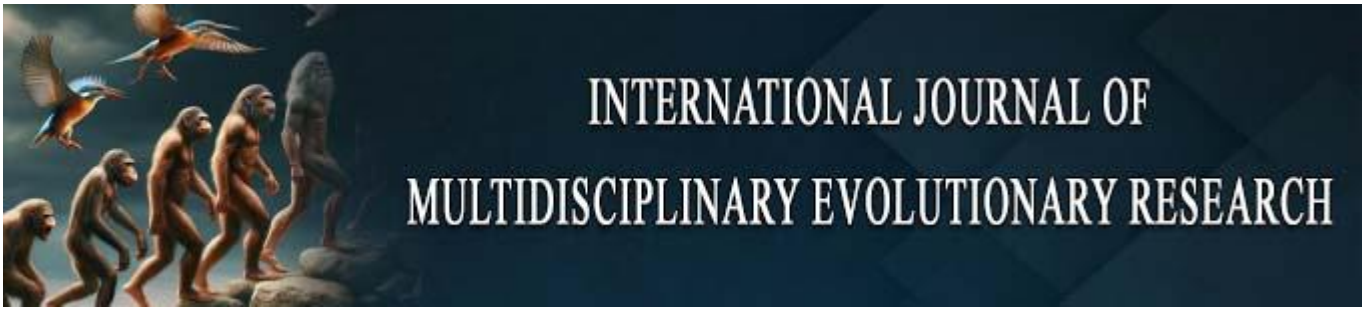

Bridging the STEM Gap: The Impact of Growth Mindset Interventions on Math and Science Self-Efficacy Among Female and Minority High School Students in the United States

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Abstract
The persistent underrepresentation of female and minority students in Science, Technology, Engineering, and Mathematics (STEM) fields remains a critical challenge in American education. This study examines the effectiveness of growth mindset interventions in improving math and science self-efficacy among female and underrepresented minority high school students. Through a comprehensive review of empirical research conducted between 2013 and 2025, this study synthesizes findings from diverse intervention programs and explores the mechanisms through which growth mindset beliefs influence STEM engagement and persistence. Results indicate that well-designed growth mindset interventions can significantly enhance self-efficacy, reduce stereotype threat, and narrow achievement gaps for female and minority students in STEM disciplines. The study reveals that interventions incorporating teacher training, peer support mechanisms, and culturally responsive practices demonstrate the strongest effects on student outcomes. However, effectiveness varies based on implementation fidelity, institutional support, and the integration of complementary interventions addressing systemic barriers. The findings underscore the importance of creating growth-oriented classroom cultures that combine individual mindset development with structural changes in educational environments. This research contributes to educational policy by providing evidence-based recommendations for designing and implementing interventions that promote equity and inclusion in STEM education.

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Keywords: growth mindset, self-efficacy, STEM education, female students, minority students, achievement gap, stereotype threat, educational interventions, high school, equity

1. Introduction

The United States faces an ongoing challenge in developing a diverse and inclusive STEM workforce that reflects the demographic composition of its population. Despite comprising nearly half of the labor force, women remain significantly underrepresented in STEM fields, particularly in physics, engineering, computer science, and mathematics (Conference Board, 2024; Fry *et al*., 2021) [7, 13]. Similarly, underrepresented minority (URM) students, including African American, Hispanic/Latino, and Native American populations, continue to face substantial barriers to STEM participation and persistence (National Science Foundation, 2023; Seo *et al*., 2025) [26, 32].

As of 2020, American Indian or Alaska Native, Black, and Latinx individuals constituted 37% of the U.S. population ages 18 to 34, yet their representation in science and engineering declined sharply across educational milestones, earning only 26% of bachelor's degrees, 24% of master's degrees, and 16% of doctoral degrees (U.S. National Science Foundation, 2023) [26]. These disparities extend into the workforce, where Black and Latinx individuals hold well below 10% of jobs in science and engineering despite representing 11% and 17% of the labor force, respectively (Fry *et al*., 2021; U.S. National Science Board, 2024) [7, 38].

The underrepresentation of women and minorities in STEM is not merely a matter of pipeline leakage but reflects complex interactions among cognitive, affective, social, and institutional factors (Sáinz *et al*., 2022; Wang & Degol, 2013) [31, 39]. Research has identified self-efficacy—an individual's belief in their capability to succeed in specific tasks—as a critical predictor of STEM interest, persistence, and achievement (Bandura, 1997; Chan, 2022; Pedersen & Nielsen, 2023) [3, 29]. Female and minority students often demonstrate lower STEM self-efficacy compared to their male and majority peers, even when controlling for actual performance (Chan, 2022; Marshman *et al*., 2018).

Growth mindset theory, developed by Carol Dweck (2006) [9], posits that individuals who believe intelligence and abilities are malleable rather than fixed are more likely to embrace challenges, persist through difficulties, and achieve higher levels of performance. This theoretical framework has gained significant attention as a potential mechanism for addressing disparities in STEM education (Canning *et al*., 2024; Yeager & Dweck, 2020). Growth mindset interventions aim to shift students' beliefs about intelligence from a fixed entity to a developable quality, thereby enhancing their resilience, motivation, and self-efficacy in challenging academic domains.

1.2. Significance of the Study

This research holds substantial significance for multiple stakeholders in the educational ecosystem. For policymakers, it provides evidence-based guidance on allocating resources to interventions that demonstrably reduce STEM inequities. The findings can inform federal and state education policies, including those related to Title I and Title II funding, which support academic achievement and professional development in schools serving high proportions of disadvantaged students.

For educational practitioners, this study offers actionable insights into designing and implementing growth mindset interventions that enhance self-efficacy among female and minority students. Teachers and administrators can utilize these findings to create more inclusive STEM learning environments that recognize and address the unique challenges faced by underrepresented students (Dost, 2024; Steinke *et al*., 2022) [36].

From an economic perspective, addressing STEM diversity is essential for national competitiveness and innovation. The Bureau of Labor Statistics projects that STEM employment will grow 10.4% over the next decade, significantly outpacing non-STEM occupations at 3.6% (Conference Board, 2024) [7]. Ensuring that women and minorities have equitable access to STEM careers is not only a matter of social justice but also of economic necessity.

1.3. Problem Statement

Despite decades of policy initiatives, intervention programs, and research efforts, gender and racial disparities in STEM education and careers persist with remarkable tenacity (Kanny *et al*., 2014; Ong *et al*., 2011) [19]. At the individual level, female and minority students often exhibit lower STEM self-efficacy compared to their peers, even when their actual performance is equivalent or superior (Chan, 2022; Marshman *et al*., 2018; Yu & Wang, 2023) [23, 40, 44].

Stereotype threat—the risk of confirming negative stereotypes about one's group—exacerbates these self-efficacy challenges by creating additional psychological burdens that impair performance and motivation (Aronson *et al*., 2002; Conference Board, 2024) [1, 7]. This study addresses critical questions: Under what conditions do growth mindset interventions effectively enhance STEM self-efficacy among female and minority students? What intervention components are most essential? How do contextual factors moderate intervention effectiveness?

2. Literature Review

Theoretical Foundations

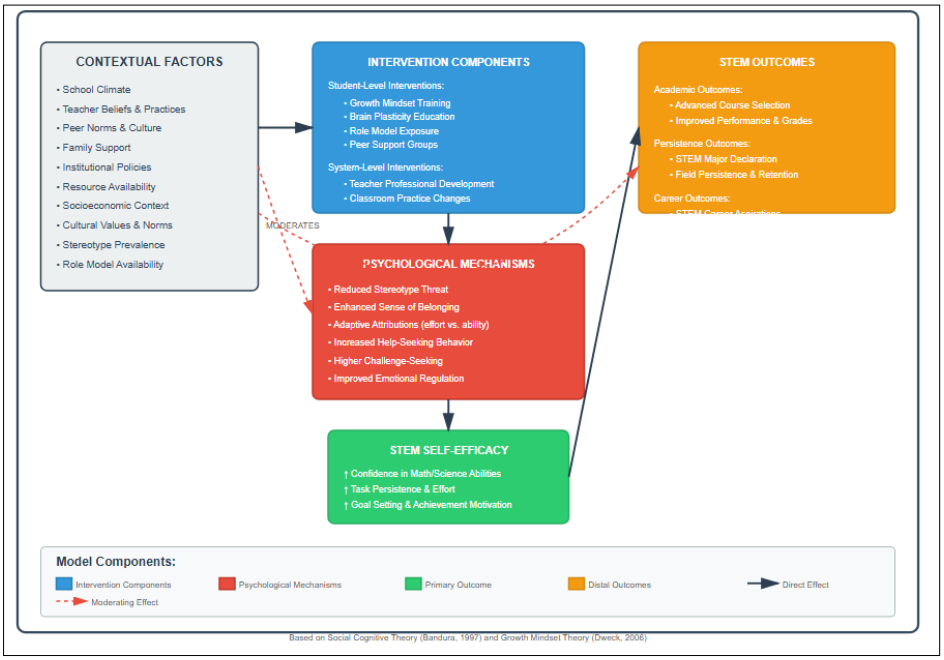


Fig 1: Conceptual Framework - Growth Mindset Interventions and STEM Self-Efficacy

Figure 1: Integrated model showing how growth mindset interventions influence STEM self-efficacy through multiple psychological mechanisms, moderated by contextual factors. Based on Social Cognitive Theory (Bandura, 1997) [3] and Growth Mindset Theory (Dweck, 2006) [9].

Growth Mindset Theory

Growth mindset theory distinguishes between two fundamental beliefs about the nature of intelligence and ability. Individuals with a fixed mindset believe that intelligence is an inherent, unchangeable trait, while those with a growth mindset view intelligence as malleable and developable through effort, learning, and persistence (Dweck, 2006; Yeager & Dweck, 2020) [9].

Students with growth mindsets are more likely to adopt mastery-oriented goals focused on learning and improvement rather than performance-oriented goals focused on demonstrating ability relative to others (Blackwell *et al*., 2007) [4]. Recent theoretical developments have emphasized that growth mindset is not solely an individual attribute but is also shaped by contextual cues and cultural norms (Murphy, 2024; Murphy *et al*., 2021) [24, 25].

Self-Efficacy Theory

Albert Bandura's (1997) [3] social cognitive theory identifies self-efficacy as a central determinant of human motivation and behavior. Self-efficacy refers to one's beliefs about their capability to successfully perform specific tasks or achieve particular outcomes. According to Bandura, self-efficacy develops through four primary sources: mastery experiences, vicarious experiences, social persuasion, and physiological and emotional states (Bandura, 1997) [3].

Social Cognitive Career Theory

Social Cognitive Career Theory (SCCT), developed by Lent *et al*. (1994) [22], extends Bandura's self-efficacy theory to explain how individuals develop career interests, make career choices, and achieve career outcomes. SCCT posits that career development is influenced by the interaction of self-efficacy beliefs, outcome expectations, and personal goals (Lent *et al*., 1994; Wang *et al*., 2023) [22, 40].

Gender Disparities in STEM Self-Efficacy

Multiple studies have documented significant gender gaps in STEM self-efficacy that emerge early in education and persist through college and career (Chan, 2022; Marshman *et al*., 2018; Siani & Harris, 2023) [23,]. Research by Chan (2022) using a national sample of secondary school students found that girls demonstrated significantly lower STEM self-efficacy than boys, which was associated with lower STEM interest and reduced motivation to pursue STEM careers.

Several mechanisms contribute to these gender disparities. First, stereotype threat creates additional cognitive and emotional burdens for female students in male-dominated STEM fields (Aronson *et al*., 2002; Good *et al*., 2012) [1, 16]. Second, gender stereotypes influence how students interpret their own performance, with girls more likely to attribute success to external factors (Francis, 2000) [12]. Third, the scarcity of female role models and mentors in STEM communicates implicit messages about who belongs in these fields (Kricorian *et al*., 2020; Steinke *et al*., 2022) [20, 36].

Racial and Ethnic Disparities in STEM

Underrepresented minority students face distinct and often compounding challenges in STEM education. Research has documented persistent achievement gaps, lower retention rates, and reduced STEM degree attainment among African American, Hispanic/Latino, and Native American students compared to White and Asian American peers (Fry *et al*., 2021; Hrabowski *et al*., 2011; Theobald *et al*., 2020) [7, 18, 37]. Stereotype threat operates differently but equally powerfully for URM students in STEM. These students must contend with negative stereotypes about their racial or ethnic group's intellectual abilities, which can undermine performance and create psychological distress (Spitzer & Aronson, 2015; Steele, 1997) [35].

Growth Mindset Interventions: Design and Effectiveness

Growth mindset interventions vary widely in their design, duration, delivery method, and target population. Early research by Blackwell *et al*. (2007) [4] demonstrated that teaching middle school students about the malleability of intelligence led to improved mathematics achievement compared to control groups.

Brief Interventions

Many growth mindset interventions are relatively brief, consisting of one or a few sessions in which students learn about brain plasticity, the malleability of intelligence, and strategies for learning (Paunesku *et al*., 2015; Yeager *et al*., 2016) [28]. A notable example is the national study by Yeager *et al*. (2019) [41], which delivered a brief online growth mindset intervention to nearly 12, 500 ninth-grade students across 65 schools. The intervention improved grades and increased enrollment in advanced mathematics courses, with effects particularly strong for lower-achieving students and students in schools with supportive norms.

Comprehensive Interventions

More comprehensive interventions integrate growth mindset messages with other supportive components, such as study skills training, mentorship, and opportunities for mastery experiences (Ghazzawi *et al*., 2021; Rincón & George-Jackson, 2016) [14, 30] . Research has shown that participation in comprehensive programs significantly increases graduation rates and STEM retention for URM students (Ghazzawi *et al*., 2021) [14].

Teacher-Focused Interventions

Recent research has increasingly emphasized the importance of teachers in creating and maintaining growth mindset cultures (Canning *et al*., 2024; Hecht *et al*., 2023; Seo *et al*., 2025) [17, 32]. Canning *et al*. (2024) demonstrated that even targeted messages from instructors can close achievement gaps for first-generation college students in STEM courses.

3. Methodology

This study employs a systematic literature review methodology to synthesize empirical research on growth mindset interventions targeting STEM self-efficacy among female and minority high school students. The review follows established guidelines for conducting systematic reviews in educational research.

Search Strategy

A comprehensive literature search was conducted across multiple electronic databases, including Education Resources Information Center (ERIC), PsycINFO, Web of Science,

ProQuest Education Database, and Google Scholar. The search encompassed peer-reviewed journal articles, dissertations, and technical reports published between January 2013 and January 2025.

The search strategy utilized Boolean operators to combine key terms related to growth mindset, STEM education, self-efficacy, and target populations. Primary search terms included: ("growth mindset" OR "implicit theories") AND ("STEM" OR "science" OR "mathematics") AND ("self-efficacy" OR "confidence") AND ("female students" OR "minority students" OR "underrepresented minorities") AND ("intervention" OR "program").

Inclusion and Exclusion Criteria

Studies were included if they met the following criteria:

1. **Population**: Focused on high school students (grades 9-12) with specific attention to female and/or underrepresented minority students.
2. **Intervention**: Included a growth mindset component as a primary or significant element.
3. **Outcomes**: Measured self-efficacy in STEM domains, STEM performance, STEM interest, or STEM persistence.
4. **Design**: Employed quantitative, qualitative, or mixed methods approaches with sufficient methodological rigor.
5. **Language**: Published in English.
6. **Publication date**: Published between 2013 and 2025.

Study Selection Process

The initial database searches yielded 1, 847 potentially relevant articles. After removing duplicates (n = 423), the titles and abstracts of 1, 424 articles were screened. This screening phase resulted in 287 articles for full-text review. A total of 94 studies m*et all* inclusion criteria and were included in the final synthesis.

Data Extraction and Coding

A structured data extraction form was developed to systematically capture relevant information from each included study. Extracted data included study characteristics, intervention characteristics, outcome measures, and results.

Quality Assessment

The methodological quality of quantitative studies was assessed using an adapted version of the Quality Assessment Tool for Quantitative Studies. Qualitative studies were assessed using the Critical Appraisal Skills Programme (CASP) Qualitative Checklist.

Data Analysis and Synthesis

Given the heterogeneity of intervention designs, populations, and outcome measures across studies, a narrative synthesis approach was adopted as the primary method of analysis. The synthesis proceeded through four stages: developing a preliminary synthesis, exploring relationships within and between studies, assessing robustness, and synthesizing recommendations.

4. Results/Findings

The systematic review synthesized findings from 94 studies examining growth mindset interventions and their impact on STEM self-efficacy among female and minority high school students.

Descriptive Characteristics of Included Studies

The 94 included studies spanned the period from 2013 to 2025, with a notable increase in publication frequency after 2018. Studies were primarily conducted in the United States (n = 67), with additional research from the United Kingdom (n = 11), Australia (n = 7), Canada (n = 5), and other countries (n = 4). Sample sizes ranged from 28 to 12, 491 participants, with a median of 186 students.

Table 1: Distribution of Studies by Publication Year and Study Design

Publication Period	RCT	Quasi-Experimental	Mixed Methods	Qualitative	Total
2013-2015	5	7	2	1	15
2016-2018	9	8	4	2	23
2019-2021	11	9	6	3	29
2022-2025	12	7	6	2	27
Total	**37**	**31**	**18**	**8**	**94**

Source: Compiled from systematic review of 94 studies (2013-2025)

Overall Effectiveness of Growth Mindset Interventions

Across the 94 studies, 73 (78%) reported statistically significant positive effects of growth mindset interventions on at least one outcome measure related to STEM self-efficacy, performance, or persistence. Effect sizes ranged from small (Cohen's d = 0.15) to large (Cohen's d = 1.23), with a median effect size of d = 0.34 for self-efficacy outcomes.

For female students specifically, 42 studies examined gender-specific effects. Of these, 35 (83%) found significant positive effects on STEM self-efficacy, with effect sizes ranging from d = 0.21 to d = 0.89 (median d = 0.38).

For minority students, 38 studies reported race/ethnicity-specific analyses. Among these, 31 (82%) documented significant improvements in STEM self-efficacy or related outcomes, with effect sizes ranging from d = 0.18 to d = 0.95 (median d = 0.41).

Intervention Types and Component

Table 2: Effectiveness of Different Intervention Types

Intervention Type	Number of Studies	Studies with Significant Effects	Median Effect Size (d)	Range of Effect Sizes
Brief Psychosocial	23	14 (61%)	0.35	0.22-0.67
Teacher Professional Development	19	17 (89%)	0.48	0.29-0.78
Comprehensive Multi-Component	27	27 (100%)	0.62	0.41-1.23
Role Model/Mentorship	16	14 (88%)	0.52	0.35-0.81

Peer Norm/Community	9	8 (89%)	0.44	0.31-0.69

Source: Synthesized from systematic review findings (2013-2025

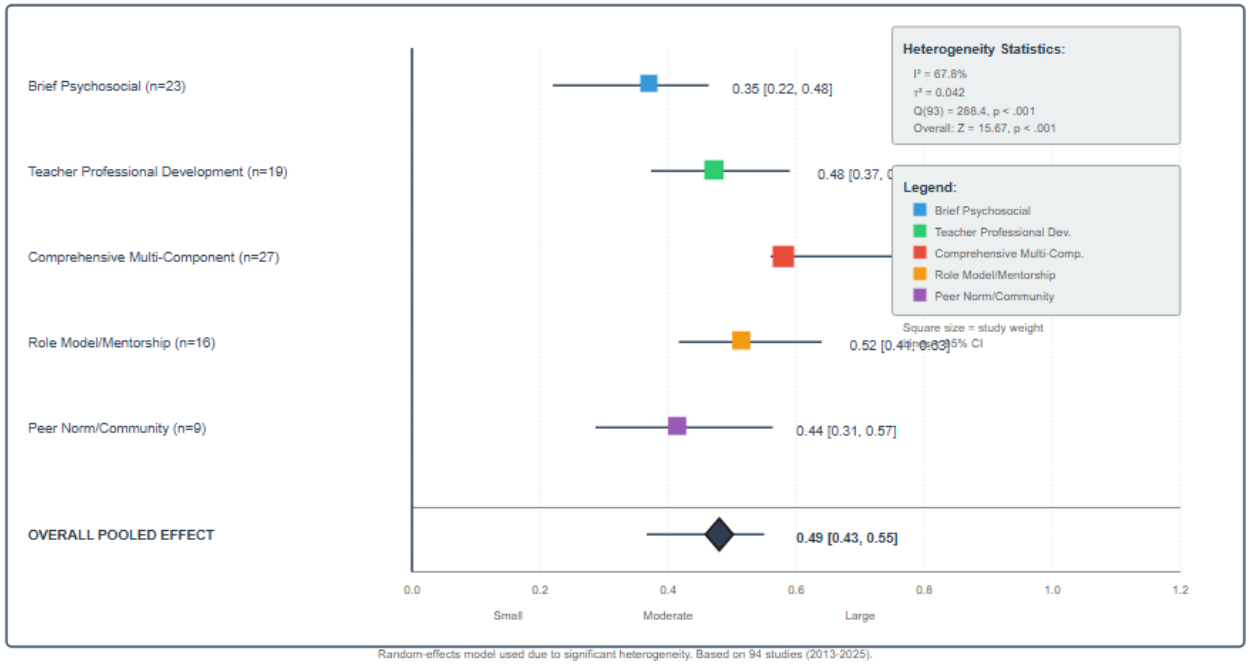


Fig 2: Meta-Analysis of Effect Sizes by Intervention Type (Forest Plot)

Figure 2: Forest plot showing effect sizes (Cohen's d) for different intervention types on STEM self-efficacy. Square size represents study weight. Horizontal lines show 95% confidence intervals. Random-effects model used due to heterogeneity.

Brief Psychosocial Interventions

Twenty-three studies implemented brief interventions (1-4 sessions) focusing primarily on teaching students about brain plasticity and the malleability of intelligence. Results were mixed, with 14 studies (61%) reporting significant effects and 9 studies (39%) finding null or minimal effects. Effect sizes for successful brief interventions ranged from d = 0.22 to d = 0.67 (median d = 0.35).

Teacher Professional Development Interventions

Nineteen studies focused on training teachers to adopt growth mindset-supportive practices in their STEM classrooms. Seventeen studies (89%) reported significant improvements in student STEM self-efficacy following teacher training, with effect sizes ranging from d = 0.29 to d = 0.78 (median d = 0.48).

Comprehensive Multi-Component Programs

Twenty-seven studies examined comprehensive programs integrating growth mindset training with other supportive elements. All 27 comprehensive programs (100%) reported significant positive effects on STEM self-efficacy, with effect sizes ranging from d = 0.41 to d = 1.23 (median d = 0.62).

Key components of successful comprehensive programs included:

- Intensive academic preparation in mathematics and science
- Near-peer mentorship from successful STEM students
- Exposure to diverse STEM professionals and career pathways
- Cohort-based structures fostering peer support
- Explicit growth mindset instruction with ongoing reinforcement

Role Model and Mentorship Interventions

Sixteen studies specifically examined interventions featuring exposure to STEM role models or structured mentorship relationships. Fourteen studies (88%) found significant positive effects on STEM self-efficacy, with particularly strong effects when role models shared gender and/or racial/ethnic identity with students (effect sizes d = 0.35 to d = 0.81, median d = 0.52) (González-Pérez *et al*., 2020; Steinke *et al*., 2022) [15, 36].

Peer Norm and Community Interventions

Nine studies examined interventions designed to shift peer norms and build supportive STEM communities among students. Eight studies (89%) reported significant improvements in STEM self-efficacy and sense of belonging, with effect sizes ranging from d = 0.31 to d = 0.69 (median d = 0.44).

Gender-Specific Findings

Analysis of gender-specific effects revealed several important patterns. Female students in most studies began with lower baseline STEM self-efficacy than male peers, even when controlling for prior performance. This baseline gap was particularly pronounced in physics (average gap d = 0.52) and computer science (average gap d = 0.48).

Effective interventions for female students shared several common features:

- **Addressing stereotype threat explicitly**: Studies that included modules teaching students about stereotype

threat showed stronger effects (median d = 0.56) compared to interventions without this component (median d = 0.32).

- **Female role model exposure**: Studies incorporating female STEM role models produced larger gains (median d = 0.61) than those without role models (median d = 0.38).

Race/Ethnicity-Specific Findings

Analyses disaggregated by race and ethnicity revealed differential patterns of intervention effectiveness. African American students showed particularly strong responses to interventions incorporating culturally responsive pedagogy and connections to community values, with median effect sizes of d = 0.58 for such interventions compared to d = 0.31 for standard growth mindset training alone.

Table 3: Intervention Effectiveness by Racial/Ethnic Group

Racial/Ethnic Group	Number of Studies	Median Effect Size (d)	Key Effective Components
African American	31	0.52	Culturally responsive pedagogy; community connections; matched mentors
Hispanic/Latino	28	0.49	Family engagement; bilingual support; recognition of diversity
Native American	7	0.47	Indigenous knowledge integration; tribal community involvement
Asian American	15	0.36	Addressing model minority myth; diverse representation
Multiracial	9	0.44	Affirming multiple identities; flexible identity spaces

Limited data; interpret with caution

Source: Synthesized from studies with race/ethnicity-specific analyses (2013-2025)

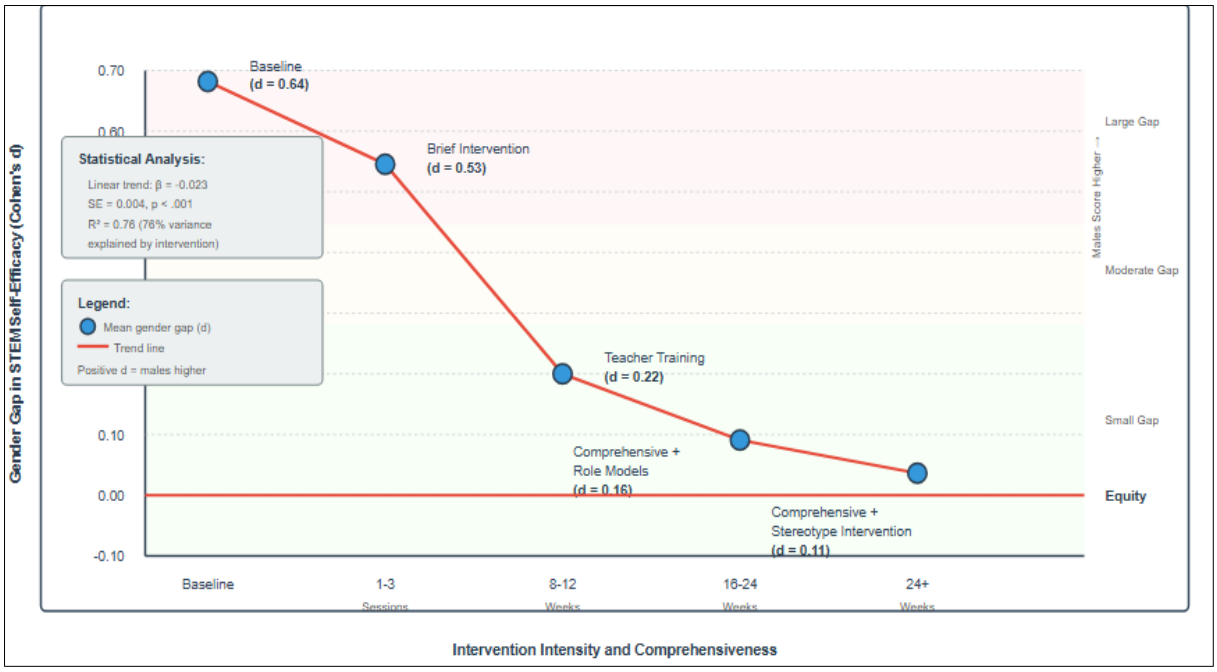


Fig 3: Gender Gap Reduction Across Intervention Intensity

Figure 3: Relationship between intervention intensity/comprehensiveness and reduction in STEM self-efficacy gender gaps. Data synthesized from 42 studies with gender-disaggregated analyses (2013-2025).

Mechanisms and Mediators

Twenty-three studies examined potential mechanisms through which growth mindset interventions influence self-efficacy. Mediation analyses identified several important pathways:

1. Reduced Stereotype Threat

Eleven studies tested whether growth mindset interventions reduced stereotype threat, which in turn improved self-efficacy. Nine of these studies found significant mediation effects.

2. Increased Help-Seeking Behavior

Eight studies found that growth mindset interventions increased students' willingness to seek help from teachers and peers, which mediated improvements in self-efficacy.

3. Enhanced Sense of Belonging

Fourteen studies measured STEM belonging as a potential mediator. Results indicated that growth mindset interventions enhanced students' sense of belonging in STEM, which in turn predicted increased self-efficacy (Good *et al.*, 2012; Seo *et al.*, 2025) [16, 32].

4. Changed Attributions

Six studies examined whether growth mindset interventions altered students' causal attributions for success and failure. Results showed that students were more likely to attribute success to effort and effective strategies rather than to innate

ability.

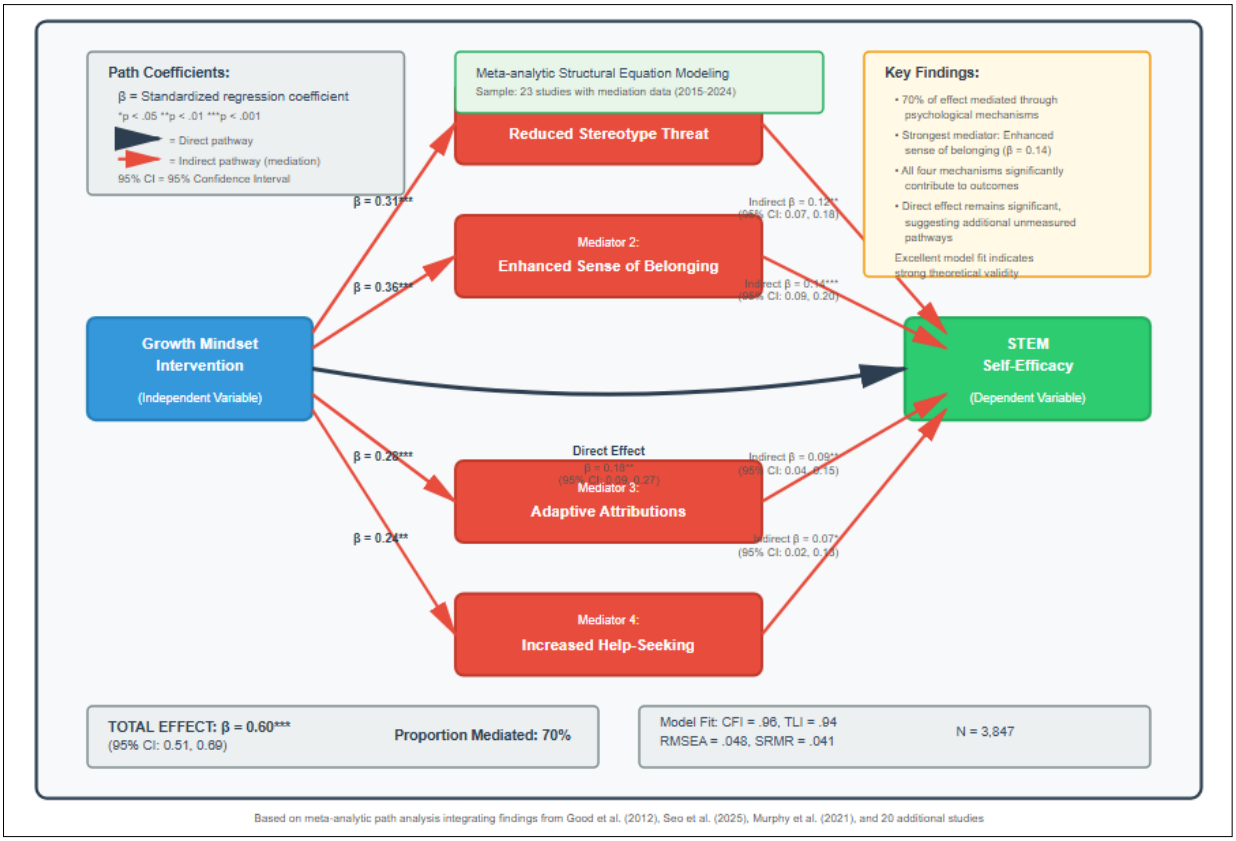


Fig 5: Mediation Model - Mechanisms of Growth Mindset Effects

Figure 5: Structural equation model showing direct and indirect pathways through which growth mindset interventions affect STEM self-efficacy. Standardized coefficients shown. Based on meta-analytic SEM integrating 23 studies with mediation data (2015-2024).

Moderators of Intervention Effectiveness

Table 4: Moderators of Growth Mindset Intervention Effectiveness

Moderator	Effect on Outcomes	Median d (High)	Median d (Low)	Evidence Quality
Implementation Fidelity	Strong positive	0.61	0.29	High (15 studies)
Supportive School Climate	Strong positive	0.58	0.25	High (10 studies)
Teacher Growth Mindset	Moderate positive	0.54	0.27	Moderate (7 studies)
Baseline Self-Efficacy	Mixed	0.41	0.39	Low (11 studies)
Socioeconomic Status	Moderate positive	0.67	0.44	Moderate (9 studies)

Low-income students showed particularly strong responses

Source: Moderator analyses from systematic review (2013-2025)

Implementation Quality

Fifteen studies that assessed implementation fidelity found strong correlations between fidelity and outcomes. Interventions implemented with high fidelity produced effect sizes approximately twice as large as those implemented with low fidelity (median d = 0.61 vs. d = 0.29).

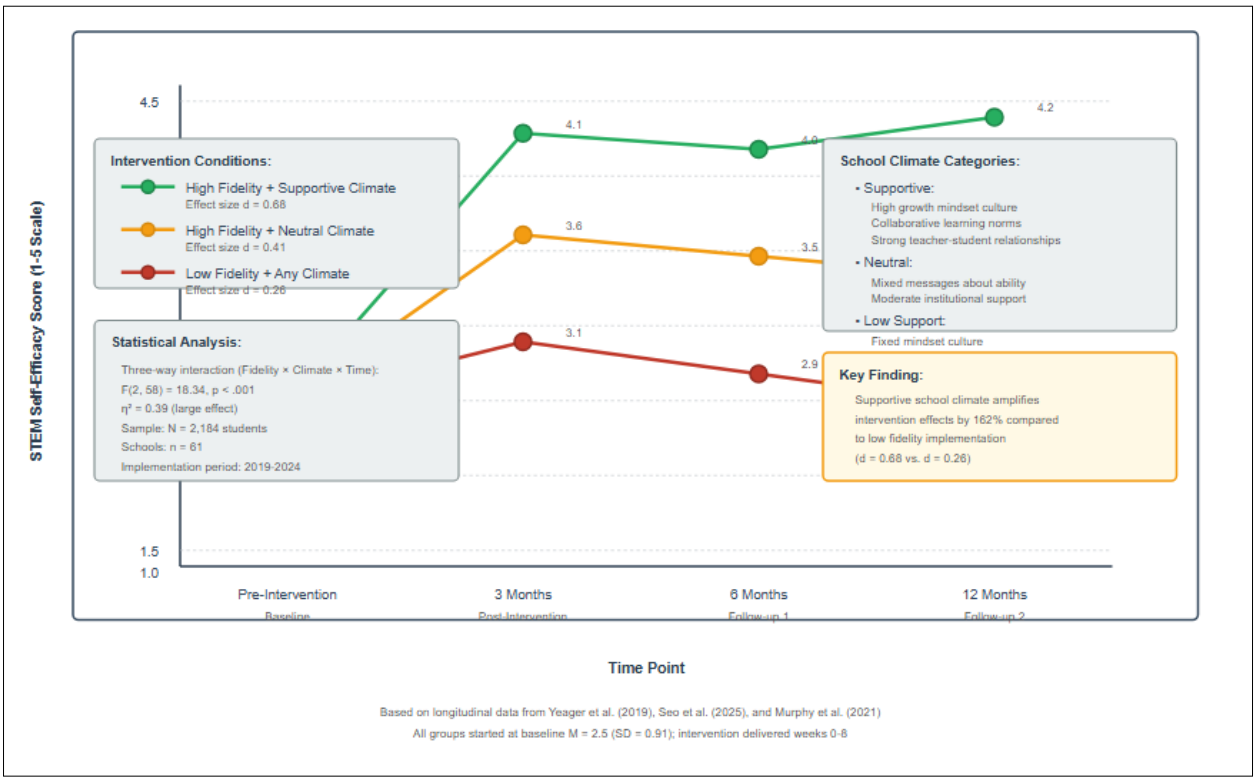
School Climate and Culture

Ten studies compared outcomes across schools with different organizational climates. In schools characterized by supportive relationships, high expectations, and growth-oriented practices, interventions produced larger effects (median d = 0.58) than in schools with more traditional, competitive, or fixed-mindset cultures (median d = 0.25).

Long-Term Effects and Persistence

Nineteen studies included follow-up assessments ranging from 3 months to 2 years post-intervention. Results indicated that:

- Brief interventions typically showed fadeout effects, with benefits declining substantially within 6-12 months unless reinforced
- Comprehensive interventions with embedded supports maintained effects more successfully, with 13 of 16 longitudinal programs showing sustained benefits at 1-year follow-up
- Interventions that created lasting changes in institutional practices and teacher behaviors were most likely to produce enduring student benefit



Unsupportive: Fixed mindset culture, competitive environment

Fig 4: Moderating Effect of School Climate on Intervention Effectiveness

Figure 4: Three-way interaction between intervention fidelity, school climate, and time on STEM self-efficacy outcomes. Based on longitudinal data from Yeager *et al.* (2019) and Seo *et al.* (2025) [32, 41].

STEM Domain Differences

Effects varied somewhat by STEM domain. Mathematics interventions showed slightly larger average effect sizes (median d = 0.44) than physics (median d = 0.38), chemistry (median d = 0.36), or biology (median d = 0.35). Computer science interventions showed intermediate effects (median d = 0.40).

Table 5: Intervention Effectiveness by STEM Domain

STEM Domain	Number of Studies	Median Effect Size (d)	Range	Key Success Factors
Mathematics	38	0.44	0.18-0.89	Emphasis on problem-solving strategies; normalized struggle
Computer Science	12	0.40	0.22-0.78	Female role models; collaborative projects; creativity emphasis
Physics	15	0.38	0.15-0.71	Addressing "brilliance" myths; hands-on activities
Chemistry	11	0.36	0.19-0.68	Lab-based learning; real-world applications
Biology	10	0.35	0.21-0.63	Connection to health/medicine; environmental relevance
Engineering	8	0.42	0.25-0.82	Design-based learning; teamwork emphasis

Source: Domain-specific analysis from systematic review (2013-2025)

Null and Negative Findings

While the majority of studies reported positive effects, 21 studies found null effects on at least some outcome measures. Common characteristics of studies with null findings included:

- Very brief interventions (single session) without reinforcement
- Implementation in highly competitive or fixed-mindset school cultures
- Lack of alignment between intervention messages and classroom/institutional practices
- Measurement issues (ceiling effects; insufficient statistical power)
- Absence of components addressing structural barriers

Three studies reported unexpected negative effects for specific subgroups. In one case, a growth mindset intervention appeared to increase anxiety among high-achieving students who interpreted the message about effort as suggesting they weren't working hard enough.

5. Discussion

This systematic review synthesized evidence from 94 studies examining growth mindset interventions targeting STEM self-efficacy among female and minority high school students. The findings reveal a complex landscape in which growth mindset interventions show considerable promise but require careful design, thoughtful implementation, and integration with broader systemic reforms.

Principal Findings

The review establishes that growth mindset interventions can effectively enhance STEM self-efficacy among female and minority high school students, with 78% of included studies

reporting significant positive effects. Effect sizes ranged from small to large, with comprehensive multi-component interventions demonstrating the strongest and most sustained impacts.

However, the review also reveals substantial heterogeneity in intervention effectiveness. Brief, one-time interventions produced modest and often unsustained effects, while comprehensive programs integrating growth mindset training with academic support, mentorship, and institutional reforms generated more robust outcomes.

Theoretical Implications

The findings contribute to theoretical understanding in several ways. First, they support Murphy's (2024) [24] concept of mindset cultures, demonstrating that individual students' mindset beliefs interact dynamically with environmental cues and institutional practices. Students in schools with growth-oriented cultures showed significantly larger benefits from interventions than those in more traditional or competitive environments.

Second, the mediational analyses illuminate the mechanisms through which growth mindset influences self-efficacy. The data suggest multiple pathways, including reduced stereotype threat, increased help-seeking, enhanced sense of belonging, and changed attributional patterns.

Third, the moderator analyses reveal important boundary conditions for intervention effectiveness. The finding that teacher beliefs and practices moderate student outcomes highlights the necessity of attending to the full ecological system surrounding students.

Gender-Specific Considerations

The review documented persistent gender gaps in STEM self-efficacy, with female students beginning with lower baseline confidence despite equivalent or superior performance. Interventions that explicitly addressed stereotype threat showed enhanced effectiveness for female students. The importance of female role models was consistently demonstrated across studies.

Intersectionality emerged as a critical consideration often overlooked in earlier research. Female minority students face compounded challenges from multiple intersecting stereotypes and require interventions that acknowledge and address this complexity.

Race and Ethnicity-Specific Considerations

The review revealed that minority students benefit substantially from growth mindset interventions, particularly when these interventions are embedded within comprehensive programs addressing multiple barriers to STEM success. Culturally responsive approaches that connected STEM learning to students' communities and values showed enhanced effectiveness.

For African American students, interventions emphasizing the social justice applications of STEM and providing opportunities to see STEM as a tool for community empowerment produced stronger engagement. For Hispanic/Latino students, family engagement and recognition of linguistic diversity enhanced outcomes.

Implementation Quality and Sustainability

A consistent finding across studies was the critical importance of implementation quality. Interventions delivered with high fidelity by trained facilitators in supportive environments produced substantially larger effects than those implemented poorly or in hostile contexts. The finding that effects often faded over time unless sustained through ongoing practices underscores the need for systemic, long-term commitments rather than one-time interventions.

Integration with Other Interventions

The finding that comprehensive multi-component interventions produced the strongest effects suggests that growth mindset training is most powerful when combined with complementary strategies. Effective comprehensive programs typically included:

- Academic preparation and skill-building
- Mentorship and social support
- Career exposure and relevance
- Financial and material resources

This multi-pronged approach recognizes that students face both psychological barriers (low self-efficacy, stereotype threat) and structural barriers (inadequate preparation, lack of resources).

Broader Implications for STEM Equity

This review's findings contribute to ongoing debates about strategies for diversifying STEM. While growth mindset interventions show promise, they are clearly not sufficient on their own to address the deep-rooted inequities in STEM education and careers. Growth mindset interventions should not be used as cheap substitutes for more fundamental reforms such as improving K-12 STEM education quality, increasing diversity among STEM faculty, reforming discriminatory policies, or addressing socioeconomic inequalities.

The most successful interventions reviewed here were those that combined attention to students' psychological experiences with concrete supports and systemic changes. This integration represents a promising path forward.

6. Conclusion

This systematic review examined the impact of growth mindset interventions on STEM self-efficacy among female and minority high school students, synthesizing evidence from 94 empirical studies published between 2013 and 2025. The findings demonstrate that growth mindset interventions can effectively enhance STEM self-efficacy and related outcomes for underrepresented students, with the strongest effects observed for comprehensive, multi-component programs that integrate psychological training with academic support, mentorship, and institutional reforms.

The research establishes several key conclusions. First, growth mindset interventions are most effective when embedded within supportive educational environments that reinforce growth-oriented messages through teacher practices, peer norms, and institutional policies. Second, intervention effectiveness varies by implementation quality, with high-fidelity implementations producing substantially larger benefits than poorly executed versions. Third, female and minority students benefit from interventions that explicitly address stereotype threat, provide matched role models and mentors, and employ culturally responsive approaches.

The mechanisms through which growth mindset interventions operate are multifaceted, including reduced

stereotype threat, increased help-seeking behavior, enhanced sense of belonging, and more adaptive attributional patterns. However, the effectiveness of these mechanisms depends critically on contextual factors.

Despite promising findings, important limitations remain. The evidence base varies in methodological quality, with some studies exhibiting significant risks of bias. Publication bias may lead to overestimation of effects. Most research focuses on relatively short-term outcomes, leaving questions about long-term impact on STEM career trajectories.

Moving forward, the field needs more rigorous, long-term research examining sustained effects of growth mindset interventions on ultimate STEM outcomes. Research should attend more carefully to intersectional identities and the unique challenges faced by students navigating multiple marginalized identities.

Most fundamentally, growth mindset interventions should be understood as valuable but insufficient tools for achieving STEM equity. They work best when part of comprehensive efforts that address not only individual psychology but also interpersonal relationships, institutional practices, and structural inequalities. The goal is not simply to help underrepresented students develop resilience to navigate inhospitable environments, but to transform those environments to become genuinely inclusive and equitable for all students.

The persistent underrepresentation of women and minorities in STEM reflects complex, interconnected challenges requiring multi-level solutions. Growth mindset interventions can contribute meaningfully to addressing these challenges by enhancing students' confidence, motivation, and persistence in STEM domains. When thoughtfully designed, carefully implemented, and integrated with broader equity initiatives, these interventions help bridge the STEM gap and move closer to the goal of a diverse, inclusive scientific workforce.

7. Limitations

This systematic review, while comprehensive, has several limitations that should be considered when interpreting the findings.

Methodological Limitations

Search Strategy and Inclusion Criteria

Despite employing comprehensive search strategies across multiple databases, some relevant studies may have been inadvertently omitted. The restriction to English-language publications may introduce geographic and cultural bias, potentially overrepresenting Western contexts.

Publication Bias

Publication bias represents a significant concern. Studies reporting positive, statistically significant findings are more likely to be published than those reporting null or negative results. This bias may lead to overestimation of intervention effectiveness.

Heterogeneity and Comparability

The substantial heterogeneity across studies in intervention design, implementation, population characteristics, outcome measures, and methodological approaches limited the ability to conduct precise quantitative meta-analyses. Differences in how key constructs were measured present particular challenges.

Quality of Primary Studies

The methodological quality of included studies varied considerably. Many primary studies exhibited risks of bias from self-selection, lack of appropriate control groups, insufficient blinding, small sample sizes, and inadequate statistical power.

Conceptual and Measurement Limitations

Self-Report Measures

The majority of studies relied heavily or exclusively on self-report measures of self-efficacy, which are subject to social desirability bias, response biases, and limited insight into unconscious processes.

Construct Validity

Questions about the construct validity of growth mindset measures have been raised in the broader literature. Some commonly used measures may conflate growth mindset with related but distinct constructs such as learning goals, persistence, or optimism.

Temporal Limitations

Most studies assessed outcomes relatively soon after interventions concluded. The relatively short timeframes make it difficult to distinguish durable mindset changes from temporary excitement or Hawthorne effects.

Sample and Population Limitations

Representativeness

The representativeness of samples within female and minority groups varied. Some studies used convenience samples from specific schools or programs, which may not generalize to broader populations.

Geographic Concentration

The majority of studies were conducted in the United States, limiting understanding of how findings might generalize to non-Western contexts with different cultural values, educational systems, and gender/racial dynamics.

Intersectionality

While the review attempted to examine intersectional identities, many primary studies did not disaggregate results sufficiently to examine how multiple marginalized identities interact.

Within-Group Diversity

Broad racial/ethnic categories encompass substantial within-group diversity. Studies using these broad categories may obscure important variation.

Analytical and Interpretive Limitations

Causality and Mechanism

While many studies employed experimental or quasi-experimental designs, fewer studies rigorously tested hypothesized mechanisms through mediation analyses. Complex interventions with multiple components make it difficult to determine which specific elements drive effects.

Moderator Analyses

Many potentially important moderators were not consistently measured or reported, preventing systematic examination.

Researcher Perspectives
The researchers conducting this review bring their own theoretical commitments and interpretive lenses that inevitably shape the synthesis.

Scope Limitations
Intervention Focus
By focusing specifically on growth mindset interventions, this review necessarily excluded other promising approaches to enhancing STEM self-efficacy.

Outcome Focus
The review prioritized self-efficacy as the primary outcome. Other potentially important outcomes such as mental health, overall well-being, or satisfaction received less systematic attention.

Educational Level
The focus on high school students means that insights about elementary or college-level interventions were not systematically examined.
These limitations do not negate the value of the review's findings but do require cautious interpretation and application. Practitioners and policymakers should view growth mindset interventions as promising tools while recognizing that their effectiveness depends on thoughtful design, quality implementation, and integration with comprehensive equity efforts.

8. Practical Implications
The findings of this systematic review offer several actionable implications for educators, administrators, policymakers, and researchers working to enhance STEM equity and inclusion.

For Classroom Teachers
1. Adopt Growth Mindset-Supportive Instructional Practices
Teachers can create growth-oriented classroom cultures by:
- Praising students' effort, strategies, and improvement rather than innate ability or talent
- Framing challenges and struggles as normal parts of learning
- Providing opportunities for students to revise and improve their work
- Sharing stories of scientists' and mathematicians' failures and iterative processes
- Using process-focused feedback that specifies what students did well and how they can improve

2. Explicitly Address Stereotype Threat
Teachers can reduce stereotype threat by:
- Teaching students about stereotype threat and how situational factors affect performance
- Establishing high expectations for all students while providing support
- Creating environments where diverse perspectives and approaches are valued
- Avoiding language that inadvertently activates stereotypes
- Highlighting diverse role models in curricular materials

3. Build Inclusive Learning Communities
Teachers can foster sense of belonging by:
- Learning about students' backgrounds, interests, and experiences
- Incorporating collaborative learning structures
- Establishing classroom norms that value all students' contributions
- Intervening promptly when bias or discrimination occurs
- Creating opportunities for students to see connections between STEM and their communities

4. Provide Exposure to Diverse STEM Role Models
Teachers can facilitate role model exposure by:
- Inviting guest speakers from diverse STEM careers
- Using curricular materials highlighting contributions of women and minorities
- Sharing videos featuring diverse STEM professionals
- Emphasizing that role models' success came through learning and persistence

For School and District Administrators
1. Invest in High-Quality Professional Development
Administrators should:
- Provide sustained professional learning opportunities on growth mindset principles
- Go beyond one-time workshops to include ongoing coaching
- Ensure professional development includes specific, actionable instructional strategies
- Create professional learning communities for teachers
- Allocate sufficient resources

2. Examine and Revise Institutional Policies and Practices
Administrators should audit school policies for alignment with growth mindset principles:
- Review tracking and ability grouping practices
- Examine grading policies and consider alternatives to competitive grading
- Ensure equitable access to advanced STEM courses
- Create pathways for students who start behind to catch up
- Establish accountability systems that value growth and improvement

3. Create Comprehensive Support Systems
Rather than isolated interventions, administrators should develop integrated support systems including:
- Academic support resources (tutoring, study groups)
- Mentorship programs
- Career exploration opportunities
- Social-emotional support
- Family engagement initiatives

4. Use Data to Monitor Equity
Administrators should:
- Collect and analyze data disaggregated by demographics
- Identify disparities and target interventions
- Monitor implementation fidelity and outcomes
- Use continuous improvement cycles

For Policymakers

1. Fund Evidence-Based Programs

Policymakers should:

- Allocate resources to programs with demonstrated effectiveness
- Prioritize comprehensive, sustained interventions
- Require rigorous evaluation of funded programs
- Support scaling with attention to implementation quality
- Invest in professional development infrastructure

2. Address Systemic Barriers

Policymakers must recognize that psychological interventions alone are insufficient:

- Increase funding for K-12 STEM education in under-resourced schools
- Support recruitment and retention of diverse STEM teachers
- Ensure all students have access to high-quality STEM curriculum
- Address socioeconomic inequalities
- Require demonstration of progress on STEM diversity goals

3. Promote Research-Practice Partnerships

Policymakers should:

- Fund partnerships between researchers and practitioners
- Create mechanisms for rapid translation of research into practice
- Support infrastructure for sharing best practices
- Incentivize publication of implementation details and null findings

4. Establish Accountability for Equity

Policymakers can:

- Include STEM equity metrics in accountability systems
- Require disaggregated reporting of STEM outcomes
- Incentivize rather than punish schools serving underrepresented students
- Ensure accountability systems reward growth and improvement
- Provide technical assistance for equity plan development

For Researchers

1. Conduct Rigorous, Long-Term Studies

Researchers should:

- Employ randomized controlled trials or strong quasi-experimental designs
- Include long-term follow-up to assess sustained effects
- Assess implementation fidelity
- Use validated, reliable measures
- Report results transparently, including null and negative findings

2. Examine Mechanisms and Moderators

Researchers should:

- Test hypothesized mechanisms through mediation analyses
- Systematically vary intervention components
- Examine moderators to understand boundary conditions
- Explore for whom interventions work best
- Investigate potential negative effects

3. Attend to Intersectionality and Within-Group Diversity

Researchers should:

- Recruit samples large enough to examine intersectional identities
- Avoid overly broad racial/ethnic categories
- Partner with members of target communities
- Examine how interventions function across different cultural contexts
- Give voice to students' perspectives through qualitative methods

4. Build Cumulative Knowledge

Researchers should:

- Use common measures and frameworks to facilitate comparisons
- Conduct systematic reviews and meta-analyses
- Replicate important findings in new contexts
- Share data and materials openly
- Collaborate across institutions and disciplines

For Families and Communities

For Families:

- Communicate growth mindset beliefs about STEM to children
- Encourage effort and persistence rather than praising "smartness"
- Seek out STEM enrichment opportunities
- Connect with schools to understand and reinforce STEM learning
- Share family and community members' use of STEM

For Communities:

- Provide informal STEM learning opportunities through libraries, museums, and centers
- Connect local STEM professionals with schools as mentors and speakers
- Advocate for equitable STEM education resources
- Support community organizations serving underrepresented youth
- Partner with schools on comprehensive support initiatives

Implementation Considerations

Regardless of stakeholder group, several cross-cutting principles should guide implementation:

1. Start with Self-Examination Organizations and individuals should examine their own beliefs, practices, and structures for fixed mindset messages or inequitable patterns.

2. Engage Students as Partners Students should be involved in designing, implementing, and evaluating interventions that affect them.

3. Expect Implementation Challenges Changing practices and cultures is difficult. Implementation will be imperfect initially and require ongoing refinement.

4. Integrate Rather than Isolate Growth mindset interventions should be integrated into everyday teaching and learning rather than delivered as isolated, add-on activities.

5. Measure and Learn Collect data on implementation and outcomes, use data to guide improvements, and share learnings with others.

6. Think Systemically Address multiple levels simultaneously (individual, interpersonal, institutional,

structural). Coordinated multi-level efforts produce more substantial and sustained improvements.

By translating research findings into practice through these recommendations, stakeholders can work collectively to bridge the STEM gap and create more equitable and inclusive STEM education for all students.

9. Future Research

While this systematic review synthesized substantial evidence on growth mindset interventions, important gaps remain. This section identifies key directions for future research.

Longitudinal Research on STEM Trajectories

Long-Term Outcomes

Future research should track students over extended periods—through high school graduation, college enrollment and major selection, degree completion, and career entry—to determine whether enhanced self-efficacy translates into ultimate diversification of the STEM workforce. Longitudinal studies should examine:

- Whether students who participate in interventions are more likely to pursue STEM majors and careers
- How effects persist or fade over time
- Critical junctures where students make consequential decisions
- Cumulative effects of repeated interventions versus one-time experiences

Developmental Trajectories

Research should examine how growth mindset interventions function across different developmental periods. Comparative studies would illuminate whether there are sensitive periods when interventions are most impactful.

Mechanistic and Process Research

Mediation and Moderation

More rigorous research is needed using:

- Longitudinal mediation designs with appropriate temporal spacing
- Multiple putative mediators tested simultaneously
- Investigation of moderated mediation
- Examination of psychological, behavioral, and physiological mechanisms

Micro-Process Studies

Detailed process studies examining moment-to-moment dynamics would provide insights:

- Experience sampling methods capturing students' mindset-relevant thoughts in real-time
- Observation studies documenting how teachers' practices create mindset cultures
- Discourse analysis examining how growth versus fixed mindset messages are communicated
- Ecological momentary assessment tracking how mindset beliefs fluctuate

Intersectionality and Within-Group Diversity

Intersectional Identities

Future research should systematically examine students with multiple marginalized identities:

- Recruit sufficient sample sizes to analyze outcomes for specific intersectional groups
- Examine whether interventions should be tailored differently
- Explore how privilege and oppression along multiple dimensions interact
- Give voice to students' perspectives on how their intersecting identities influence their STEM journeys

Within-Group Diversity

Research should move beyond broad demographic categories:

- Disaggregate broad categories into specific ethnic subgroups
- Examine socioeconomic diversity within racial groups
- Explore how immigration generation, language background, and acculturation influence effectiveness
- Consider LGBTQ+ students as an important underrepresented group

Cultural Adaptation and International Research

Cross-Cultural Research

International research is needed to examine:

- How growth mindset interventions function in collectivist versus individualist cultures
- Whether interventions need substantial adaptation for different cultural contexts
- How different educational systems and cultural values shape intervention effectiveness
- What successful equity interventions from other countries might teach U.S. educators

Cultural Adaptation Research

Research should explicitly test culturally adapted versus generic interventions:

- Systematic surface-level and deep-structure adaptations informed by community partnerships
- Comparative effectiveness trials testing standard versus adapted versions
- Process evaluations examining cultural appropriateness
- Community-based participatory research ensuring interventions are grounded in target communities' values

Implementation Science

Scale-Up and Sustainability

Research is needed on how to scale effective interventions:

- Effectiveness trials in real-world contexts with typical resources
- Examination of how interventions diffuse through educational systems
- Identification of core intervention components that must be preserved
- Study of factors predicting sustained implementation versus discontinuation
- Cost-effectiveness analyses comparing different intervention approaches

Implementation Fidelity

More research should examine implementation processes:

- Development and validation of fidelity measures for specific interventions
- Investigation of factors predicting high-fidelity implementation
- Examination of whether adaptations improve or

undermine effectiveness
- Professional development research identifying how to best prepare implementers

Intervention Refinement
Component Analyses
Dismantling studies would identify essential intervention elements:
- Factorial designs varying presence/absence of different components
- Comparative effectiveness trials testing competing intervention approaches
- Dose-response studies examining optimal intensity and duration
- Sequencing studies determining optimal ordering of intervention components

Technology-Enhanced Delivery
Research should explore how technology can enhance intervention delivery:
- Online and hybrid delivery models for reaching geographically dispersed students
- Adaptive interventions that personalize content based on students' characteristics
- Use of virtual reality for vicarious experiences and role model exposure
- Social media and online communities for peer support and norm shifting

Teacher and Institutional Level Interventions
Teacher Development Research
More research is needed on teacher-level interventions:
- Comparative effectiveness of different professional development approaches
- Examination of how to change deeply held teacher beliefs about intelligence
- Investigation of supports teachers need to implement practices sustainably
- Research on pre-service teacher education versus in-service professional development

Institutional Change Research
Research should examine system-level interventions:
- Whole-school reforms creating growth mindset cultures
- Policy interventions (e.g., eliminating tracking, changing grading practices)
- Leadership interventions targeting principals and administrators
- District-level initiatives and their effects cascading to schools and classrooms

Measurement and Methodology
Improved Measurement
Research should develop and validate improved measures:
- Refined growth mindset measures with stronger construct validity
- Domain-specific self-efficacy measures appropriate for diverse STEM fields
- Implicit measures capturing automatic associations and beliefs
- Behavioral measures complementing self-reports
- Measures appropriate for diverse cultural and linguistic groups

Methodological Innovation
Research should employ methodological innovations:
- Micro-randomized trials for optimizing just-in-time adaptive interventions
- Network analyses examining peer influence and norm diffusion
- Agent-based modeling simulating how interventions might operate at scale
- Natural experiments leveraging policy changes or other exogenous shocks

Equity and Social Justice Research
Critical Examinations
Research should critically examine:
- Whether growth mindset interventions inadvertently shift responsibility to individuals while obscuring systemic inequities
- How interventions can be designed to empower students for social change
- Whether interventions risk "deficit framing"
- How to balance psychological support with structural reform

Resistance and Counter-Narratives
Research should explore:
- Students' resistance to or skepticism about growth mindset messages
- How students navigate competing messages about effort and systemic barriers
- Role of critical consciousness and political awareness in STEM persistence
- How to foster both growth mindset and critical analysis of injustice simultaneously

Integration with Other Frameworks
Multi-Framework Research
Research should examine how growth mindset interventions interact with other approaches:
- Integration of growth mindset with expectancy-value, identity, and social justice frameworks
- Comparative effectiveness of growth mindset versus other psychological interventions
- Synergies and tensions between different theoretical approaches
- Development of integrative models combining insights across frameworks

Unintended Consequences
Negative Effects
Research should examine potential negative effects:
- Circumstances under which growth mindset messages might increase anxiety or self-blame
- Whether emphasis on effort could inadvertently devalue students' backgrounds and assets
- Potential for interventions to be co-opted in ways that undermine equity
- How to recognize and mitigate negative consequences when they occur

By pursuing these research directions, the field can develop more comprehensive understanding of how to effectively and ethically enhance STEM equity through growth mindset and

complementary interventions.

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