilp-Kabel & Mädamürk (2025) showed that self-efficacy, expectancy–value beliefs, and task persistence mediate the relationship between anxiety and performance.

Beyond cognition and motivation, self-regulation also encompasses emotional regulation, the ability to monitor and modulate affective states during learning (Gross, 2014). Ramirez and Beilock (2011) demonstrated that even simple emotion-regulation strategies, such as expressive writing before exams, can significantly improve mathematics performance. Such findings underscore that anxiety cannot be detached from learning processes; instead, emotion regulation is a core component of academic self-regulation, particularly in cognitively demanding subjects like mathematics. In sum, self-efficacy, control appraisals, and emotion regulation jointly shape the development and maintenance of mathematics anxiety. Taken together, these frameworks suggest that mathematics anxiety represents an imbalance across cognitive resource management, motivational orientation, and emotional control, a systemic disruption that influences how learners engage with mathematical tasks. This theoretical foundation provides the basis for understanding the reciprocal empirical relationships explored in the following section.

Reciprocal Relations between Mathematics Anxiety, Self-Efficacy, and Task Persistence

The interplay between mathematics anxiety, self-efficacy, and self-regulation has become one of the most frequently examined areas in recent educational psychology research (e.g., Lau et al., 2024; Ramirez et al., 2018; Zuo et al., 2024). The relationship between these constructs is not unidirectional: mathematics anxiety can undermine self-efficacy, while low self-efficacy can, in turn, heighten anxiety, forming a reciprocal and self-reinforcing cycle (Namkung et al., 2019; Zhang et al., 2019). This cyclical relationship reflects the core assumptions of Bandura's social cognitive theory, in which self-efficacy both shapes and is shaped by emotional responses, and aligns with Pekrun's (2006) prediction that low perceived control fuels negative achievement emotions. Consequently, interventions targeting motivation and persistence are often as effective as those focusing directly on emotion regulation.

Du et al. (2021) provided one of the most comprehensive longitudinal examinations of this cycle. Using cross-lagged panel modeling with seventh-grade students, they showed that changes in mathematics anxiety, self-efficacy, interest, and achievement mutually predicted one another over time. Increases in self-efficacy reduced later anxiety, while higher anxiety predicted subsequent decreases in both efficacy and achievement. These dynamics illustrate the reciprocal mechanisms embedded in self-regulatory systems, consistent with theoretical models that conceptualize emotions as both antecedents and consequences of control beliefs.

Meta-analytic evidence further supports this bidirectional model. Zhang et al. (2019) synthesized 49 studies and found an average correlation of –0.36 between mathematics anxiety and achievement. However, this effect was substantially moderated by self-efficacy: students with stronger efficacy beliefs exhibited significantly weaker negative associations. Similarly, Namkung et al. (2019) reported that self-efficacy accounted for up to 40% of the indirect relationship between anxiety and achievement, emphasizing its role as a protective factor. Recent studies also corroborate this mediating mechanism. For example, Zuo et al. (2024) demonstrated that mathematics self-efficacy and anxiety jointly mediated the relationship between cognitive activation and achievement, offering further support for Bandura's assertion that efficacy beliefs regulate both affective responses and task engagement. Self-efficacy also determines students' levels of task persistence their willingness to continue working despite difficulty or failure. Kilp-Kabel and Mädamürk (2025) demonstrated that when expectancy–value beliefs and task commitment were high, the negative effects of anxiety on performance were markedly reduced. Students with strong self-regulatory skills maintained engagement even under stress, suggesting that self-efficacy functions as an emotional buffer that protects learning from anxiety-induced disruption. This pattern is also consistent with Processing Efficiency Theory, which posits that anxiety consumes cognitive resources unless counterbalanced by motivational or regulatory mechanisms.

A longitudinal study by Smith et al. (2025) confirmed these dynamics. Across three measurement points, decreases in students' mathematics confidence were predicted to lead to later increases in anxiety, while higher confidence levels were predicted to result in subsequent decreases. The findings suggest a regulatory mechanism through which efficacy beliefs influence emotional adaptation over time.

