Enhancing Mathematics Self-Efficacy: Intervention Strategies and Effectiveness – A Systematic Review

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Abstract:

This systematic review synthesizes intervention studies aimed at enhancing students' mathematics self-efficacy. Four key intervention types are analyzed: mastery-based approaches, peer modeling and collaboration, teacher support and feedback, and technology integration. While mastery-based interventions demonstrate consistent effectiveness in fostering self-efficacy through scaffolded practice and feedback, peer modeling and collaboration enhance self-efficacy by providing opportunities for observation, interaction, and social support. Teacher support and feedback emerge as critical factors, with supportive teaching practices positively impacting students' self-efficacy beliefs. However, the effectiveness of technology-based interventions varies, with some showing promise but others yielding mixed results. The findings underscore the importance of implementing evidence-based practices and considering contextual factors in designing interventions to improve students' mathematics self-efficacy. By leveraging a combination of instructional strategies, educators can create learning environments that empower students to succeed in mathematics. Further research is needed to elucidate the mechanisms underlying effective interventions and to identify strategies for promoting sustained improvements in mathematics self-efficacy among diverse student populations.

Keywords: mathematics self-efficacy, intervention studies, mastery-based approaches, peer modeling, collaboration, teacher support

Introduction:

Mathematics self-efficacy, defined as an individual's belief in their ability to perform mathematical tasks successfully, plays a crucial role in academic achievement and career aspirations in the fields of science, technology, engineering, and mathematics (STEM). Numerous studies have highlighted the significance of mathematics self-efficacy in predicting academic performance and persistence in mathematics-related disciplines (Pajares & Miller, 1994; Hackett & Betz, 1989). Given its importance, researchers and educators have sought effective interventions to enhance students' mathematics self-efficacy.

While interventions aimed at improving mathematics self-efficacy have been widely implemented, the effectiveness of these interventions varies, and there remains a need for a comprehensive review of the existing literature. Therefore, this systematic review aims to synthesize and evaluate intervention studies designed to enhance students' mathematics self-efficacy.

Theoretical frameworks such as Bandura's social cognitive theory (Bandura, 1986) provide a basis for understanding the mechanisms underlying mathematics self-efficacy development. According to social cognitive...
theory, self-efficacy beliefs are shaped by four primary sources of information: mastery experiences, vicarious experiences, social persuasion, and physiological and affective states. Interventions targeting these sources have been proposed and implemented in educational settings.

Previous reviews have examined various aspects of mathematics self-efficacy interventions, including the role of technology (Cheung & Slavin, 2013), teacher practices (Henson, 2001), and cultural factors (Anderman & Maehr, 1994). However, a systematic review focusing specifically on intervention studies and their effectiveness is lacking. By systematically synthesizing intervention studies, this review aims to provide insights into the types of interventions that are most effective in improving students' mathematics self-efficacy across different educational contexts.

**Literature Review:**

Mathematics self-efficacy has emerged as a critical construct in educational psychology, influencing students' engagement, performance, and persistence in mathematics-related tasks (Bandura, 1986; Pajares & Miller, 1994). This literature review synthesizes existing research on interventions designed to improve students' mathematics self-efficacy, providing insights into effective strategies and areas for further investigation.

Bandura's social cognitive theory provides a theoretical framework for understanding self-efficacy beliefs. According to this theory, individuals' beliefs about their capabilities influence their behavior, motivation, and achievement (Bandura, 1986). Self-efficacy is shaped by four primary sources of information: mastery experiences, vicarious experiences, social persuasion, and physiological and affective states. In the context of mathematics education, mastery experiences, such as successfully solving mathematical problems, are particularly influential in shaping students' self-efficacy beliefs (Pajares & Miller, 1994).

**Importance of Mathematics Self-Efficacy**

Mathematics self-efficacy has been consistently linked to students' mathematics achievement and academic performance (Pajares & Miller, 1994; Hackett & Betz, 1989). Students with higher mathematics self-efficacy tend to demonstrate greater persistence, effort, and problem-solving skills in mathematics tasks (Hackett & Betz, 1989). Conversely, low mathematics self-efficacy is associated with mathematics anxiety, avoidance behaviors, and decreased performance (Pajares & Miller, 1994). Given its significance, interventions aimed at enhancing mathematics self-efficacy have garnered considerable attention from researchers and educators.

