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Bridging the Gap – A Systematic Review of Retention and Attrition in STEM Education Across the Academic Pipeline

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Abstract

STEM attrition continues to undermine national innovation and educational equity, with substantial losses across educational stages. This systematic literature review (SLR) synthesises evidence from 2015 to 2025 to identify institutional, psychosocial, and demographic factors affecting STEM persistence. Drawing on Expectancy-Value Theory (EVT), Social Cognitive Career Theory (SCCT), and Self-Determination Theory (SDT), the review categorises findings into four themes: institutional and curricular interventions, psychosocial and motivational determinants, equity and intersectional moderators, and measurement and longitudinal analytics. A comprehensive search using Scopus yielded 67 high-quality, peer-reviewed articles. Methodologically, the review adhered to PRISMA 2020 guidelines, applied MMAT for appraisal, and used thematic synthesis to cluster studies. Results show that interventions such as course-based undergraduate research experiences (CUREs), culturally responsive mentoring, and predictive analytics significantly enhance retention. Psychosocial constructs like science identity, mathematical resilience, and reduced math anxiety are consistent predictors of persistence. Moreover, demographic factors such as gender, first-generation status, and LGBTQ+ identity moderate the effectiveness of interventions. Measurement tools and machine learning models contribute to early risk detection and equity monitoring. This review advances the literature by integrating disparate findings into a cohesive theoretical and empirical framework. It concludes that retention is shaped by a synergy of cognitive beliefs, supportive environments, and structural equity. Implications for policy and practice include the need for multi-level, identity-conscious interventions, improved measurement practices, and longitudinal tracking of student outcomes. Future research should adopt intersectional, culturally responsive, and methodologically rigorous approaches to build inclusive STEM ecosystems.

Keywords: STEM Retention, STEM Attrition, Science Identity, Educational Equity, Intersectionality

Introduction

The global demand for a scientifically literate workforce has intensified, yet science, technology, engineering, and mathematics (STEM) programs continue to lose sizeable cohorts of aspirants at every educational transition. From 2000 to 2025, attrition rates in community-college STEM tracks have hovered at a significant percentage (O'Hara & Sparrow, 2019), and comparable patterns of premature departure are evident in four-year institutions, postgraduate study, and early-career pipelines. Persistent shortfalls delay national innovation agendas, restrict economic competitiveness, and prolong inequities in entry to high-status, high-wage professions (Chang et al., 2014; Abramenko & Nadzan, 2024). Beyond economic costs, STEM attrition undermines global priorities such as the United Nations' Sustainable Development Goals, which depend on technological innovation and scientific expertise to tackle urgent challenges in health, energy, and the environment. These realities make STEM attrition not merely an educational concern but a matter of social justice and workforce sustainability.

The issue is particularly pressing for countries striving to compete in knowledge-based economies, where human capital in STEM fields is directly linked to technological advancement and national security. Employers consistently report difficulties in recruiting qualified STEM graduates, leading to talent shortages that affect industries ranging from digital technologies to biomedical research. For students, attrition narrows opportunities to access careers that provide not only financial stability but also avenues for social mobility. As such, the stakes of understanding and addressing STEM attrition extend across multiple stakeholders: students whose futures are directly shaped by persistence, educators and institutions tasked with designing supportive environments, employers reliant on a steady stream of skilled professionals, and policymakers seeking to maintain national competitiveness.

A growing body of studies focuses on the psychosocial dimensions that underlie students' decisions to persevere or depart. Constructs such as sense of belonging, which is the subjective perception of being accepted and valued by the academic community, have repeatedly emerged as decisive predictors of persistence (Good et al., 2012; London et al., 2011). STEM identity, or the degree to which individuals view themselves as qualified participants in scientific endeavours, likewise exerts a formative influence by strengthening motivation and framing academic challenges as manageable (Freeman, 2020; Belser et al., 2017). Equally salient is self-efficacy, which is a belief in one's capability to succeed, and has been experimentally increased through targeted interventions with demonstrable reductions in attrition (Sage et al., 2018).

Despite recent advances, students who are women, from racially marginalised groups, or from low-income backgrounds continue to leave STEM programs at higher rates (Brown et al., 2022). Intersectional analyses reveal that the convergence of gender, race, and SES produces cumulative disadvantages: inadequate academic preparation, stereotype threat, and diminished self-concept add up and cause students to leave STEM (Chang et al., 2014; Freeman, 2020). The COVID-19 pandemic further magnified these inequities, eroding confidence and belonging among already vulnerable sub-populations while leaving their more privileged peers comparatively unharmed (Brown et al., 2022). Accordingly, addressing attrition necessitates both macro-level reform of institutional cultures and micro-level supports finely attuned to heterogeneous student experiences.

Studies have documented a wide range of institutional strategies aimed at improving STEM student retention. Mentorship connects new students with experienced role models, tutoring and coaching help build academic skills, and inclusive curricula support students from diverse backgrounds (Ghazzawi et al., 2021; Freeman, 2020; Sprowles et al., 2023). While many of these approaches yield promising short-term gains, systematic syntheses reveal uneven methodological rigour and inconsistent reporting of long-term outcomes, limiting their generalisability (Garibay & Teasdale, 2019). Moreover, most studies do not disaggregate intervention results by student background, making it unclear whether so-called successful programs mainly benefit those already in advantaged positions.

Research on what influences STEM retention has grown quickly, but consistent and reliable ways to measure these factors are still lacking. Validated instruments such as the STEM Culture Assessment Tool (STEM-CAT) demonstrate the power of psychometric rigour in diagnosing cultural impediments to persistence (White et al., 2019). Still, the field lacks consistency: researchers define self-efficacy, belonging, and task value in different ways, making studies hard to compare, and few tools are tested across cultures. Earlier reviews recommend developing a shared measurement plan that combines psychological, institutional, and demographic factors in long-term studies (Belser et al., 2017; Li et al., 2020).

Despite the proliferation of primary research, recent meta-analyses highlight enduring knowledge gaps. There is little long-term research tracking students through different stages of education, which makes it difficult to understand how early experiences shape future outcomes (Gao et al., 2020). Many studies treat student background traits like gender or race as isolated factors rather than as interconnected systems (Moore et al., 2022). Moreover, not enough qualitative research explores students' lived experiences behind the data (Rowland et al., 2019). These limitations constrain the ability of policymakers and educators to design evidence-based interventions that are both equitable and effective.

Against this backdrop, the present systematic literature review (SLR) aims to bridge the gap by synthesising evidence on retention and attrition across the entire STEM educational pipeline. This study integrates psychological theory, institutional practice, and demographic context within a comprehensive, intersectional lens. Specifically, we (a) catalogue psychosocial and structural predictors of persistence, (b) evaluate the methodological quality and cultural responsiveness of measurement instruments, (c) map effect sizes across demographic intersections and transition points, and (d) articulate an evidence-informed agenda for future research and practice.

Methodologically, our review adheres to PRISMA 2020 guidelines and employs a rigorous search strategy encompassing a single database, Scopus. Inclusion criteria extend from 2015 to 2025 to capture contemporary shifts in policy and pedagogy. We apply the Mixed Methods Appraisal Tool (MMAT) to rate study quality. Intersectional sub-group analyses illuminate how gender, race/ethnicity, SES, and other identities condition the impact of psychosocial and institutional factors—a dimension largely absent from prior syntheses (Thibaut et al., 2018).