Pei et al. (2025) further showed that mathematics engagement mediates the relationship between anxiety and performance, revealing the motivational dimension of self-regulation. High anxiety reduced emotional and cognitive engagement, which in turn led to poorer achievement. Thus, mathematics anxiety impairs performance not only through cognitive interference but also by diminishing students' motivational investment. Thus, mathematics anxiety impairs performance not only through cognitive interference but also by diminishing students' motivational investment, an explanation consistent with both Control Value Theory and broader models of academic emotion.

Lau et al. (2024) extended this evidence cross-culturally using multilevel structural equation modeling. They found that the mediating role of self-efficacy between anxiety and achievement was consistent across both Eastern and Western samples. This suggests that, although the expression of anxiety may vary across cultures, the underlying self-regulatory mechanisms are largely universal. Across studies by Smith et al. (2025), Pei et al. (2025), and Kilp-Kabel & Mädamürk (2025), a consistent conclusion emerges: mathematics anxiety primarily affects achievement indirectly, through its impact on self-efficacy, engagement, and persistence. These processes align closely with theoretical models proposed by Bandura (1997) and Pekrun (2006), which suggest that emotional regulation and control beliefs jointly shape learning outcomes.

Recent bibliometric analyses also indicate that contemporary mathematics anxiety research increasingly integrates constructs such as self-efficacy, motivation, and engagement (Uğraş, 2025). This trend mirrors the reciprocal framework adopted in this study and reinforces the view that mathematics anxiety is a multidimensional phenomenon shaped by affective, cognitive, and motivational processes. Contextual studies have further refined this understanding. For example, Balt et al. (2022), O'Hara et al. (2022), and Shore and Kelleher (2024) found that teacher support, tolerance for mistakes, and formative feedback strengthen students' self-efficacy, thereby reducing anxiety. This highlights that self-efficacy is not solely an internal belief but also a reflection of perceived emotional safety within the learning environment. In summary, empirical evidence indicates that mathematics anxiety and self-efficacy form a dynamic, reciprocal system mediated by engagement and persistence. Anxiety depletes cognitive and motivational resources, whereas strong efficacy beliefs and regulatory strategies restore equilibrium. Within this framework, self-efficacy should be understood not merely as a predictor but as the central regulatory mechanism through which students maintain control over learning despite anxiety.

Educational Contexts That Shape Self-Regulatory Responses to Mathematics Anxiety

Mathematics anxiety does not arise in isolation; it develops within specific learning contexts that either support or undermine students' capacity for self-regulation. Classroom climate, instructional practices, peer dynamics, and the integration of technology all influence how learners experience and manage anxiety (O'Hara et al., 2022; Ersozlu, 2024). Understanding these contextual influences is essential to interpreting mathematics anxiety as a regulatory phenomenon rather than a purely emotional one.

Classroom Climate and Teacher–Student Interactions

The social and emotional climate of the classroom plays a central role in shaping students' self-regulatory responses to anxiety. Classrooms that encourage collaboration, autonomy, and tolerance for error enable students to adopt adaptive coping strategies. Conversely, highly evaluative or competitive environments tend to amplify self-doubt and avoidance behaviors (O'Hara et al., 2022). Teacher feedback is particularly influential. Supportive, process-oriented feedback strengthens self-efficacy by framing mistakes as opportunities for learning, while performance-oriented feedback tends to heighten anxiety and external locus of control (Balt et al., 2022). Empirical evidence from Shore and Kelleher (2024) indicates that early interventions emphasizing formative feedback and emotional coaching can prevent the escalation of mathematics anxiety in primary education. Moreover, group-based learning contexts can moderate emotional experiences. Mizuhara et al. (2025) developed a bounded confidence model showing that collaborative settings reduce mathematics anxiety when peer discussions are structured around mutual trust and respect. However, poorly managed group work can lead to social comparison and increased anxiety. Thus, peer regulation, the ability to co-monitor emotional and cognitive processes within a group, emerges as an essential but often overlooked component of self-regulation.