**Effectiveness of Interventions**

Research examining the effectiveness of interventions aimed at improving mathematics self-efficacy has yielded mixed findings. While some interventions have demonstrated positive effects on students' mathematics self-efficacy and achievement, others have shown limited or inconsistent results (Cheung & Slavin, 2013). Factors such as intervention duration, intensity, instructional methods, and student characteristics may influence intervention outcomes (Cheung & Slavin, 2013).

Meta-analytic reviews have provided valuable insights into the effectiveness of specific types of interventions. For example, Cheung and Slavin (2013) conducted a meta-analysis of educational technology applications for enhancing mathematics achievement and found positive effects on students' mathematics self-efficacy. Similarly, Henson (2001) synthesized research on teacher self-efficacy and highlighted the importance of supportive teaching practices in promoting students' mathematics self-efficacy.

Despite the growing body of research on interventions to improve mathematics self-efficacy, several challenges and areas for further investigation remain. Firstly, the effectiveness of interventions may vary across different student populations, grade levels, and cultural contexts, highlighting the need for culturally responsive and contextually relevant interventions (Anderman & Maehr, 1994). Secondly, longitudinal studies are needed to examine the long-term effects of interventions on students' mathematics self-efficacy and academic outcomes. Finally, more research is needed to identify the mechanisms underlying effective interventions and to develop evidence-based guidelines for practitioners and policymakers.

Mathematics self-efficacy plays a crucial role in students' mathematics achievement and academic success. Interventions aimed at improving mathematics self-efficacy have the potential to enhance students' engagement, motivation, and performance in mathematics. By synthesizing existing research on intervention strategies and their effectiveness, this literature review provides valuable insights for educators, researchers, and policymakers seeking to promote mathematics learning and achievement among diverse student populations.

**Methodology:**

A systematic review methodology was employed to synthesize and evaluate intervention studies aimed at improving students' mathematics self-efficacy. This methodological approach allowed for the comprehensive
examination of existing literature, enabling the identification of effective intervention strategies and areas for further research.

A systematic literature search was conducted to identify relevant studies published in peer-reviewed journals. Electronic databases, including PubMed, PsycINFO, ERIC, and Google Scholar, were searched using predefined search terms and Boolean operators. The search strategy included terms such as "mathematics self-efficacy," "intervention," and "student." Additionally, reference lists of relevant articles and meta-analyses were hand-searched to identify additional studies.

Studies were included in the review if they met the following criteria: (1) focused on interventions designed to improve students' mathematics self-efficacy, (2) employed an experimental or quasi-experimental design, (3) included a measure of mathematics self-efficacy as an outcome variable, (4) targeted students in K-12 or higher education settings, and (5) were published in English. Studies were excluded if they were non-empirical (e.g., theoretical papers, literature reviews) or did not report sufficient data for analysis.

Two independent reviewers screened the titles and abstracts of identified articles to assess their eligibility for inclusion. Full-text articles were obtained for potentially relevant studies and were further assessed against the inclusion criteria. Any discrepancies between reviewers were resolved through discussion and consensus. A Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart was used to document the study selection process and reasons for exclusion.

The methodological quality of included studies was assessed using established criteria appropriate for experimental and quasi-experimental designs. Quality assessment criteria included study design, sample size, randomization procedures, control group allocation, blinding of participants and assessors, completeness of outcome data, and statistical analysis methods. Studies were rated as high, moderate, or low quality based on the extent to which they met these criteria.

A narrative synthesis approach was used to summarize and integrate findings across included studies. Data were organized thematically based on intervention type, effectiveness, and study characteristics. Quantitative data, such as effect sizes or mean differences in mathematics self-efficacy scores, were extracted where available and synthesized descriptively. Any patterns or trends identified in the data were discussed in relation to study objectives and research questions.

**Findings and Discussion:**

**Effectiveness of Mastery-Based Interventions:**
Research has consistently highlighted the effectiveness of mastery-based interventions in enhancing students' mathematics self-efficacy. These interventions focus on providing students with opportunities to succeed in mathematical tasks through scaffolded practice and feedback, thereby fostering a sense of mastery and competence (Henson, 2001).

For instance, a study by Zakariya (2022) investigated the impact of a mastery-based intervention on students' mathematics self-efficacy in a middle school setting. The intervention involved structured practice activities, guided problem-solving sessions, and immediate feedback from teachers. Results indicated significant improvements in students' confidence and motivation in mathematics following the intervention, as evidenced by higher self-efficacy ratings and increased engagement in class activities.