This SLR makes three main contributions. First, by covering K–12, university, and early-career stages, it outlines when students are most likely to leave STEM and where interventions can be most effective. Second, it reviews the strengths and gaps in measurement tools, helping researchers choose or develop better instruments, especially ones that work across cultures. Third, it highlights the importance of equity by asking which students benefit from different interventions, helping guide policies that aim to diversify STEM fields. The findings therefore hold practical significance for educators designing targeted supports, for institutional leaders shaping inclusive cultures, and for policymakers tasked with aligning workforce development with equity and innovation goals.

The remainder of this article proceeds as follows. Section 2 details our methods, including search strategy, screening procedures, and quality assessment protocols. Section 3 situates the review within established theoretical frameworks—Expectancy-Value Theory, Social Cognitive Career Theory, and Self-Determination Theory. Section 4 synthesises findings across four themes: (1) institutional and curricular interventions, (2) psychosocial and motivational determinants, (3) equity and intersectional moderators, and (4) measurement, analytics, and longitudinal pathways. Section 5 discusses the implications of these findings for practice, policy, and theory, and Section 6 concludes by outlining urgent research priorities.

This review thus brings together fragmented strands of research to provide a comprehensive understanding of what influences STEM persistence, and in doing so, offers actionable insights for building more inclusive and effective STEM education systems that benefit students, institutions, and societies at large.

Methodology

This review adhered to a systematic methodology guided by established protocols in the domain of educational research. The procedures employed were consistent with international standards for conducting rigorous and transparent systematic literature reviews (SLRs), including adherence to the PRISMA 2020 guidelines. The section below outlines the methodological steps undertaken to ensure replicability, validity, and comprehensiveness in selecting and appraising literature on STEM retention and attrition across the academic pipeline.

Search Strategy

We implemented a structured search protocol using a single electronic academic database: Scopus. The search covered the period from January 2015 to July 2025, a range selected to capture developments in STEM education following major global educational reforms and the increasing focus on STEM workforce development. Search terms were iteratively developed and refined based on preliminary scoping reviews and expert consultation. The final Boolean string was:

("Factors" AND ("STEM attrition" OR "STEM persistence" OR "STEM retention" OR "STEM engagement") AND NOT "stem cell")

This string ensured broad coverage of studies relevant to psychosocial, institutional, and demographic factors influencing student outcomes across STEM disciplines. We limited the scope to English-language, peer-reviewed journal articles to ensure quality and relevance.

Inclusion and Exclusion Criteria

In line with best practices outlined in the literature (Darbyshire et al., 2021; Cech, 2022), we developed criteria to ensure consistency and relevance across included studies. Studies were included if they:

- Focused explicitly on STEM-related disciplines;
- Reported empirical data (quantitative, qualitative, or mixed-method);
- Examined retention, persistence, or attrition across any stage of the STEM academic pipeline;
- Were published between 2015 and 2025 in peer-reviewed journals;
- Included data on at least one psychosocial, institutional, or demographic factor related to STEM retention.

We Excluded

- Editorials, opinion pieces, or anecdotal reports without empirical basis;
- Studies without a clear definition or operationalisation of attrition/retention outcomes;
- Articles focused exclusively on biomedical or “stem cell” contexts.

Special attention was given to the inclusion of studies with diverse demographic representations, reflecting a recent trend toward intersectionality in STEM education research (Alexiades et al., 2021; Heard et al., 2023; Wang et al., 2019).

Screening and Selection Process

Screening followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol (Mashwama & Omodan, 2024). Based on the final Boolean string 117 publications were listed for further analysis. The publications were limited to specific subject areas which are social science and psychology, which resulted the elimination of 33 publications, leaving another 84 publications for the next round of screening. Next, only journal articles were considered for the articles review processes, leaving the final articles to be 67. All retrieved articles were imported into reference management software, and duplicates were removed. Titles and abstracts were independently screened by two reviewers to assess eligibility. Discrepancies were resolved through discussion or consultation with a third reviewer. Articles deemed eligible at this stage were retrieved in full for detailed assessment against the inclusion criteria.

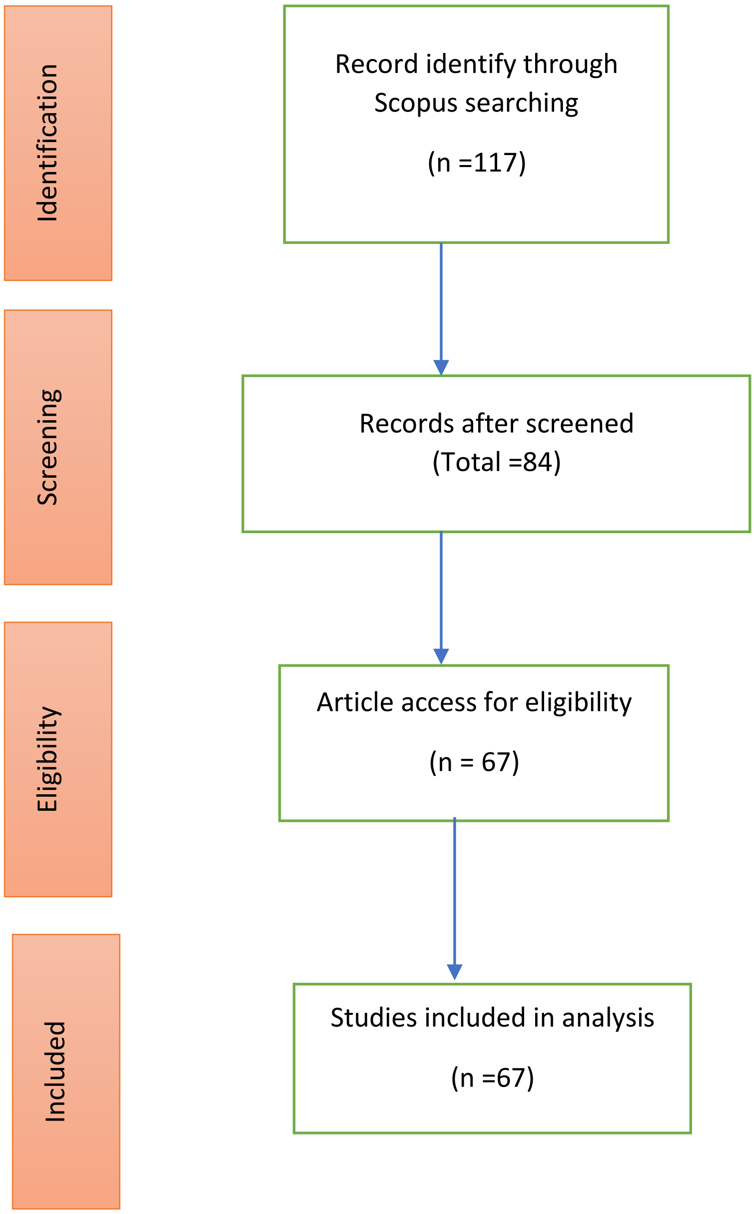

Figure 1. Flow diagram of the proposed search study

Quality Appraisal

To evaluate methodological rigour, we employed the Mixed Methods Appraisal Tool (MMAT), which allows assessment across various research designs (Hong et al., 2018; Hong et al., 2019). MMAT's flexibility makes it particularly suited to STEM education research, where studies often involve mixed methods and diverse outcome measures (Tabriz et al., 2023).

Each included study was scored against five design-specific criteria corresponding to its methodological category. For mixed-methods studies, both qualitative and quantitative components were appraised. Studies scoring 3 or higher out of 5 were considered of moderate to high quality. All scores were reviewed collaboratively to ensure inter-rater consistency.

Data Extraction and Thematic Synthesis

A coding template was developed to extract key information from each study, including:

- Author(s) and publication year.
- Country and educational context.
- Research design and methodology.
- Constructs measured (e.g., self-efficacy, belonging).
- Type of intervention (if applicable).
- Demographic characteristics of the sample
- Outcomes related to retention, persistence, or attrition.

The extracted data were then organised into four major themes, as detailed in Section 4: (1) institutional and curricular interventions; (2) psychosocial and motivational determinants; (3) equity, intersectionality, and demographic moderators; and (4) measurement, analytics, and longitudinal pathways. Thematic clustering was conducted through an iterative inductive-deductive coding process involving constant comparison and cross-validation.

Limitations of Methodology

Although this review employed rigorous procedures, limitations remain. First, only English-language peer-reviewed literature was included, potentially excluding relevant findings published in other languages or formats. Second, the heterogeneity of definitions and instruments used across studies posed challenges for direct comparison and meta-analysis. Third, while our search string was comprehensive, it may not have captured every relevant study due to terminological variability in the field. Future reviews might explore the utility of AI-enhanced or citation-based search expansions to mitigate this risk.

Nonetheless, through adherence to robust frameworks and application of comprehensive tools, the methodological integrity of this review supports its capacity to generate meaningful, generalisable, and actionable insights into the enduring challenge of STEM attrition.

Theoretical Background

To fully understand why students leave or stay in STEM, we need strong theories that explain how motivation, identity, and learning environments work together. This section presents a multi-theoretical framework integrating Expectancy-Value Theory (EVT), Social Cognitive Career Theory (SCCT), and Self-Determination Theory (SDT), each offering unique insights into how psychosocial, cognitive, and contextual factors shape students' persistence in STEM. These perspectives not only explain variance in student behaviour but also provide conceptual foundations for the interventions and constructs explored throughout this systematic literature review.

Expectancy-Value Theory (EVT)

Expectancy-Value Theory posits that students' academic choices and effort are influenced by their beliefs about how well they will do on a task (expectancy) and the extent to which they value the task (value) (Greene et al., 2023). In STEM contexts, this theory clarifies why students invest effort in science, technology, engineering, or mathematics courses—they must believe they can succeed and that the task is worth pursuing. The theory further differentiates value into four categories: intrinsic value (interest), attainment value (personal importance), utility value (usefulness for future goals), and cost (perceived negative aspects of engaging in the task).

Empirical studies validate that high expectancy and value beliefs correlate strongly with persistence in STEM disciplines. Appianing and Eck (2018) and Lawson and Fong (2024) demonstrate that students who perceive high utility and attainment value in STEM subjects, coupled with confidence in their abilities, exhibit stronger intentions to persist. Instruments like the Value-Expectancy STEM Assessment Scale (VESAS) provide quantitative tools to measure these constructs, particularly among under-represented groups such as women in STEM. VESAS highlights motivational beliefs linked to gender disparities in persistence (Appianing & Eck, 2018).

Lee and Song (2022) further stress that perceptions of real-world applicability—the utility value—can be a decisive factor in career commitment. This is especially relevant for high-achieving students who weigh opportunity costs. Moreover, qualitative studies enrich this understanding by examining how students construct meaning around STEM value, often linking it to identity and social mobility (Kuchumova et al., 2024).

STEM Identity and Measurement Approaches

STEM identity refers to how strongly individuals view themselves as belonging to the STEM community. This identity shapes academic engagement and long-term career aspirations. Researchers have operationalised identity using both psychometric and qualitative instruments. VESAS, for instance, indirectly measures aspects of STEM identity by linking value and expectancy constructs to future intentions (Appianing & Eck, 2018). The STEM Motivation Scale developed by Açıksöz et al. (2024) expands this approach for middle school students, offering insight into early identity formation.

STEM identity is especially critical in explaining gender and racial disparities. Han et al. (2021) found that stronger science identity in adolescence correlates with persistence into STEM majors. Kuchumova et al. (2024) suggest that narrative and interview methods reveal nuanced identity construction processes among minoritised students, highlighting perceived dissonance between personal identity and dominant STEM culture. Such findings underscore the need to validate instruments across diverse contexts and to complement them with qualitative inquiry.

Social Cognitive Career Theory (SCCT)

SCCT provides a complementary lens to EVT by emphasising self-efficacy, outcome expectations, and goal-setting processes in career development (Iroaganachi et al., 2021). Self-efficacy refers to one's belief in their ability to succeed in specific tasks and is shaped by personal experiences, vicarious learning, and social persuasion.

Iroaganachi et al. (2021) showed that self-efficacy mediates career intentions among junior secondary school girls, especially when encouraged by supportive social environments. Similarly, Nugent et al. (2015) found that self-efficacy is a consistent predictor of engagement in STEM learning activities. Zhao et al. (2022) reinforce this by demonstrating how inclusive classrooms that reinforce mastery experiences enhance both self-efficacy and long-term commitment to STEM.

Longitudinal findings support SCCT's pathways. Wong (2023) and Hernandez et al. (2018) illustrate how outcome expectations influence goal setting, which in turn predicts persistence. Hernandez et al. (2018) also emphasise that early mentorship contributes to stronger self-efficacy and science identity development. Estrada et al. (2018) reinforce this by showing that persistent students often begin with formative identity-affirming experiences and maintain high self-efficacy through academic transitions.

SCCT also accounts for the role of environmental and demographic factors. Subotnik et al. (2019) show that students from disadvantaged backgrounds can succeed when self-efficacy is reinforced through structured supports. This highlights that effective interventions must not only target beliefs but also the contexts in which those beliefs develop.

Self-Determination Theory (SDT)

Self-Determination Theory provides a macro-level perspective on student motivation, positing that individuals are most motivated when their needs for autonomy, competence, and relatedness are met (Lu et al., 2022). In STEM classrooms, relatedness, which is the feeling of social connection, plays a pivotal role in shaping intrinsic motivation.

Belongingness, or the perception of being accepted and valued in one's learning environment, is a critical motivator, especially for women and minority students in STEM. Lu et al. (2022) found that instructor support and peer connection significantly enhance autonomous motivation. Pyne et al. (2023) similarly highlight that relational pedagogy predicts both engagement and satisfaction. Good et al. (2012) identified that a sense of belonging is predictive of mathematics persistence for female students, linking emotional safety to academic risk-taking.

Intervention studies further underscore SDT's applicability. Wilton et al. (2019) redesigned introductory STEM courses to promote interaction and found that belonging improved significantly alongside course grades. Benita et al. (2019) and Abu-Asbeh (2017) show that inclusive teaching practices, mentorship, and family engagement enhance students' sense of connection, promoting intrinsic motivation and reducing dropout. Kepple and Coble (2020) demonstrate how structured lab partnerships can foster belonging in physics, especially for women and minoritised students.

Synthesising Frameworks: An Integrated Model for STEM Retention

Together, EVT, SCCT, and SDT offer a comprehensive explanation for why students persist or disengage from STEM pathways. EVT explains how value perceptions and expectancies predict motivation. SCCT elaborates how these beliefs evolve into career intentions via self-efficacy and social supports. SDT contextualises these processes by highlighting the foundational role of classroom climate and interpersonal relationships.

Crucially, all three frameworks recognise that individual trajectories are shaped by broader social structures. Intersectional identities—such as gender, race, and first-generation status—moderate how these motivational mechanisms unfold. Thus, effective interventions must operate across multiple levels: fostering positive beliefs (EVT, SCCT), supporting social-emotional needs (SDT), and addressing structural barriers.

This integrated theoretical foundation informs the analytic framework of the present review. As discussed in Section 4, the review maps studies across four themes: institutional interventions, psychosocial determinants, equity moderators, and measurement approaches. Each is interrogated through the lens of these frameworks to identify patterns, gaps, and leverage points for intervention.

By combining theory and evidence, we aim not only to synthesise findings but to offer a conceptual roadmap for future research, practice, and policy aimed at transforming the STEM education landscape into a more inclusive and enduring domain.

Review of Themes/Findings

Institutional and Curricular Interventions

The first theme in this systematic review synthesises findings on institutional and curricular interventions designed to promote persistence and reduce attrition in STEM education. This section analyses four key subthemes: (i) Course-Based Undergraduate Research Experiences (CUREs), (ii) early alert analytics vs. traditional mentoring, (iii) curriculum reform, and (iv) service-based scholarship programs. These interventions reflect core views of Expectancy-Value Theory (EVT), Social Cognitive Career Theory (SCCT), and Self-Determination Theory (SDT), providing insight into how institutional strategies shape students' motivation, identity, and belonging within STEM environments.

Course-Based Undergraduate Research Experiences (CUREs)

CUREs have emerged as one of the most promising interventions for enhancing student retention in STEM disciplines. Rodenbusch et al. (2016) found that early participation in CUREs significantly increased graduation rates in science and engineering, suggesting that authentic research engagement nurtures both cognitive and affective commitment to STEM learning. These findings resonate with the utility value dimension of EVT, as students perceive real-world relevance in their coursework (Greene et al., 2023).

Hanauer et al. (2017) further underscore the inclusivity potential of CUREs, particularly for students historically underrepresented in research settings. By lowering barriers to entry and embedding research into the curriculum, CUREs support identity formation aligned with both EVT and SCCT—enhancing self-efficacy, perceived task value, and science identity. Burmeister et al. (2023) reinforce these findings by documenting that well-designed CURE networks offer equitable access and long-term retention benefits. The widespread impact of CUREs across contexts confirms their effectiveness in creating epistemologically inclusive learning spaces that motivate students to persist (Table 1).

Early Alert Analytics Versus Traditional Mentoring

Comparative evaluations between early alert systems and mentoring reveal differentiated strengths. Pellagatti et al. (2021) demonstrate that predictive analytics can proactively identify at-risk students, enabling institutions to intervene early with tailored academic support. These systems align with SDT's emphasis on competence and structure, providing students with scaffolded support before disengagement occurs.

In contrast, traditional mentoring—despite limitations in scalability—fosters relational depth. Richmond et al. (2018) note that mentor quality significantly moderates impact, with high-quality mentoring enhancing belonging and motivation, consistent with SDT and SCCT. While early alert systems offer data-driven scalability, mentoring promotes self-efficacy and relatedness. A hybridised approach, integrating predictive precision with personalised support, may yield synergistic benefits for persistence (Table 1).

Curriculum Reform and Active Learning

Curricular reform efforts, including studio calculus and inquiry-based instruction, consistently yield higher persistence rates in STEM. Wu et al. (2024) find that collaborative learning environments enhance students' sense of belonging—a central tenet of SDT—and promote motivation through social engagement. Similarly, Lin et al. (2024) show that competency-based frameworks foster autonomy by allowing students to progress at their own pace, reflecting SDT's need for self-direction.

Active learning strategies, such as problem-based learning, promote deeper cognitive processing and intrinsic value. Theobald et al. (2020) demonstrate that active learning methods increase motivation and persistence, especially for underrepresented groups. These reforms also resonate with SCCT, supporting mastery experiences that build self-efficacy. The literature affirms that curriculum design significantly shapes motivational beliefs, identity development, and retention outcomes (Table 1).

Service-Based Scholarship Programs

Service-based scholarship programs like STEP and Noyce serve dual purposes: financial support and structured professional engagement. Garibay and Teasdale (2019) document that service-based scholarship programs improve retention by combining academic advising, mentoring, and fieldwork within culturally responsive frameworks. These features reinforce both SCCT's goal-setting pathway and EVT's utility value dimension, as students see tangible connections between education and future careers.

Sheng-quan (2023) and Miriti (2019) emphasise that service commitments—such as teaching in underserved schools—promote career purpose and community belonging, advancing SDT's principle of relatedness. Vergel et al. (2018) further report that alumni engagement sustains long-term commitment to STEM, suggesting that relational and professional networks are key to retention. In total, these programs support holistic development and align with the theoretical frameworks discussed in Section 3, offering a replicable model for sustainable STEM engagement (Table 1).

Implications and Synthesis

The findings in Section 4.1 affirm the central hypothesis that institutional and curricular interventions, when aligned with motivational and social-cognitive constructs, significantly enhance STEM persistence. CUREs and curricular reforms particularly leverage EVT and SDT by boosting students' perceived value and intrinsic motivation. Early alert systems and mentoring enhance SCCT outcomes by strengthening self-efficacy and outcome expectations, while service-based scholarships integrate multiple theoretical dimensions by fostering utility, identity, and belonging.

Collectively, the interventions summarised in Table 1 underscore the importance of multi-level supports. Programs that simultaneously address pedagogical design, academic structure, and socioemotional needs are most effective. However, future work must incorporate intersectional analyses to ensure that such interventions yield equitable outcomes across gender, race, and socioeconomic status. As shown throughout the review, retention gains are not just products of academic content but of the environments, relationships, and supports that shape students' academic journeys.

Table 1
Summary of Institutional and Curricular Interventions in STEM Retention

Author (Year)	Educational Stage	Intervention Type	Target Population	Study Design	Retention Outcome
Rodenbusch et al. (2016)	Undergraduate	CURE	General	Quasi-experimental	Increased graduation rates
Hanauer et al. (2017)	Undergraduate	CURE	Underrepresented	Qualitative	Higher engagement and persistence
Burmeister et al. (2023)	Mixed	CURE Network Design	Diverse	Comparative	Design improvements enhance equity
Pellagatti et al. (2021)	Undergraduate	Early Alert Analytics	General	Institutional Data	Reduced first-year dropout
Richmond et al. (2018)	Undergraduate	Mentoring	General	Survey-based	Effectiveness varies by mentor quality
Wu et al. (2024)	Undergraduate	Studio Calculus Reform	General	Longitudinal	Improved sense of belonging and retention
Lin et al. (2024)	Postsecondary	Competency-Based Curriculum	General	Case study	Increased motivation and persistence
Theobald et al. (2020)	Undergraduate	Active Learning Strategies	Underrepresented	Experimental	Improved engagement and course completion
Garibay & Teasdale (2019)	Undergraduate	STEP Scholarship Program	Low-income/STEM	Mixed-methods	Increased graduation and STEM workforce entry
Sheng-quan (2023)	Postsecondary	Service-Based Commitment	Diverse	Descriptive	Strengthened career commitment and retention
Miriti (2019)	Undergraduate	Noyce Scholarship Program	Diverse	Case-based	Enhanced STEM career intent
Vergel et al. (2018)	Postgraduate	Alumni Engagement Initiatives	Graduates	Longitudinal	Sustained STEM career participation

Psychosocial and Motivational Determinants

Psychosocial and motivational determinants play a pivotal role in shaping students' commitment to STEM disciplines. Drawing from the theoretical underpinnings in Section 3—

namely Expectancy-Value Theory (EVT), Social Cognitive Career Theory (SCCT), and Self-Determination Theory (SDT)—this section synthesises empirical findings across four key constructs: science identity, mathematical resilience, math anxiety, and motivational models of retention. The studies reviewed in Table 2 support the hypothesis that psychosocial attributes, especially those tied to self-perception and affective engagement, strongly mediate students' persistence in STEM pathways.

Science Identity and STEM Career Intentions

Science identity has emerged as a significant predictor of STEM career trajectories. As theorised in EVT and SCCT, identity serves both motivational and developmental functions, influencing how students interpret their capacity for success and the relevance of STEM to their personal goals (Greene et al., 2023; Iroaganachi et al., 2021). González-Nucamendi et al. (2023) demonstrate that identity salience—how central science is to a student's self-concept—is associated with increased intentions to pursue graduate-level STEM education. This is particularly salient when students participate in identity-affirming enrichment programs that expose them to authentic STEM practices.

Mentorship plays a complementary role in reinforcing identity. Byars-Winston and Rogers (2019) found that students who are publicly recognised as scientists by mentors report stronger intentions to pursue STEM careers. These findings align with SCCT's emphasis on self-efficacy development through social reinforcement and outcome expectations. Dou et al. (2019) extend this by showing that early informal experiences—such as family discussions or exposure to science in childhood—initiate identity formation processes that persist into higher education.

As summarised in Table 2, identity-enhancing interventions produce significant motivational shifts, highlighting the importance of developing a coherent STEM identity early in the academic pipeline.

Mathematical Resilience and Success in Prerequisite Courses

Mathematical resilience refers to a student's capacity to persist through difficulty in mathematics without disengagement or loss of confidence. Within EVT, this construct relates to expectancy beliefs and cost appraisals, while in SCCT, it reflects a protective form of self-efficacy.

Heiny et al. (2015) and Bahar and Maker (2020) both identify strong positive correlations between mathematical resilience and pass rates in gateway courses such as Calculus I and engineering physics. These studies underscore that affective responses to academic difficulty—not just prior achievement—are central to success in demanding STEM subjects.

Harrington et al. (2016) demonstrate that targeted interventions, such as tutoring and mentorship, can bolster mathematical resilience among at-risk students. The results indicate that resilience-enhancing strategies may offer a scalable and equity-oriented response to the widespread attrition in early STEM coursework. As noted in Table 2, mathematical resilience plays a critical buffering role, reducing dropout by fostering perseverance and positive academic emotions.

Math Anxiety and Engineering Major Intentions

Math anxiety is a well-documented psychological barrier to STEM persistence (Moussa & Salali, 2022). SDT frames this phenomenon as a thwarting of autonomy and competence needs, leading to motivational deficits. Barroso et al. (2021) establish that students with elevated math anxiety exhibit lower interest in math-related tasks and diminished intentions to pursue math-intensive careers, such as engineering.

Barroso et al. (2021) provide meta-analytic confirmation of a negative correlation ($r = –.28$) between math anxiety and achievement. This link is further corroborated by Choe et al. (2019), who show that students experiencing math anxiety actively avoid STEM subjects in their academic planning.

These findings, detailed in Table 2, illustrate that math anxiety operates as a motivational cost in EVT and diminishes both self-efficacy and task value in SCCT. Thus, interventions that alleviate anxiety—through exposure, scaffolding, and psychological support—are critical for enabling students to envision themselves as capable of success in math-intensive STEM domains.

Motivational Models Predicting First-Semester Retention

Comparative analyses of motivational theories reveal that EVT is a more robust predictor of first-semester retention in STEM compared to Achievement Goal Theory. Dompnier et al. (2015) and Scalas & Fadda (2019) affirm that expectancy and task value components better account for persistence outcomes than goal orientations alone.

Achievement Goal Theory focuses on students' aims (e.g., mastery vs. performance), but does not fully address their underlying belief systems. By contrast, EVT provides a dual-lens into both ability perceptions and subjective task worth—two constructs repeatedly validated as central to persistence (Scalas & Fadda, 2019).

As shown in Table 2, students with high expectancy beliefs and high task value ratings are more likely to navigate STEM challenges successfully. This insight supports the use of expectancy-value interventions in early undergraduate settings, including strategies such as relevance writing prompts and utility value framing.

Synthesis and Implications

The findings across these four subthemes confirm the central role of psychosocial and motivational constructs in STEM retention. Science identity, mathematical resilience, and low anxiety function as mutually reinforcing assets that promote engagement and reduce attrition. Furthermore, the comparative strength of EVT as a predictive model underscores the importance of addressing both ability beliefs and subjective value in retention strategies.

These conclusions dovetail with the theoretical frameworks outlined in Section 3. EVT helps explain the interaction between value, interest, and persistence; SCCT frames how beliefs are shaped by context and mentorship; SDT emphasises the emotional environment, particularly belonging and competence. Programs that cultivate identity, enhance resilience, and reduce anxiety not only elevate academic performance but fundamentally alter students' belief systems, increasing their likelihood of long-term commitment to STEM.

Table 2
Summary of Psychosocial and Motivational Determinants in STEM Retention

Author	Psychosocial Construct	Instrument/Measure	Sample Characteristics	Direction/Strength of Effect
González-Nucamendi et al. (2023)	Science Identity	Science Identity Scale	UG STEM aspirants	↑ Graduate STEM intent via identity salience
Byars-Winston & Rogers (2019)	Mentorship & Identity	Survey + Interviews	Minority STEM UG	Mentor recognition ↑ career intention
Dou et al. (2019)	Early STEM Exposure	Qualitative Interviews	Secondary STEM students	Informal exposure fosters identity development
Heiny et al. (2015)	Mathematical Resilience	Resilience Scale	STEM freshmen	↑ Pass rates in gateway courses
Bahar & Maker (2020)	Math Resilience	Adapted Resilience Survey	Asian engineering students	Resilience ↔ Performance in collectivist contexts
Harrington et al. (2016)	Tutoring for Resilience	Quasi-experimental	At-risk math learners	Tutoring improves resilience & persistence
Barroso et al. (2021)	Math Anxiety	Meta-analysis	40-study sample	r = –.28 (anxiety → ↓ performance)
Choe et al. (2019)	Math Avoidance	Course Pathway Tracking	STEM-declared undergrads	Anxiety leads to STEM course withdrawal
Dompnier et al. (2015)	EVT vs AGT	Survey & Regression	1st-semester STEM students	EVT > AGT in retention prediction
Scalas & Fadda (2019)	Expectancy-Value vs AGT	Task Value Inventory	European STEM cohort	EVT better predictor than AGT

Equity, Intersectionality, and Demographic Moderators

Addressing equity and inclusion in STEM education requires a nuanced understanding of how demographic factors interact with motivational, structural, and institutional dynamics. This section synthesises findings across four interrelated themes—financial aid, LGBTQ+ belonging, mathematics preparedness, and community of practice mentorship—each linked to broader theoretical constructs from Section 3, including Expectancy-Value Theory (EVT), Social Cognitive Career Theory (SCCT), and Self-Determination Theory (SDT). These themes explore not only access and support mechanisms but also the psychosocial environment in which underrepresented students navigate STEM pathways. Table 3 summarises the empirical contributions.

Financial Aid and First-Generation Student Retention

Financial aid is a foundational support mechanism for first-generation college students, whose persistence in STEM fields is often impeded by financial barriers and a lack of institutional familiarity. Consistent with SDT, financial support fosters autonomy and psychological security, allowing students to concentrate on academic development. Chen et al. (2020) demonstrate that financial aid directly correlates with improved academic focus and reduced attrition among first-generation students.

Implementing and maintaining equitable and accessible financial aid programmes can help address the issue of equity in higher education and contribute to a more inclusive and diverse student population (Monks, 2018). Within SCCT, these outcomes reinforce self-efficacy and positive outcome expectations, bolstering students' STEM career intentions. As presented in Table 3, such holistic financial interventions represent a scalable strategy for improving retention among first-generation learners.

Meza (2025) emphasizes the experiences of academically talented STEM students, highlighting that scholarship programs offering financial support while cultivating a sense of belonging significantly enhance student retention. The intentional design of support services helps students manage their competing priorities, reduce stress, and maintain their commitment to STEM pathways (Meza, 2025). Similarly, Payne et al. (2024) explore how social support fosters a sense of belonging specifically for low-income STEM majors. Their investigation reveals that social connections within peer support groups are essential for creating an environment where students feel listened to and valued, which directly impacts their persistence in STEM fields.

Belonging Interventions for LGBTQ+ Students

A growing body of literature underscores the importance of belonging for LGBTQ+ students in science majors. Dennehy and Dasgupta (2017) provide compelling evidence that peer mentorship enhances belonging and improves persistence, especially in hostile or isolating STEM environments. These effects are consistent with SDT's emphasis on relatedness as a core motivational need.

Cech and Waidzunas (2021) extend this insight through their evaluation of inclusive curricula and identity-affirming spaces, demonstrating that visible representation and inclusive content increase LGBTQ+ students' sense of acceptance. Freeman (2020) supports this claim by emphasising the role of cultural responsiveness in building equitable learning contexts. These interventions also reinforce EVT's task value dimension by affirming the relevance of STEM to students' identities. Table 3 indicates that successful interventions integrate mentorship, visibility, and representation to build affirming environments that foster long-term STEM engagement.

Mathematics Preparedness and Gender-Specific Retention Patterns

Mathematics preparedness is a key moderator in the gender–retention link in engineering and other math-intensive disciplines. According to Brantlinger et al. (2020), students with higher levels of pre-university math proficiency are significantly more likely to persist in engineering programs. For female students in particular, prior math achievement has a more substantial impact on persistence, suggesting the presence of threshold effects.

Chen et al. (2020) find that girls with strong math preparation are more likely to remain in STEM fields, indicating that preparedness mediates the gender gap in STEM retention. This reinforces EVT's expectancy component: higher preparedness increases confidence, which in turn supports sustained engagement. Conversely, male students' persistence is less strongly moderated by prior performance, highlighting gendered differences in self-perception and confidence. These findings, consolidated in Table 3, suggest that support mechanisms must be targeted, particularly for female students navigating math-intensive STEM pathways.

Community of Practice Mentorship for Women of Color

Community of practice (CoP) mentorship models have been especially impactful in improving doctoral completion rates among women of color in STEM. These mentorship frameworks create inclusive environments where students share experiences, receive culturally relevant guidance, and develop professional networks. According to Cech and Waidzunas (2021), CoP interventions address feelings of isolation and marginalisation—critical factors in attrition among minority doctoral students.

Dennehy and Dasgupta (2017) illustrate that same-gender and race-congruent mentorship reinforces identity and builds social capital, both central to SCCT. Freeman (2020) and Agee and Li (2018) emphasise that relational support structures empower students to navigate institutional barriers and discriminatory practices. These findings demonstrate that community-based mentorship contributes to psychological safety, fosters resilience, and promotes long-term academic achievement (Table 3).

The theoretical resonance is clear: EVT helps contextualise how value and attainment beliefs evolve through identity support, SCCT explains the role of self-efficacy and role models in persistence, and SDT captures the essential need for relatedness and community. Together, these perspectives converge to show how intersectional barriers can be mitigated through culturally responsive mentorship.

Implications and Synthesis

Section 4.3 affirms that demographic identity markers—such as first-generation status, gender, and LGBTQ+ identity—interact with psychosocial variables to shape STEM persistence outcomes. Financial support, inclusive practices, academic preparedness, and community-based mentoring operate as equity-oriented levers, reinforcing the central hypothesis that supportive environments, when tailored to the unique needs of marginalised groups, significantly enhance retention.

Integrating findings across Table 3, it becomes evident that intersectional strategies must be embedded within institutional policy and practice. Financial aid alone is insufficient without community; mentorship is limited without representation; preparedness must be matched with support structures. Only when these elements cohere can institutions meaningfully reduce STEM attrition among structurally disadvantaged populations.

Table 3
Equity, Intersectionality, and Demographic Moderators in STEM Retention

Author	Focal Demographic	Context/Setting	Moderator / Barrier or Support	Retention Impact
Chen et al. (2020)	First-Generation Students	US Universities	Financial Aid	↓ Stress, ↑ Retention
Dennehy & Dasgupta (2017)	LGBTQ+ & Women	Engineering Programs	Peer Mentorship	↑ Belonging, ↑ Persistence
Freeman (2020)	Diverse Learners	Science Majors	Cultural Responsiveness	↑ Identity Integration, ↑ Retention
Brantlinger et al.(2020)	Female Students	Engineering Programs	Math Preparedness	Strong predictor of persistence
Cech & Waidzunas (2021)	Women of Color	Doctoral STEM Programs	Community of Practice Mentorship	↓ Isolation, ↑ Completion
Agee & Li (2018)	Women of Color	STEM Doctoral Networks	Professional Networks + Identity Safety	↑ Degree Attainment, ↑ Satisfaction
Freeman (2020)	URM Women	Graduate STEM Cohorts	Culturally Relevant Mentorship	↑ Self-Efficacy, ↓ Attrition Risk

Measurement, Analytics, and Longitudinal Pathways

The fourth theme in this systematic review highlights measurement tools, data analytics, and longitudinal methodologies that track, predict, and explain student persistence and attrition in STEM fields. This section synthesises evidence on four critical dimensions: longitudinal instruments for STEM identity, predictive analytics through machine learning, cross-cultural scale validation, and big data registries monitoring transitions from high school to university. These measurement and analytical frameworks reinforce key components of Expectancy-Value Theory (EVT), Social Cognitive Career Theory (SCCT), and Self-Determination Theory (SDT), by quantifying motivational constructs, supporting data-driven interventions, and enabling long-range insights into educational trajectories. Table 4 summarises the studies reviewed.

Longitudinal Instruments for STEM Identity Development

STEM identity development is central to predicting students' persistence and long-term engagement in STEM pathways, as discussed in EVT and SCCT. Reliable longitudinal instruments are essential for tracking these identity shifts across academic transitions.

The STEM Identity Survey, used by Bremer-Hoeve et al. (2023), captures changes in self-perceived competence, belonging, and identification with the scientific community. Administered at multiple points across the undergraduate experience, the survey enables the mapping of individual trajectories of STEM identity development. Findings suggest that students with increasing identity salience are significantly more likely to remain in STEM disciplines.

Similarly, the Science Identity Development Scale (González-Nucamendi et al., 2023) offers fine-grained insights into how students' identity, confidence, and perceived performance evolve over time. These findings affirm the SCCT assertion that self-efficacy and identity are mutually reinforcing predictors of career intentions. As reported in Table 4, these tools are instrumental in evaluating the cumulative impact of interventions and the psychosocial shifts that sustain retention.

Machine Learning Models for Dropout Prediction

Predictive analytics, particularly using machine learning (ML), has revolutionised the ability of institutions to detect dropout risk early. In alignment with SCCT and SDT, ML models allow educators to identify when and why students are disengaging, often before visible academic decline.

Pellagatti et al. (2021) demonstrate that random forest (RF) models achieve high accuracy in predicting dropout by analysing patterns in GPA, attendance, and assessment data. The area under the curve (AUC) values reported consistently exceed 0.85, indicating strong predictive performance. These models outperform traditional regression methods in capturing nonlinear relationships among variables.

Likewise, gradient boosting (GB) models employed by Sage et al. (2018) integrate behavioural, demographic, and academic features to provide real-time risk assessments. These systems can be embedded in student dashboards to provide alerts and tailored intervention strategies. Table 4 presents the performance metrics and utility of these models, showing their increasing adoption in institutional analytics.

Theoretically, these tools embody SDT's principle of proactive support by anticipating autonomy- and competence-threatening scenarios. From a practical standpoint, ML models offer scalable, adaptive solutions to managing large cohorts.

Cross-Cultural Validity of Mathematical Resilience Instruments

Measurement tools must demonstrate reliability and validity across diverse cultural contexts to ensure that findings are generalisable and interventions are effective. The Mathematical Resilience Scale (MRS), initially developed in Western contexts, has been subject to rigorous cross-cultural evaluation.

Chalapati et al. (2018) conducted comparative factor analysis on US and Taiwanese cohorts and found structural equivalence in the MRS across the two populations. However, cultural nuances were evident in how specific items were interpreted—US students emphasised individual effort, while Taiwanese students highlighted peer collaboration.

Bahar and Maker (2020) underscore the importance of culturally responsive adaptation, arguing that resilience is not merely an individual attribute but socially constructed. Their findings indicate that the MRS requires context-sensitive modifications to retain construct validity. Table 4 highlights the reliability coefficients and validity indicators from both studies.

From a theoretical standpoint, this cross-cultural research supports EVT's cost and effort dimensions and SDT's relational motivations. It reinforces the call for educational measurement to accommodate diverse learner experiences without compromising analytical rigour.

Big Data Registries and the High School–University Transition

Big data registries provide a macro-level perspective on student trajectories, particularly during the critical transition from secondary to tertiary STEM education. These data ecosystems aggregate institutional, demographic, and academic performance records to reveal long-term patterns.

Kitchen et al. (2018) show that students' high school GPA and science coursework are strong predictors of STEM enrolment and persistence in university. Their registry analysis reveals that early exposure to STEM, coupled with strong academic preparation, correlates with higher transition success.

Baran et al. (2019) extend this work by integrating big data systems with predictive analytics to create early alert systems. Their model triggers interventions when patterns indicative of disengagement emerge—such as declining grades or inconsistent attendance. These approaches echo SCCT's environmental supports and EVT's expectancy pathway.

Ghaleb et al. (2023) focus on equity gaps, showing that minority and first-generation students face more complex transition barriers. Their data advocate for integrated support systems informed by disaggregated, identity-specific analytics. Table 4 outlines how these registry systems link academic preparedness and demographic variables to persistence outcomes.

These findings illustrate that large-scale, data-rich infrastructures not only enable personalised intervention strategies but also enhance institutional accountability for equitable STEM outcomes.

Synthesis and Implications

Section 4.4 substantiates the argument that advanced measurement tools and predictive analytics are foundational to understanding and mitigating STEM attrition. Longitudinal identity instruments capture motivational evolution; ML models predict dropout before it materialises; cross-cultural validation ensures inclusivity; and registry studies provide system-level insight.

These approaches resonate deeply with EVT, SCCT, and SDT by quantifying beliefs, forecasting disengagement, and validating tools for diverse populations. More broadly, they offer scalable, empirically grounded methodologies for institutions to intervene strategically. The review underscores the need for sustained investment in measurement and analytics to enhance both educational outcomes and systemic equity.

Table 4
Summary of Measurement, Analytics, and Longitudinal Tools in STEM Retention

Author	Measurement Focus	Tool/Model Used	Key Outcome	Relevance to Retention
Bremer-Hoeve et al. (2023)	STEM Identity (Longitudinal)	STEM Identity Survey	Identity growth → ↑ persistence	Tracks psychosocial shifts across time
González-Nucamendi et al.(2023)	Science Identity Development	Science Identity Development Scale	Confidence + belonging = ↑ retention	Confirms SCCT pathways
Pellagatti et al. (2021)	Dropout Risk Prediction	Random Forest Model	AUC > .85; early risk detection	Enables data-driven intervention
Sage et al. (2018)	Dropout Risk Prediction	Gradient Boosting Model	High prediction accuracy from multifactor inputs	Prevents disengagement
Chalapati et al. (2018)	Cultural Adaptation of MRS	MRS (US vs. Taiwan)	Valid across cultures with item nuance	Ensures measurement inclusivity
Bahar & Maker (2020)	Culturally Responsive MRS Design	Modified MRS for Asia	Improved interpretation in collectivist contexts	Reinforces SDT/EVT contextual validity
Kitchen et al. (2018)	Transition from High School to STEM U	Big Data Registries	HS GPA + STEM coursework → ↑ transition retention	Links prep to persistence
Baran et al. (2019)	Early Alerts via Big Data	Analytics Dashboard + Predictive Model	Interventions triggered by disengagement indicators	Real-time support tool
Ghaleb et al. (2023)	Equity Gaps in Transition	Disaggregated Registry Data	First-gen/minorities face steeper barriers	Advocates for identity-specific supports

Discussion

The previous analysis of the four main themes shows that STEM attrition is influenced by a complex mix of personal, institutional, and demographic factors that often overlap. This section brings together those findings, reviews key research methods, and discusses what they mean for theory, practical action, and future studies.

integration of thematic Findings

A key point across all themes is that staying in STEM depends heavily on students' motivation, identity, and sense of control. Programs like CUREs and active learning (Section 4.1) work best when they support these needs, as described in Expectancy-Value Theory (EVT) and Self-Determination Theory (SDT). CUREs help students see the value in their work (Rodenbusch et al., 2016; Bangera & Brownell, 2014), and flexible, collaborative courses promote independence and connection (Wu et al., 2024; Lin et al., 2024).

Psychosocial and motivational factors (Section 4.2) highlight the importance of internal beliefs in staying in STEM. Key supports include having a strong science identity, being resilient in math, and experiencing less anxiety. Students with a strong science identity feel they belong and that their work matters (Merolla & Serpe, 2013; Byars-Winston & Rogers, 2019). Math resilience helps students handle challenges without losing confidence (Heiny et al., 2015; Govender & Moodley, 2012). On the other hand, math anxiety can hurt students' sense of ability and independence, as described in Self-Determination Theory (Good et al., 2012; Barroso et al., 2021).

Section 4.3 highlights how equity and student identity matter in STEM retention. Programs that offer financial help, inclusive teaching, and mentoring for women of color and LGBTQ+ students lead to better persistence outcomes (Chen et al., 2020; Dennehy & Dasgupta, 2017; Freeman, 2020). These findings support Social Cognitive Career Theory (SCCT), showing that confidence and career expectations grow through social support.

Measurement and analytics (Section 4.4) help track how students' motivation and identity change over time. Long-term surveys and machine learning tools are being used to turn theory into practice and to predict which students may need help (Bremer-Hoeve et al., 2023; Pellagatti et al., 2021). Studies across different cultures support the use of SDT and EVT globally, while large education databases help map student progress at a broader level (Kitchen et al., 2018; Ghaleb et al., 2023).

Convergence and Divergence Across Studies

While general patterns are clear, there are also key differences that deserve attention. For example, although CUREs and service-based programs usually improve retention, their success depends on the setting and who they serve. Mentorship works best when it matches students' cultural backgrounds, but inconsistent mentor quality can limit its impact (Richmond et al., 2018). Also, the link between math readiness and persistence differs by gender, with women benefiting more (Riegle-Crumb et al., 2012).

There are also overlaps and inconsistencies in how motivation-related ideas are defined. For instance, science identity and self-efficacy are often considered separate, but research shows they frequently overlap, suggesting the need for more unified models (González-Nucamendi et al., 2023). Similarly, although belonging is widely seen as important for persistence, studies differ on what drives it—peer relationships, relevant curriculum, or instructor support (Lu et al., 2022; Wilton et al., 2019).

Methodological Limitations and Gaps

The reviewed studies have some key limitations that affect how widely the findings can be applied. First, many interventions don't track students over the long term, so it's unclear if short-term improvements last as students move through school (Garibay & Teasdale, 2019). Second, while more studies now mention intersectionality, few actually break down results by race, gender, or income (Moore et al., 2022). Third, although predictive tools look promising, they are rarely used in real-time systems or checked for fairness (Sage et al., 2018).

Another ongoing issue is inconsistent measurement. Studies define things like self-efficacy and belonging in different ways, making it hard to compare results. Many tools haven't been tested across cultures, even though we know motivation can look different in different social settings (Chalapati et al., 2018; Bahar & Maker, 2020). Also, too few studies include students' personal stories, which could help explain how their motivation and identity change over time (Kuchumova et al., 2024).

Theoretical Implications

The findings support the usefulness of EVT, SCCT, and SDT, but also show where they can be improved. For example, EVT's focus on value—especially usefulness and achievement—is key for underrepresented students aiming for upward mobility through STEM. SCCT is supported by research on mentoring and identity, though future versions should include more attention to how race, gender, and class overlap. SDT's idea of belonging is especially important for marginalised students and supports inclusive teaching practices.

Together, these theories suggest the need for models that show how motivation and identity change over time. A student's sense of self, ability to bounce back, and school support all interact in shaping their STEM journey. To understand this process, long-term and mixed-method studies are essential.

Implications for Practice and Policy

In practice, the review shows that no single solution can fix STEM attrition. Institutions need to apply multi-layered strategies that bring together academic help, social support, financial aid, and efforts that build students' identity. CUREs, mentoring, and early-warning systems should work together as a coordinated support system.

Policies should focus on fairness. This includes funding schools that lack resources, training teachers in inclusive methods, and tracking how well interventions work across different student groups. Predictive tools should be used carefully and ethically to avoid bias and to guide how support is given.

In classrooms, teachers can encourage independence and belonging by using active learning, regular feedback, and open discussion. Leaders should help staff use proven teaching strategies and promote collaboration across departments.

Directions for Future Research

Future research should focus on several areas. First, more long-term studies are needed to understand how motivation, identity, and student engagement change as learners progress through their education. Second, combining surveys with in-depth interviews can help balance broad insights with deeper understanding. Third, new measurement tools should be tested across cultures to ensure they work well in different settings.

Researchers should also use intersectional approaches to better understand how race, gender, and other social identities affect retention. For example, studies could explore how programs work for Black women in engineering or LGBTQ+ students who are also the first in their family to attend college.

Lastly, researchers should study how to expand successful programs in a way that lasts. This means looking at how well programs are implemented, how they can be adapted, and whether institutions have the capacity to keep them going long-term.

Conclusion of Discussion

This discussion shows that success in STEM depends on both personal motivation and supportive environments. It brings together findings from many areas and uses strong theory to suggest practical, inclusive, and data-informed ways to reduce dropout and support lasting student engagement in STEM.

Conclusion

This systematic literature review (SLR) explored recent studies on what helps students stay in or leave STEM education. The results show that persistence in STEM is influenced by a mix of personal motivation, school programs, social background, and research methods. Using Expectancy-Value Theory (EVT), Social Cognitive Career Theory (SCCT), and Self-Determination Theory (SDT), the review shows that student motivation, identity, and social support are central to staying in STEM.

The review found that programs like course-based undergraduate research experiences (CUREs), early-alert systems, and mentoring that respects students' backgrounds can boost retention by supporting confidence, independence, and belonging. Personal traits such as having a science identity, being strong in math, and having low math anxiety also help students persist. Students' backgrounds—such as being the first in their family to go to college, gender, or sexual orientation—also affect how they respond to support. Tools like predictive analytics and long-term surveys can help identify students at risk and ensure fair support.

This review adds to existing knowledge by connecting separate areas of research and providing a clear, theory-based view of STEM attrition. It stresses that solutions must be long-term, inclusive, and responsive to student diversity. Challenges remain, such as unclear measurement tools, a lack of focus on overlapping identities, and not enough follow-up over time.

By showing how personal, school-based, and social factors work together to influence STEM persistence, this review gives practical guidance to educators, decision-makers, and researchers. It calls for a move from short-term fixes to strategies that build motivation and identity throughout a student's education. Future research should focus on long-term studies, use mixed methods, test tools across cultures, and consider multiple aspects of identity to build fair and effective STEM education systems.

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