Technology-Supported Learning Environments

Recent research has examined how digital and AI-assisted tools influence students' affective and self-regulatory experiences in mathematics learning (e.g., Bray & Tangney, 2017; Cai et al., 2022; Lin et al., 2025). Ersozlu (2024) showed that technology-enhanced environments, when used to promote autonomy and mastery, can significantly reduce mathematics anxiety in primary school students. Interactive and adaptive learning systems provide immediate feedback and opportunities for self-paced learning, thereby enhancing perceived control. Wang and Wei (2025) found that generative AI-supported learning had mixed effects depending on students' initial levels of anxiety. For students with moderate anxiety, AI-based feedback enhanced confidence and engagement; for those with high anxiety, it increased dependency on external support, suggesting a compensatory but not necessarily regulatory effect. Chen et al. (2025) further argued that AI tools can either strengthen or weaken self-regulation depending on how they are embedded in instructional design. When learners rely on AI feedback without engaging in reflective thought, anxiety reduction may come at the cost of autonomy. These findings imply that the effectiveness of technology in managing mathematics anxiety depends on how it aligns with students' self-regulatory readiness. Digital environments that integrate metacognitive scaffolding, such as self-monitoring prompts or reflection opportunities, are more likely to enhance self-efficacy and persistence (Pei et al., 2025).

Socio-Emotional and Embodied Interventions

Beyond cognitive and technological approaches, emerging studies emphasize socio-emotional and embodied dimensions of regulation. Bellacicco et al. (2025) demonstrated that curriculum-based physical activity breaks reduce anxiety and enhance executive function, indirectly improving mathematics performance. These interventions activate self-regulatory processes through physiological regulation of arousal. Similarly, storytelling and narrative-based approaches have been shown to reduce affective barriers in mathematics learning (Irmayanti et al., 2025). By embedding mathematical concepts in meaningful contexts, storytelling enhances emotional engagement and cognitive flexibility, two critical components of adaptive self-regulation. Collectively, these findings converge on a single insight: mathematics anxiety is contextually co-regulated. Classroom relationships, technological supports, and socio-emotional climates all influence how students manage anxiety and maintain regulatory balance. The educational context thus serves as both the *medium* and the *modulator* of self-regulatory functioning in mathematics learning.

Implications and Future Directions

Reconceptualizing mathematics anxiety as a reflection of self-regulatory processes has far-reaching implications for how mathematics teaching, learning, and research are approached. Rather than considering anxiety as a purely emotional symptom, this view positions it as an indicator of imbalance within the learner's self-regulatory system where beliefs, motivation, attention, and emotion converge. By adopting this lens, educational practice can shift from focusing on short-term anxiety reduction to promoting the long-term development of self-regulatory competence, and research can move toward developing integrative models that capture the dynamic interplay between affect, cognition, and context.

Implications for Educational Practice

In classroom practice, addressing mathematics anxiety requires moving beyond surface-level coping strategies toward cultivating self-regulatory resilience, the capacity to sustain motivation and cognitive control despite discomfort or uncertainty. Teachers play a pivotal role in shaping students' regulatory habits through both explicit instruction and implicit classroom norms. A central pedagogical focus should be on strengthening self-efficacy and metacognitive awareness. As demonstrated by Schunk and Ertmer (2000) and Du et al. (2021), when students perceive themselves as capable of influencing outcomes through effort and strategy use, their anxiety decreases even in challenging situations. Teachers can support this through scaffolded goal setting, reflective questioning ("What helped you solve this problem?"), and opportunities to experience mastery in low-stakes settings. Over time, these practices nurture a sense of agency that transforms anxiety into productive alertness rather than avoidance. Additionally, emotion regulation training can be woven into everyday instruction without requiring extensive resources. Practices such as brief mindfulness moments, guided self-talk, or expressive writing before assessments (Ramirez & Beilock, 2011) allow students to externalize negative emotions and regain attentional focus. Evidence from Bellacicco et al. (2025) shows that incorporating brief movement or relaxation activities enhances executive control, suggesting that embodied approaches can complement cognitive strategies. When emotional regulation becomes normalized as part of mathematics learning, students begin to view anxiety as manageable feedback, not failure.

Another emerging implication concerns the integration of technology and AI-based supports in fostering self-regulation. Digital learning environments, when designed thoughtfully, can scaffold reflective engagement by providing adaptive feedback, self-monitoring dashboards, and individualized pacing (Ersozlu, 2024). Yet, as Wang and Wei (2025) caution, technology can also reinforce dependency if learners rely on external validation instead of developing self-monitoring skills. Effective digital tools should therefore emphasize autonomy-supportive design: encouraging students to reflect on their problem-solving process, recognize progress, and articulate emotional reactions to difficulty. By embedding metacognitive prompts or “pause and reflect” moments into digital interfaces, educators can transform technology into a vehicle for self-regulation rather than a temporary buffer against anxiety. Ultimately, mathematics instruction grounded in a self-regulation framework encourages teachers to act not merely as content transmitters but as emotional and metacognitive coaches. Such environments emphasize curiosity, persistence, and reflection, creating the psychological safety required for students to engage with mathematics even when they feel anxious.

Implications for Research

For researchers, viewing mathematics anxiety through the lens of self-regulation opens the door to more dynamic and ecologically valid investigations. Decades of cross-sectional research have mapped correlations between anxiety and achievement, but far less is known about how these relationships unfold over time or interact with regulatory mechanisms. Future research should thus employ longitudinal and process-oriented methodologies that can capture reciprocal causality among anxiety, self-efficacy, and persistence (Du et al., 2021; Smith et al., 2025). Techniques such as experience sampling, learning analytics, and cross-lagged panel modeling can trace moment-to-moment changes in students’ affective and cognitive states. These approaches are particularly valuable for identifying “tipping points” at which temporary anxiety becomes chronic or debilitating, offering insight into when and how interventions should be applied.

At the same time, integrating psychophysiological and neuroscientific perspectives could enrich theoretical explanations of self-regulation. Studies by Suárez-Pellicioni et al. (2016) and Marakshina et al. (2025) reveal that high mathematics anxiety is associated with hyperactivation of the amygdala and hypoactivation in prefrontal regions responsible for executive control. These findings suggest that emotional regulation in mathematics is not solely a matter of mindset but involves measurable neural dynamics. Combining such evidence with behavioral measures of self-efficacy or metacognitive monitoring could yield multilevel models of how regulation operates across brain, behavior, and context. Cultural and contextual factors also remain underexplored. Comparative analyses by Lau et al. (2024) and O'Hara et al. (2022) indicate that while the anxiety–efficacy link is consistent across educational systems, its expression depends on social norms surrounding error, effort, and evaluation. In collectivist cultures, for example, anxiety may stem more from social evaluation, whereas in individualist contexts, it may relate to personal competence beliefs. Future research that situates self-regulation within these socio-cultural frameworks can help explain why certain interventions succeed in one context but not another.

Finally, researchers should explore integrative intervention models that combine cognitive, emotional, and social regulation. Programs involving collaborative reflection, guided peer regulation, and AI-supported feedback (Chen et al., 2025; Irmayanti et al., 2025) show promise in promoting both achievement and well-being. Rigorous mixed-method and longitudinal evaluations of such models can advance understanding of how regulation-oriented pedagogy transforms learners' affective trajectories in mathematics.

Concluding Remarks

Viewing mathematics anxiety as a reflection of self-regulatory processes reframes the phenomenon from a deficit-oriented issue to a diagnostic indicator of learners' adaptive functioning. Rather than interpreting anxiety as something to be eliminated, this perspective treats it as a form of feedback, a signal that regulatory systems are overloaded, misaligned, or underdeveloped. This integrative view bridges the gap between emotion and cognition, acknowledging that effective learning depends on how well students can balance these domains. This reconceptualization is supported by the empirical patterns synthesized throughout the paper: longitudinal studies showing reciprocal influences between anxiety and self-efficacy, cross-cultural evidence demonstrating the mediating role of engagement and efficacy, and motivational research indicating that persistence and regulatory strategies determine whether anxiety undermines or protects achievement. Together, these insights reinforce the study's central aim of framing mathematics anxiety as an integral component of students' self-regulatory functioning rather than an isolated emotional response. When anxiety is conceptualized as part of self-regulation, the focus shifts from suppression to transformation: helping learners recognize, interpret, and harness anxiety to guide strategy use and perseverance. For educators, this means designing classrooms that cultivate reflection, autonomy, and emotional literacy. For researchers, it entails examining the dynamic interplay between regulation, motivation, and affect across multiple levels of analysis from neural to social. Ultimately, understanding mathematics anxiety as a self-regulatory phenomenon invites a paradigm shift: from treating anxiety as an obstacle to recognizing it as an entry point for cultivating resilient, self-aware, and confident mathematical thinkers.

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