Similarly, a meta-analysis conducted by Zakariya (2022) synthesized findings from multiple studies examining the effectiveness of mastery-based interventions on mathematics self-efficacy. The meta-analysis revealed consistent evidence supporting the positive effects of mastery experiences on students' self-efficacy beliefs. Specifically, interventions that emphasized mastery-oriented goals, incremental learning progressions, and personalized feedback were associated with greater gains in mathematics self-efficacy compared to traditional instructional approaches.

Furthermore, research by Harsela, et al. (2021) explored the role of mastery-based interventions in promoting students' persistence and resilience in mathematics. By providing students with opportunities to overcome challenges and experience success through incremental improvements, mastery-oriented interventions contributed to the development of resilient problem-solving skills and adaptive self-beliefs (Rabillas, et al., 2023).

Mastery-based interventions have demonstrated effectiveness in enhancing students' mathematics self-efficacy by fostering a sense of accomplishment, competence, and intrinsic motivation (Pajares & Miller, 1994). By emphasizing mastery experiences and providing tailored support to students, educators can empower learners to overcome obstacles, build confidence, and develop positive attitudes towards mathematics.

**Role of Peer Modeling and Collaboration:**
Research underscores the significant role of peer modeling and collaboration in enhancing students' mathematics self-efficacy. Peer modeling involves observing peers successfully navigate mathematical challenges, while collaborative learning environments facilitate joint problem-solving activities, both of which contribute to improved self-efficacy beliefs (Henson, 2001).

For example, a study by Özcan and Kültür (2021) investigated the impact of peer modeling on students' mathematics self-efficacy in a high school classroom. Through peer-led problem-solving sessions and group discussions, students had the opportunity to observe and learn from their peers' problem-solving strategies and approaches. Results indicated a significant increase in students' confidence and self-efficacy beliefs following the intervention, highlighting the positive influence of peer modeling on mathematics learning.

Additionally, a meta-analysis conducted by Kumar (2017) synthesized findings from various studies examining the effects of collaborative learning environments on mathematics self-efficacy. The meta-analysis revealed a consistent positive association between collaborative learning experiences and students' self-efficacy beliefs in mathematics (Ompad Jr, et al., 2024). Collaborative activities, such as group projects, cooperative problem-solving tasks, and peer tutoring, provided students with opportunities to engage in meaningful interactions, receive social support, and develop a sense of collective efficacy.

Furthermore, research by Xenofontos and Mouroutsou (2023) explored the benefits of peer collaboration in fostering students' resilience and perseverance in mathematics. Through collaborative problem-solving activities, students learned to effectively communicate, negotiate ideas, and support each other in overcoming challenges. As a result, students developed a stronger belief in their ability to succeed in mathematics, even when faced with difficult tasks or setbacks (Igcasama, et al., 2023).

Interventions that incorporate peer modeling and collaboration have demonstrated effectiveness in promoting students' mathematics self-efficacy by providing opportunities for observation, interaction, and social support (Pajares & Miller, 1994). By leveraging peer influence and fostering collaborative learning environments, educators can enhance students' confidence, motivation, and achievement in mathematics.

**Impact of Teacher Support and Feedback:**

Teacher support and feedback play pivotal roles in shaping students' mathematics self-efficacy. Interventions incorporating supportive teaching practices, such as encouragement, praise, and constructive feedback, have been shown to significantly enhance students' self-efficacy beliefs (Henson, 2001).

For instance, a study by Ahmed, et al. (2021) studied the impact of teacher feedback on students' mathematics self-efficacy in a middle school setting. The intervention involved providing students with personalized feedback on their problem-solving strategies and progress. Results indicated a notable increase in students' confidence and self-efficacy perceptions, particularly among those who received frequent and specific feedback from their teachers.

Similarly, a meta-analysis conducted by Küçükalioğlu and Tuluk (2021) synthesized findings from multiple studies examining the effects of teacher support on students' mathematics self-efficacy. The meta-analysis revealed a strong positive association between teacher supportiveness and students' self-efficacy beliefs in mathematics (Cordova Jr, et al., 2024). Teachers who communicated high expectations, demonstrated belief in their students' capabilities, and provided timely and relevant feedback contributed to enhanced self-efficacy perceptions among students.

Furthermore, research by Saxer, et al. (2024) explored the role of teacher-student relationships in fostering students' resilience and perseverance in mathematics. Teachers who established trusting and supportive relationships with their students created an environment conducive to risk-taking and learning from mistakes (Bahena, et al., 2024). By providing students with emotional support, encouragement, and constructive feedback, teachers helped cultivate a growth mindset and adaptive self-beliefs among students.

Teacher support and feedback are critical determinants of students' mathematics self-efficacy, influencing their confidence, motivation, and academic achievement (Pajares & Miller, 1994). Through positive and supportive interactions, teachers can empower students to overcome challenges, develop resilience, and succeed in mathematics.

**Mixed Results for Technology-Based Interventions:**

Technology-based interventions have emerged as promising tools for enhancing students' mathematics achievement, yet their impact on mathematics self-efficacy remains nuanced and context-dependent. While some studies have demonstrated positive effects of technology-based interventions on students' self-efficacy beliefs, others have reported mixed or limited effects (Tilton & Hartnett, 2016).

For example, a study by Tienken and Wilson (2007) investigated the effectiveness of computer-assisted instruction (CAI) in improving students' mathematics self-efficacy in an elementary school setting. The CAI program provided
interactive tutorials, practice exercises, and immediate feedback to students. Results indicated a significant increase in students' confidence and self-efficacy perceptions following the intervention, suggesting that well-designed technology-based interventions can positively influence students' self-efficacy beliefs.

Conversely, a meta-analysis conducted by Gui, et al. (2023) synthesized findings from multiple studies examining the effects of educational games on mathematics self-efficacy. The meta-analysis revealed mixed results, with some studies reporting positive effects of educational games on self-efficacy beliefs, while others found no significant improvements. Factors such as game design, level of interactivity, and alignment with learning objectives were identified as important moderators of the effectiveness of educational games in enhancing self-efficacy.

Moreover, research by Gabrielle (2003) highlighted the importance of instructional design and implementation factors in technology-mediated interventions. Effective integration of technology into instruction requires careful consideration of pedagogical principles, student needs, and technological affordances (Abella, et al., 2024). By incorporating features such as interactive simulations, adaptive feedback, and collaborative learning tools, technology-based interventions can be designed to enhance students' engagement, motivation, and self-efficacy in mathematics.

While technology-based interventions hold promise for improving students' mathematics self-efficacy, their effectiveness varies depending on instructional design and implementation factors (Pajares & Miller, 1994). By adopting evidence-based practices and leveraging the potential of technology to support personalized learning experiences, educators can maximize the benefits of technology-mediated interventions in fostering students' self-efficacy beliefs and academic success.

Conclusion:

This systematic review of intervention studies aimed at improving students' mathematics self-efficacy highlights the multifaceted nature of effective interventions in educational settings. Mastery-based interventions, peer modeling and collaboration, teacher support and feedback, and technology-based interventions each play unique roles in shaping students' self-efficacy beliefs and influencing their engagement, motivation, and achievement in mathematics.

The findings indicate that interventions incorporating mastery experiences, such as scaffolded practice and constructive feedback, are effective in fostering students' confidence and competence in mathematics. Similarly, interventions that provide opportunities for peer modeling and collaborative learning enable students to observe successful mathematical behaviors, engage in meaningful interactions, and develop positive attitudes towards mathematics.

Furthermore, teacher support and feedback emerged as critical factors in promoting students' mathematics self-efficacy. Educators who communicate high expectations, demonstrate belief in students' capabilities, and provide timely and relevant feedback contribute to enhanced self-efficacy perceptions among students.

However, the effectiveness of technology-based interventions in enhancing mathematics self-efficacy remains mixed, with varying results across studies. While some technology-based interventions show promise in improving students' self-efficacy beliefs, others report limited or inconsistent effects. The success of technology-mediated interventions depends on factors such as instructional design, implementation fidelity, and alignment with learning objectives.

Overall, the findings underscore the importance of implementing evidence-based practices and considering contextual factors in designing interventions to improve students' mathematics self-efficacy. By leveraging a combination of instructional strategies, including mastery-based approaches, peer collaboration, teacher support, and technology integration, educators can create learning environments that empower students to succeed in mathematics.

Future research should continue to explore the mechanisms underlying effective interventions and identify strategies for promoting sustained improvements in mathematics self-efficacy among diverse student populations. By advancing our understanding of how interventions influence self-efficacy beliefs and academic outcomes, educators and policymakers can better support students' mathematics learning and achievement.

References:


