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Inclusive curricular interventions and pedagogy in undergraduate engineering: a literature review

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Abstract

This systematic literature review investigates how inclusive curricular interventions and pedagogy in undergraduate engineering education influence sense of belonging, professional identity, and persistence among historically underserved students. Analyzing 40 peer-reviewed studies published between 2000 and 2024, we employed thematic analysis across two coding cycles to identify patterns in intervention types and outcomes. Multiple curricular themes emerged: fostering personal connections through representation and mentorship; implementing student-centered pedagogies; cultivating collective responsibility for inclusivity; increasing structural access; empowering students through introspection and critical analysis; reframing narratives of belonging; and leveraging professional engineering organizations. These interventions yielded three primary outcomes: cultivating community cultural wealth (navigational, social, aspirational, familial, resistance, and linguistic capital), fostering inclusive engineering identities characterized by heightened awareness of systemic barriers, and improving belonging, professional identity, and persistence intentions. Identity-matched mentorship and participation in identity-based organizations significantly enhanced retention among women and underrepresented minority students. However, findings reveal a persistent gap between students' awareness of inequities and their translation of this knowledge into equitable practice. We conclude that isolated interventions are insufficient; inclusive curricula must be integrated longitudinally across engineering education. Future research should employ rigorous mixed-methods designs with larger samples to establish efficacy and facilitate replication.

Keywords Inclusive, Undergraduate, Engineering, Education, Curriculum

1 Introduction

As engineers design solutions for an increasingly diverse global population, the need for a workforce that reflects this diversity has never been more urgent [58]. Yet students from historically underserved communities remain significantly underrepresented in engineering programs (National Center for Educational Statistics, n.d.) [60] not by accident, but by design: systemic barriers including stereotyping, discrimination, and

exclusionary classroom cultures persistently drive attrition [15, 47, 48, 53, 54, 55, 66]. These barriers compound for students navigating intersecting identities, who frequently face pressure to compartmentalize aspects of themselves to gain acceptance within engineering culture [47, 66]—a dynamic that undermines both belonging and persistence.

A growing body of research suggests that inclusive curricular interventions and pedagogy can meaningfully address these inequities [30, 41, 57, 88, 90]. We define inclusive curriculum broadly to encompass not only full-scale redesigns but also discrete instructional interventions, teaching strategies, and educational modules that make content, pedagogy, and assessment more accessible and responsive to all students [74]. In engineering specifically, such interventions—whether a targeted module or a course-long strategy—have been shown to foster belonging, mitigate stereotype threat, and affirm student identity [30, 47, 57, 88].

Despite this growth, the field lacks a systematic synthesis of which curricular and pedagogical interventions are most effective, for whom, and under what conditions. This review addresses that gap directly. Drawing on 40 peer-reviewed studies published between 2000 and 2024, we identify inclusive practices with the strongest empirical support, explain how interventions function within instructional and assessment systems, and highlight recurring methodological limitations that limit conclusions. Our aim is to provide researchers and practitioners with an evidence-based roadmap for improving equity, representation, and persistence across undergraduate engineering programs.

2 Background

2.1 Inclusive pedagogy

Inclusive pedagogy employs instructional strategies to support all students, thereby creating an environment in which every individual feels valued [23]. For instance, instructors often use Universal Design for Learning (UDL), a framework for creating flexible experiences that accommodate diverse learners [63]. UDL provides multiple means of engagement, representation, and action [9], enabling students to interact with the material in ways that align with their strengths. By proactively embedding flexibility, UDL ensures accessibility without requiring retrofitting [33].

Another example of inclusive pedagogy is Culturally Responsive Teaching (CRT). CRT draws on students' diverse cultural knowledge to make learning relevant [27]. Moving beyond mere acknowledgement, CRT intentionally integrates cultural assets into the curriculum [1]. This validation fosters critical awareness of social inequities Ladson-Billings, [42]. Ultimately, bridging home cultures and academia increases engagement and improves outcomes for underserved populations [27, 43].

Equity-focused pedagogy offers another approach to inclusive teaching. Unlike equality-based models that treat all students the same, equity-focused pedagogy recognizes that students require different levels of support based on their preparation and privilege [4]. Differentiated instruction reflects this principle by tailoring strategies to individual needs [78], but equity-focused pedagogy goes further, addressing systemic barriers and remedying structural injustices rather than focusing solely on individual accommodation [32].

Inclusive pedagogy also aligns with student-centered learning, which shifts focus to students' active construction of knowledge (see [89]). Student-centered approaches validate diverse backgrounds by encouraging students to integrate lived experiences and

exercise autonomy over their learning [46]. This emphasis on agency cultivates academic ownership and intrinsic motivation, deepening student engagement [3, 68].

Central to inclusive pedagogy is the creation of a culture of belonging and psychological safety [24]. Instructors foster this culture by establishing respectful norms and mitigating bias. Psychological safety—a shared belief that risk-taking is welcome—encourages students to voice ideas without fear of judgment [22], reinforcing active participation and academic self-efficacy [91].

2.2 The need for inclusive pedagogy in engineering

Persistent disparities in student retention and graduation rates underscore the need for inclusive pedagogy in engineering education. Historically, engineering programs have relied on a "weed-out" culture characterized by high-stakes testing, rigid curricular structures, and a meritocratic ideology that assumes student attrition is solely a function of individual ability rather than environmental factors Seymour & Hunter, [71]. This traditional pedagogical approach disproportionately affects students from historically underserved communities, including women, students of color, and first-generation college students, who often leave the major not due to a lack of academic competence, but fails to validate their identities or support their learning needs [28]. Consequently, the exclusive nature of traditional engineering instruction perpetuates a homogeneity in the field that stifles innovation and limits the profession's ability to address complex, global challenges [59].

Furthermore, the disconnect between engineering coursework and the lived realities of diverse student populations impedes the development of professional identity. Research indicates that underrepresented students are more likely to persist when they can perceive the social relevance of engineering and connect their technical work to community impact [52]. Inclusive pedagogy addresses this by shifting the educational focus from a deficit model—which attempts to "fix" the student to fit the system—to a structural model that adapts the learning environment to welcome diverse perspectives [72]. By integrating culturally relevant examples and fostering psychological safety, inclusive pedagogy provides the scaffolding for all students to develop an engineering identity, thereby transforming the classroom from a gatekeeper into a gateway to a diverse technical workforce.

2.3 Operationalizing belonging in engineering education

Sense of belonging is multidimensional and inconsistently defined, shaping how findings are interpreted and compared. In the psychological tradition, belonging refers to feeling accepted and valued within an academic community [31, 84]. Interventions in this vein, such as social affirmations and ecological belonging exercises, aim to reshape students' interpretations of challenge, normalize struggle, and reduce isolation [29, 85].

A complementary institutional tradition draws on Tinto's [80] model of academic and social integration, framing belonging as engagement with an institution's intellectual and social systems. Here, belonging is inferred from behavioral indicators and outcomes (e.g., participation in campus organizations, faculty interaction, academic performance) that are more directly tied to persistence and departure. Several studies in this review adopt this lens when examining professional engineering organizations and mentorship programs as supports for underrepresented students' institutional integration [15, 73].

A third lens, Schlossberg's [69] theory of mattering and marginality, emphasizes whether students feel noticed, affirmed, and valued—experiences that may be especially salient for those with intersecting marginalized identities. This framework is useful for interpreting mentorship and professional organization findings, where students describe being actively recognized and affirmed within a professional community rather than simply included [34, 64].

Across the 40 studies reviewed, these traditions are often blended without explicit framing. Operationalizations, therefore, vary widely—from validated psychological scales to qualitative accounts to institutional persistence data—limiting direct cross-study comparison and constituting a key methodological finding.

2.4 Professional identity in engineering

Professional identity is the extent to which an individual internalizes a professional role as central to their self-concept and is a critical determinant of persistence in engineering [37]. Drawing on identity theory [13, 76], researchers conceptualize engineering identity as hierarchically organized. When "being an engineer" is central to students' identities, they are more likely to seek mentorship, participate in professional organizations, and persist despite academic setbacks.

Complementing this psychological perspective, Wenger's [87] Communities of Practice framework situates identity development as an inherently social process. Rather than residing solely within the individual, professional identity emerges through legitimate peripheral participation—that is, the gradual, supported movement from novice to full member of a practice community. In engineering education, this framework helps explain why interventions such as identity-based professional organizations, peer mentorship, and collaborative design projects are particularly effective for underrepresented students, as they provide structured pathways for participation in communities where students can see themselves reflected and valued [67, 73].

The intersection of these frameworks is especially relevant for historically underserved students, who must negotiate engineering identity while navigating environments that historically have not affirmed their membership [47, 53]. Inclusive curricular interventions, in this light, serve not merely as pedagogical accommodations but as identity-affirming structures that reshape the community of practice itself. Tripon, [81] further illustrates how service-learning and community-engaged approaches can support this identity development by connecting students' professional formation to broader societal purposes, including equity and sustainability.

2.5 Critical race theory and asset-based frameworks

This review was informed by Critical Race Theory (CRT) in education and its asset-based extensions. CRT positions race and racism as enduring structural features of educational institutions, challenges hegemonic claims of meritocracy and colorblindness, and legitimizes the experiential knowledge of historically marginalized communities as an analytic foundation [44, 75]. In engineering education, these tenets are directly relevant. The field's meritocratic ideology has been well-documented as a mechanism that naturalizes exclusion by attributing attrition to individual deficits rather than structural conditions [72].

Building on CRT, Yosso's (2005) Community Cultural Wealth (CCW) framework represents a foundational asset-based approach that explicitly rejects deficit thinking — the tendency to evaluate underrepresented students against a white, middle-class normative standard and to frame their experiences in terms of what they lack [83]. Instead, CCW identifies six forms of capital (i.e., navigational, social, aspirational, familial, resistance, and linguistic) that students from marginalized communities develop precisely because of, not despite, their lived experiences. We position inclusive engineering curricula not as remediation for underprepared students but as structures that recognize, activate, and amplify the assets students already possess. This reframing has significant implications for how engineering educators design interventions and for how researchers measure their effects.

3 Methods

The goal of this review was to evaluate the effectiveness of inclusive curricular interventions and pedagogy in undergraduate engineering. Specifically, this study addresses the following research questions:

> RQ1: What curricular interventions and pedagogical strategies are instructors implementing in undergraduate engineering programs to increase inclusivity?
> RQ2: How do these interventions influence undergraduate engineering students' sense of belonging, professional identity, and intentions to persist?

3.1 Search strategy and data collection

We conducted a comprehensive search of Google Scholar, ERIC, and PsycNet for peer-reviewed articles published between 2000 and 2024. We employed a search string utilizing Boolean operators to combine the following terms: "inclusive" AND "undergraduate" AND "engineering" AND "curriculum" AND "belonging" AND "identity" AND "persistence" AND "intervention." This initial search yielded 26,900 results.

3.2 Screening and inclusion criteria

We applied a multi-stage screening process to narrow the results. First, we filtered for articles with "engineering" in the title, reducing the pool to 70. We then screened titles and abstracts using the following inclusion criteria: studies must (a) address inclusive curriculum for undergraduate engineering students (or use synonymous terms) and (b) report empirical results on curricular effectiveness. This process yielded a final sample of 40 studies.

3.3 Data analysis

Two researchers analyzed the final sample using thematic analysis across two coding cycles. In the first cycle, we assigned descriptive codes to each article for curriculum type, student outcomes, and participant demographics. In the second cycle, we grouped these codes to identify patterns across curricular types and outcomes, allowing overarching themes to emerge. The coders met to discuss differences until reaching a consensus.

Table 1 Common goals and approaches of inclusive curriculum in undergraduate engineering education

Theme statements
Theme 1: Personal connections to the curriculum Inclusive curricula foster personal connections to engineering by anchoring technical content in diverse representation and cultural relevance, thereby allowing historically underrepresented students to visualize themselves within the profession.
Theme 2: Pedagogical methods Shifting from traditional, rote instruction to student-centered and collaborative pedagogies reinforces professional identity and engagement, particularly for women and students of color, by validating diverse approaches to problem-solving.
Theme 3: Cultivating collective responsibility and inclusivity Curricula that explicitly establish inclusive norms and heighten social awareness—specifically regarding disability and global diversity—empower students to move beyond passive empathy toward active identification and remediation of barriers.
Theme 4: Increasing access Dismantling structural and resource-based barriers—through holistic admissions, financial support, and specialized research opportunities—broadens participation and allows neurodiverse and underrepresented students to engage with engineering as autonomous, creative scholars.
Theme 5: Empowering thoughtful action through introspection and analysis Curricula utilizing introspection and liberative pedagogies cultivate student agency, enabling learners to reframe resistance as a positive tool for critiquing societal inequities and challenging the "myth of objectivity" in engineering.
Theme 6: Changing the narrative around belonging Interventions that reframe non-belonging as a transient, collective experience rather than a personal deficit significantly improve persistence and confidence by normalizing struggle and integrating personal values into engineering identity.
Theme 7: Professional engineering organizations and professional development Participation in identity-based Professional Engineering Organizations (PEOs) is a critical curricular component that provides representation, professional skill acquisition, and a protective community for students navigating intersectional barriers.

3.4 Findings

3.4.1 RQ1: What curricular interventions and pedagogical strategies are instructors implementing in undergraduate engineering programs to increase inclusivity?

Our analysis identified seven main themes about curricular interventions and pedagogical strategies used to increase inclusivity in undergraduate engineering programs. While some studies described comprehensive curricular redesigns, most interventions consisted of specific instructional strategies or modules integrated into existing courses (see Table 1). Each theme is described in more detail below.

3.5 Theme 1: personal connections to the curriculum

Multiple studies found that inclusive curricula foster personal connections between students and engineering content [6, 10, 17, 21, 35, 56, 64, 77]. Instructors achieved this primarily through representation and cultural relevance.

Several studies integrated representation directly into course materials by highlighting contributions of individuals from diverse backgrounds [6, 79] or using media to explore engineering demographics [17]. For example, Benson et al. [6] and Szczesny et al.[77] both implemented modules focused on broadening representation, though with different emphases. Benson et al., focused on the historical contributions of underrepresented groups, whereas Szczesny et al., addressed implicit bias and racial and gender inequality. Building on earlier work [17, 18] engaged students with socially relevant material, including an analysis of a speech on NASA's demographic composition and a reflection on the film *Hidden Figures*. Other interventions incorporated representation through

design projects centered on customers with disabilities [19, 50, 61]. Researchers also found that allowing students to select their own project topics strengthened connections between their cultural backgrounds and the curriculum [10, 56].

Beyond course content, mentorship emerged as a key strategy for helping underrepresented students see themselves as engineers [21, 64]. Dennehy and Dasgupta, [21] found that female peer mentors significantly improved women's sense of belonging, self-efficacy, career aspirations, and retention, while mitigating feelings of threat. Similarly, Rayford et al. [64] reported that mentoring programs positively affected Latino students' sense of belonging.

3.6 Theme 2: pedagogical methods

The second theme focused on pedagogical methods, specifically on interventions that improved student-centered learning and collaborative group work. Student-centered approaches included creative assignments without traditional grading [34], project-based learning [10], design thinking [67], and strengths-based projects [20, 56]. Collaborative strategies included cooperative learning [86], peer-led team learning [51], and structured group activities [82].

Several studies illustrated the nuances of these approaches. Motaref [56] combined strengths-based projects with real-world examples in a mechanics of materials course designed to support neurodivergent students. The intervention improved belonging, engagement, participation, and conceptual understanding across the full cohort. However, the absence of disaggregated data for neurodivergent students made it difficult to assess the intervention's specific impact on that population.

Rodriguez et al., [67] used case studies to examine how design thinking influenced engineering identity in computer, electrical, and software engineering programs. Among 21 participants, 12 of whom were from historically marginalized groups, the approach reinforced engineering identity, particularly for women and students of color. Participants noted that traditional coursework often felt rote and linear, lacking opportunities for creative design. However, the authors cautioned that prior experiences of marginalization might lead some students to avoid teamwork, potentially limiting the benefits of collaborative design activities.

3.7 Theme 3: cultivating collective responsibility and inclusivity

The third theme focused on cultivating collective responsibility by increasing social awareness [6, 7, 49, 50, 62, 77] and establishing inclusive cultural norms within classrooms, programs, and campuses [2, 5, 17, 82]. One impactful approach was to use study abroad programs to foster these competencies. Rahhal and Ayllon. [62] investigated a diversity and inclusion-oriented curriculum in short-term study-abroad courses. They found that this curriculum not only increased the participation of women and traditionally underrepresented students but also enhanced students' cultural competence and confidence in discussing diversity and inclusion.

Other studies specifically targeted awareness regarding people with disabilities. Ludi et al. [50] tested interventions to improve accessibility awareness, comparing approaches such as lectures and design projects with direct interaction and collaboration with teammates with disabilities. They concluded that "interventions that lead to first-hand interaction or increased empathy with technology users with disabilities may help students go

from noticing a barrier to taking steps to address it" (p. 722). Similarly, Newell et al., [61] integrated disability studies into engineering through an Engineering for Development (E4D) service course. By utilizing lectures and discussions on accessibility, mobility, and assistive technology, the course assessed students' ability to synthesize engineering design principles while respecting the autonomy and perspectives of disabled technology users.

3.8 Theme 4: increasing access

The fourth theme focused on interventions designed to broaden entry into engineering programs [36], improve access to resources [21, 25, 26, 45], and expand research opportunities [34]. Resource-related interventions included financial support such as scholarships [11], mentorship programs [21, 25, 26, 64], and approachable office hours [45].

For instance, in one study, Hain et al. [34] developed a specialized research experience for students with ADHD that provided mentorships, workshops, and roundtable discussions tailored to participants' strengths and needs. Beyond expanding access, the program employed alternative pedagogical approaches that allowed students to see themselves represented among peers. Participants valued the high degree of creativity and autonomy, specifically citing opportunities to solve open-ended problems without prescribed instructions, move physically while working, and make mistakes in an ungraded setting.

In another study, Hartman et al., [36] modified admissions standards to foster a more inclusive student body through holistic reviews that considered applicants' resilience, socioeconomic status (as indicated by participation in the free lunch program), and GPA. These structural changes produced significant demographic shifts: underrepresented minority enrollment increased from 25% to 44%, and female enrollment rose from 14% to 29%.

3.9 Theme 5: empowering thoughtful action through introspection and analysis

The next theme focused on curriculum and instructional interventions designed to empower students through introspection, develop student agency [70], and encourage critical thinking and reflection [2, 7, 49, 61, 62, 65]. These studies highlighted curriculum and instructional strategies that included journaling, meta-level thinking, and reflective identity exercises.

Secules et al., [70] positioned agency as a mechanism to resist oppression, enabling students to control the narrative of their marginalization. Through a case study of an Asian woman in engineering, the authors found that the participant enacted agency through reflective dialogue. The researchers characterized her narrative as one of vulnerability rather than low self-efficacy, arguing that expressing vulnerability creates space to acknowledge difficult emotions while constructing logical critiques. Although she initially feared judgment regarding her cultural background and familial pressures, the interviewer's non-judgmental approach allowed her to navigate these tensions independently. This introspective process contributed to her persistence, helped her establish her place in the field, and motivated her to advocate for other students.

Drawing from liberative pedagogies, Riley and Claris [65] argued that student resistance can be a positive element of empowerment. They employed a multimodal curriculum that altered seating arrangements to shift power dynamics, reframed mistakes as

learning opportunities, and decentered Western, male-dominated perspectives. Central to their approach was encouraging epistemic transformation—helping students recognize that the scientific method is not the sole source of reliable knowledge. The curriculum also emphasized praxis by having students apply thermodynamic concepts to societal issues. Through this work, the researchers identified multiple forms of engagement, including critical reflection, resistance to responsibility, and interdisciplinary thinking.

3.10 Theme 6: changing the narrative around belonging

This theme focused on curricular interventions and instructional strategies designed to normalize feelings of struggle and non-belonging and to integrate personal values into engineering identity [29, 85]. Supporting strategies included fostering a growth mindset [8, 82] and reframing mistakes as learning opportunities [65]. A common approach involved sharing narratives of past students to normalize current students' experiences [29, 85].

In one study, Walton et al., [85] demonstrated the impact of reframing belonging for female students through two interventions. The first, a social belonging intervention, normalized non-belonging as a common, transient experience in engineering. The second, an affirmation training intervention, equipped students with coping mechanisms to manage stress related to marginalization using a "saying is believing" approach in which students wrote letters to future students describing how integrating personal values into their engineering work helped them manage stress.

In another study, Godwin et al., [29] describe the implementation of an ecological belonging intervention designed to normalize adversity and emphasize its surmountability. The instructor explicitly described common challenges, after which students wrote about their own struggles and engaged with stories from past students. Compared with a control group (n = 265), this approach significantly improved students' sense of belonging and odds of passing the course while reducing isolation and boosting confidence.

3.11 Theme 7: Professional engineering organizations and professional development

This theme captured curricular interventions emphasizing professional skill acquisition [12, 25] and participation in professional engineering organizations [15, 14, 73]. Interventions in this area often targeted communication skills and encouraged engagement with identity-based or major-specific organizations. This theme frequently overlapped with representation, as many such organizations are explicitly designed to support specific demographic groups.

Campbell-Montalvo et al., [15] and Smith et al., and [73] examined the impact of organizations such as the Society of Women Engineers (SWE), the National Society of Black Engineers (NSBE), and the Society of Hispanic Professional Engineers (SHPE), finding that participation provided critical representation and support for women and underrepresented minority students. Campbell-Montalvo et al. [14] subsequently investigated the experiences of students with intersecting marginalized identities. Surveying 477 sexual minority and gender minority students—those who do not identify as heterosexual or cisgender, respectively—the authors examined participation in groups like oSTEM (Out in Science, Technology, Engineering, and Mathematics), SWE, NSBE, and SHPE.

The study highlighted the unique benefits of these organizations in helping students navigate barriers associated with intersecting identities in engineering.

In summary, our analysis identified seven themes characterizing inclusive curricula in undergraduate engineering. To foster personal connections, instructors emphasized diverse representation, cultural relevance, and identity-matched mentorship. These efforts were supported by pedagogical methods that prioritize student-centered, collaborative learning, alongside interventions that cultivate collective responsibility and awareness of accessibility. At the intrapersonal level, interventions empowered students through critical reflection and agency while normalizing struggle and promoting a growth mindset. Structural and professional dimensions included increasing access through holistic admissions and leveraging professional engineering organizations to support students with intersecting identities. Having identified what interventions are being implemented, we now turn to how they influence students' sense of belonging, professional identity, and intentions to persist.

3.11.1 RQ2: How do these interventions influence undergraduate engineering students' sense of belonging, professional identity, and intentions to persist?

We identified the following three main themes in response to the second research question: Cultivating Cultural Community Wealth; Inclusive Engineering Identity; and Identity, Belonging, and Persistence. It is important to note that these are deeply interconnected; rather than being confined to a single theme, the data demonstrate that a single curricular intervention often yields benefits across multiple categories of student development simultaneously.

3.12 Theme 2.1: Cultivating community cultural wealth (CCW)

The most common theme was 'cultivating community cultural wealth.' Inclusive curricula transform students' diverse backgrounds into professional assets, fostering the six forms of capital needed for career success and persistence: navigational, social, aspirational, familial, resistance, and linguistic.

3.12.1 Navigational capital

Inclusive curricula significantly enhanced students' professional skills and competence [10, 19, 25]. Professional Engineering Organizations (PEOs) like SHPE and NSBE foster these skills among women and underrepresented minority (URM) students [15, 73]. Curricula positively impact academic performance: an intervention minimized the gender GPA gap [85], and an ecological belonging intervention increased the odds of passing for Black, Latinx, and Indigenous students by 80% [29]. Qualitative gains included self-efficacy and systemic awareness, enabling students to advocate against systemic failures [10, 34].

3.12.2 Social capital

PEOs consistently provided the primary source of social capital for underrepresented students [15, 73]. Identity-based organizations offered representation and validation. SHPE, NSBE, and SWE provided distinct benefits, including social networking, career opportunities for Latinx/Black students, and mentorship for women [73]. However, a survey of 477 sexual minority (SM) and gender minority (GM) students found that GM

students reported lower levels of community and social networking compared to their cisgender peers [16].

3.12.3 Aspirational capital

Inclusive curricula foster aspirational capital by empowering learners and building confidence, thereby encouraging "dreaming bigger" [21, 25]. This confidence increased commitment to engineering and intentions to pursue graduate education [51]. For example, women with female peer mentors maintained steady graduate school aspirations, whereas those with male or no mentors did not [21].

3.12.4 Familial capital

Curricula built bridges between students' cultural identities and engineering, enabling them to leverage existing capital and select community-impacting projects [10, 67]. Marginalized students explicitly linked course material to their backgrounds [67]. SHPE provided Latinx students with a familiar cultural environment [73]. Experiences can also empower students to become sources of familial capital for others [70].

3.12.5 Resistance capital

Reflective curricula facilitated resistance capital, enabling students to critique and challenge educational systems [65, 70]. Fostering "narrative agency" helped students shift the locus of causality from personal shortcomings to the engineering system [70]. This realization—that difficulties stem from systemic barriers—was mirrored in studies of students with disabilities [34, 61]. Curricula also fostered active resistance by incorporating activism into projects [10].

3.12.6 Linguistic capital

Participants accessed linguistic capital by refining their professional communication [12, 73]. An audience-centered approach improved collaboration and professional interaction [12]. PEOs developed specific employment tools: Latinx students in SHPE refined resume skills, while Black students in NSBE developed elevator pitches [73].

3.13 Theme 2: inclusive engineering identity (IEI)

Inclusive engineering identity emerged as a distinct outcome defined by heightened awareness of systemic barriers. It increased cultural competence, though the transition from understanding these concepts to actively confronting inequity in design and practice varied significantly. Studies indicated that inclusive pedagogy primarily fostered IEI by heightening awareness of the barriers faced by marginalized groups [5, 7, 50, 61, 62, 65, 73, 79, 85]. Participants frequently expressed shock regarding the lack of diversity in the field [5, 50] and the pervasive inequities in design [18, 79]. While students gained specific knowledge regarding racism and ableism, the translation to practice was mixed. For instance, although students improved their understanding of accessibility codes and expressed sympathy, many still failed to view disability as relevant to their own design work [50, 61]. Conversely, direct exposure to feedback from disabled users did help some students find equitable design rewarding [50].

For marginalized students, IEI was often linked to community impact. Authors found that giving back to their communities was integral to these students' identities,

suggesting that a new generation of engineers may prioritize equity [7, 73]. This connection was reinforced by curricula that centered on human narratives, such as design thinking and storytelling [67].

Regarding action, results were varied. Rahhal and Ayllon. [62] found that a short-term study abroad program significantly improved cultural competence, with students gaining an average of 6.26 points on the IDI—far surpassing the typical 2.37 gain. However, resistance persisted; Bennett and Sekaquaptewa [5] noted that while men became more likely to confront racism, they remained hesitant to address sexism. Furthermore, some students reacted defensively to discussions of racism in infrastructure [17]. Finally, Boudreau et al. [10] found that allowing a marginalized student to choose a community-focused project fostered inclusive design; however, this student faced harmful rhetoric during data collection, underscoring the urgent need to protect marginalized students engaged in equity work.

3.14 Theme 3: sense of belonging, professional identity, and persistence intentions (BIP)

The final theme of the review focuses on the direct, measured impact of inclusive interventions on three core constructs: Sense of Belonging, Professional Identity, and Persistence Intentions. These studies provided both quantitative evidence (e.g., pre- and post-survey changes) and qualitative testimonials regarding the impact on students.

3.14.1 Sense of belonging

Inclusive engineering interventions consistently improved the sense of belonging among marginalized students and, in some cases, across the entire class cohort [11, 15, 29]. Regarding gender, mentorship, and identity-based programs proved critical. Women with female peer mentors maintained steady belonging over time (p = 0.46), while those with male mentors (p = 0.02) or no mentors (p = 0.007) experienced significant decreases [21]. Similarly, women participating in a Scholars program scored higher on belonging measures than non-participants [11], and interventions encouraged students to view women as belonging in the engineering field [85].

For underrepresented minority (URM) students, belonging was closely tied to cultural affirmation. An ecological belonging intervention significantly improved scores for Black, Latinx, and Indigenous students compared to a control group [29]. Identity-based Professional Engineering Organizations (PEOs) positively affected perceived fit among women and URM students [15], with Latinx participants reporting feeling respected and valued [64]. Research on neurodiversity further demonstrated that opportunities for students with ADHD to participate in research enhanced their sense of belonging by countering self-doubt and connecting them with peers facing similar challenges [34].

3.14.2 Professional identity

Specific curricular strategies and opportunities actively shaped students' professional identity, enabling them to visualize themselves as engineers. For instance, design thinking curricula positively influenced the engineering identity of women and People of Color (POC) by linking identity to interest and performance [67]. Participants reported that external validation of their work and the integration of personal interests enabled them to reframe their perceptions of the field. Additionally, following a student success course, participants frequently emphasized the importance of altruistic

motivation—specifically, giving back to their families and communities. The literature asserts that supporting this motivation is essential for enhancing the professional identities of marginalized students [49].

3.14.3 Persistence intentions

Inclusive interventions—including gender-matched mentorship, PEOs, and specialized research—significantly contributed to persistence among women [21, 70], Latinx students [73], and students with ADHD [34]. Gender-matched mentorship had a strong impact on retention for women: 100% of those with female mentors were retained through the first year, compared to 82% with male mentors and 89% with no mentor ($p < 0.01$) [21]. Furthermore, intentions to pursue advanced degrees remained stable among women with female mentors ($p = 0.81$), but declined significantly among those with male or no mentors ($p = 0.001$, $p = 0.003$). PEOs also bolstered persistence; for example, SWE improved women's confidence, while SHPE expanded Latinx students' career knowledge [73]. Similarly, students with ADHD reported increased persistence intentions following participation in specialized research [34]. While fostering "narrative agency" helped participants persist with greater purpose [70], persistence remains an ongoing process. Despite gaining agency, one participant notably struggled to view her undergraduate career as a "success story of persistence" (p. 207), underscoring the complexity of personal narrative construction.

In summary, inclusive engineering interventions significantly influence undergraduate students' development by focusing on three outcomes. First, interventions cultivate Community Cultural Wealth (CCW) by transforming students' diverse backgrounds into professional assets, fostering six forms of capital: navigational, social, aspirational, familial, resistance, and linguistic. Second, interventions foster an Inclusive Engineering Identity (IEI) by heightening students' awareness of systemic barriers and inequities in the field. Third, interventions directly improve Belonging, Professional Identity, and Persistence Intentions (BIP). Specific examples of impact include the critical role of identity-based Professional Engineering Organizations (PEOs) in enhancing belonging and career knowledge, and the strong relationship between gender-matched mentorship and student retention.

4 Discussion

4.1 Methodological trends

The reviewed literature employed diverse approaches (qualitative, quantitative, and mixed methods) and collected data through surveys, interviews, journaling, and records. Qualitative studies offered rich context but were mostly cross-sectional, hindering claims about long-term effects (e.g., [70]). Quantitative studies relied heavily on Likert surveys with few time points, making it difficult to isolate intervention effects. Mixed methods provided the most robust perspectives.

Major methodological limits included inconsistent measurement, which prevented trend identification across studies. The simultaneous implementation of multiple strategies confounded outcome attribution. Rigorous experimental and quasi-experimental designs were rare among the 40 included studies; only a small subset employed control or comparison groups [11, 21, 29, 85], and these typically featured small samples. The majority of studies relied on pre/post survey designs without comparison conditions,

qualitative case studies, or cross-sectional methods — approaches that limit causal inference. This methodological gap directly informs our call for future research that employs more rigorous designs and larger, more representative samples.

Demographically, the literature primarily focused on women (22 studies) and URM students (20 studies). Fewer studies examined specific populations: Latinx (5), Black (4), neurodiverse (3), disabled (3), low socioeconomic status (3), LGBTQ+ (2), Indigenous (2), and Native Hawaiian (1) students. Engagement with intersectional identities was minimal, and implementation details varied significantly.

Of the 40 included studies, only two measured actual retention behaviorally [21, 36]. The remainder relied on self-reported persistence intentions, belonging scores, or identity measures — proxies that, while theoretically linked to retention, do not confirm whether students remained enrolled. This distinction reinforces our recommendation for longitudinal designs that track students across multiple time points.

4.2 Utilizing multiple inclusive curriculum interventions

Facilitators often employ multiple inclusive curricula simultaneously, with the most prevalent being fostering personal connections, employing inclusive pedagogies, and cultivating collective responsibility due to their broad impact and feasibility. Research shows that inclusive pedagogical methods (e.g., PBL, UDL) have successfully improved Belonging, Identity, and Persistence (BIP) and cultivated Community Cultural Wealth (CCW) among neurodiverse, women, and URM students [34, 67]. However, these methods were used less frequently to address systemic marginalization or to foster Inclusive Engineering Identity (IEI). Conversely, establishing personal connections was highly effective in fostering IEI and improving BIP across demographic groups, including Black, Latinx, and students with disabilities [17, 64]. Similarly, cultivating collective responsibility primarily targeted creating IEI [17, 62], though it was less frequently used to improve BIP or CCW. These strategies often complemented one another: pedagogy facilitated personal connections [17], and personal connections frequently co-occurred with collective responsibility when material raised DEI awareness [50].

Viewed through Wenger's [87] Communities of Practice framework, this pattern is theoretically coherent. Interventions that create opportunities for legitimate peripheral participation (e.g., mentorship, collaborative design, PEO engagement) are those that most directly support identity development and belonging, because they provide structured pathways into the engineering community rather than simply increasing awareness of its demographics.

4.3 Awareness and acceptance without action

Although students demonstrated increased DEI awareness and acceptance, they frequently failed to translate this knowledge into practice unless explicitly encouraged to connect projects to their communities [10, 50]. This disconnect fuels a self-perpetuating cycle: the lack of representation in design deters marginalized students, while non-marginalized students remain unaware of the inequities [5, 79]. Breaking this cycle requires educators to move beyond isolated interventions. To ensure that future engineers view DEI as a professional necessity, inclusive curricula must be prioritized and integrated longitudinally across the undergraduate and graduate experience.

Several theoretical frameworks help explain this disconnect between cognitive awareness (knowing that inequities exist) and behavioral transformation (taking action to remedy them). These are distinct mechanisms, and the reviewed literature suggests that inclusive interventions are considerably more effective at producing the former than the latter. First, attitude-behavior inconsistency is well documented in social psychology: positive attitudes toward equity do not automatically lead to behavioral change without structural prompts or explicit accountability mechanisms. Second, moral licensing theory suggests that completing a DEI module or expressing awareness may itself function as a form of moral credit, paradoxically reducing the motivation to act further. Third, identity-protective cognition may account for the defensive reactions observed among non-marginalized students [17] acknowledging systemic inequity threatens the meritocratic self-concept prevalent in engineering culture [72], prompting resistance rather than engagement. Together, these frameworks suggest that closing the awareness-to-practice gap requires pedagogical designs that explicitly bridge reflection and action, build accountability structures, and challenge the ideological assumptions undergirding engineering identity itself.

4.4 Polarization, activism, and marginalized student well-being

The data reveal a complex tension regarding student engagement with social justice: while students are often willing to confront blatant discrimination, they remain hesitant to acknowledge or address systemic sexism, ableism, and racism [5, 17, 50, 61]. In some instances, students reacted with reluctance or even offense when asked to critically examine marginalization within engineering.

This resistance creates a hostile environment for those pursuing social equity. Students advancing community interests faced negative feedback that directly harmed their well-being [10]. Additionally, participants feared judgment from researchers regarding their upbringing and culture [70]. These findings underscore the heavy emotional toll of activism on marginalized students and highlight the critical need for inclusive engineering identities across the entire student body, preventing the burden of challenging systemic inequity from falling solely on those most affected.

CRT provides a theoretical lens for understanding why non-marginalized students selectively engage with equity content, embracing it when it affirms their sense of fairness, but resisting it when it challenges their complicity in systemic inequities [44]. This same dynamic helps explain why marginalized students disproportionately bear the burden of advocacy. They must develop the capacity to recognize and push back against systemic inequities while navigating the emotional burden this work imposes in environments that are frequently resistant to such critique [90].

4.5 Operationalizing inclusion through pedagogy vs. curriculum

A critical insight from this review is the distinction between 'inclusive curriculum' as a formalized document of topics and 'inclusive pedagogy' as the delivery of that content. Many successful interventions identified in this study (e.g., student choice in projects, peer-led team learning) are not unique to engineering education, nor are they always explicitly labeled as 'diversity' initiatives. However, their application in this context serves a distinct purpose: mitigating the specific 'chilly climate' of engineering. By shifting the focus from *what* is taught (e.g., Calculus concepts) to *how* it is taught (e.g.,

emphasizing growth mindset or collaborative problem-solving), instructors effectively created an 'inclusive curriculum' through pedagogical intervention. This suggests that engineering educators need not rewrite their entire syllabi to foster inclusion; rather, they can strategically integrate inclusive modules and instructional choices that can significantly affect students' belonging and identity.

This distinction also has implications for how outcomes are theorized. If belonging is understood through Tinto's (1987) institutional integration model, then pedagogical interventions may be insufficient on their own, because integration requires sustained structural engagement across the full undergraduate experience, not just within a single course. Conversely, psychological belonging interventions [84] may produce meaningful short-term gains in students' sense of fit without necessarily changing the structural conditions that generated that sense of non-belonging in the first place. Collectively, these frameworks suggest that while inclusive pedagogy is an important starting point, meaningful and lasting change requires corresponding reform at the institutional level.

4.6 Limitations and future research

This study is constrained by the demographic composition of the engineering field, which limits the available literature on inclusive undergraduate education and restricts the generalizability of findings to historically underrepresented populations. Interpreting long-term trends is further complicated by the difficulty of isolating discrete variables within complex educational environments. The authors additionally acknowledge that the scope of their own positionality and experiences may limit the depth and diversity of perspectives captured.

These limitations reflect the broader challenge of applying theoretical frameworks like CCW and Communities of Practice in contexts where the research designs were not originally built to test them. To address these limitations, future research should employ larger, more representative samples and longitudinal designs with multiple data collection points to better establish intervention efficacy over time. Mixed-methods approaches and validated survey instruments would strengthen both contextual richness and methodological rigor. Researchers are also encouraged to document implementation processes and feasibility considerations in sufficient detail to support the dissemination and replication of effective inclusive curricula.

Future inquiry in undergraduate engineering education should examine whether the pedagogical approaches identified in this review similarly promote cognitive flexibility and transdisciplinary thinking, as recent work in biology education has begun to demonstrate [38, 39, 40]. Moreover, while this review found interdisciplinary thinking to be a promising outcome of liberative curricula, future studies might productively explore biomimetic projects and transdisciplinary design frameworks as novel pathways for advancing inclusive engineering education.

5 Conclusion

This literature review demonstrates that inclusive undergraduate engineering curricula are powerful tools for cultivating community cultural wealth, fostering inclusive engineering identities, and improving persistence among historically underserved students. Our analysis of 40 studies reveals that interventions ranging from identity-based mentorship to socially relevant design projects can significantly bolster students' sense of

belonging and professional identity. However, a critical gap remains: while students are increasingly aware of systemic inequities, they often lack the opportunities or support to translate this awareness into equitable engineering practice. This disconnect, exacerbated by a polarized political climate, risks perpetuating a cycle of exclusion where marginalized students bear the burden of advocacy alone. Therefore, we conclude that for inclusive curricula to be truly transformative, they must move beyond isolated interventions and be integrated as a core, longitudinal component of engineering education. Future research must support this shift by employing rigorous, mixed-methods designs to map the long-term impact of these curricula on both student success and the culture of the engineering profession.

Author contributions
BH: Conceptualization, data collection, writing—original draft. KP: Conceptualization, writing—review and editing. PL: Writing—review and editing. AH: Conceptualization, writing—review and editing. EJ Conceptualization, writing—review and editing. SA: Conceptualization, data coding, writing—review and editing.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This article is a literature review and does not involve the collection of new data from human participants or animals; formal ethical approval was therefore not required. This study did not involve human subjects, and we have no conflicts of interest to report.

Consent for publication
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References

1. Aronson B, Laughter J. The theory and practice of culturally relevant education: A synthesis of research across content areas. Rev Educ Res. 2016;86(1):163–206. ttps://doi.org/10.3102/0034654315582066.
2. Atadero RA, Paguyo C, Rambo-Hernandez KE, Henderson HL, Conference ASEEA, Exposition. ttps://doi.org/10.18260/p.25994
3. Baeten M, Kyndt E, Struyven K, Dochy F. Using student-centered learning environments to stimulate deep approaches to learning: Factors encouraging or discouraging their effectiveness. Educational Res Rev. 2010;5(3):243–60. ttps://doi.org/10.1016/j.edurev.2010.06.001.
4. Banks JA. Equity pedagogy: An essential component of multicultural education. Theory Into Pract. 1995;34(3):152–8. ttps://doi.org/10.1080/00405849509543674.
5. Bennett JE, Sekaquaptewa D. Setting an egalitarian social norm in the classroom: Improving attitudes towards diversity among male engineering students. Soc Psychol Educ. 2014;17:343–55. ttps://doi.org/10.1007/s11218-014-9253-y.
6. Benson B, Callenes J, Malek A. (2020, June). Incorporating diversity and inclusion in the computing classroom. In 2020 ASEE Virtual Annual Conference Content Access. ttps://doi.org/10.18260/1-2--34807
7. Bielefeldt AR. (2023, June). Integration of diversity, equity, and inclusion topics into a first-year introduction to civil engineering course. In 2023 ASEE Annual Conference & Exposition. ttps://doi.org/10.18260/1-2--43787
8. Bielefeldt AR, Tsai JY, Myers BA, Godrick DA, Sullivan JF. (2021, January). Minority status and belonging: Engineering math as a vehicle to build community. In 2021 CoNECD. ttps://doi.org/10.18260/1-2--36109
9. Boothe KA, Lohmann MJ, Donnell KA, Hall DD. Applying the principles of Universal Design for Learning (UDL) in the college classroom. J Special Educ Apprenticesh. 2018;7(3):1–13. https://scholarworks.lib.csusb.edu/josea/vol7/iss3/2/.
10. Boudreau K, Bunyea LR, DiBiasio D, Johnson R, Reidinger Z, Diversity C. ttps://doi.org/10.18260/1-2--31772
11. Brobst JA, Davishahl J, Litzler E, Klein AG, Alqudah S. (2023, June). Examining first-year engineering programs' impacts on sense of belonging across gender. In 2023 ASEE Annual Conference & Exposition. ttps://doi.org/10.18260/1-2--43481
12. Burchfield J, Akintewe O, Chilton J. (2022, August). A cultural approach to teaching teamwork in undergraduate engineering courses. In 2022 ASEE Annual Conference & Exposition. ttps://doi.org/10.18260/1-2--41678
13. Burke PJ, Stets JE. Identity theory. Oxford University Press; 2009.

14. Campbell-Montalvo R, Cooke H, Smith C, Puccia E, Miller MH, Skvoretz J, Wao H, Conference. & Exposition. ttps://doi.org/10.18260/1-2--43490
15. Campbell-Montalvo R, Kersaint G, Smith CA, Puccia E, Sidorova O, Cooke H, Wao H, Martin JP, Skvoretz J, MacDonald G, Lee R. The influence of professional engineering organizations on women and underrepresented minority students' fit. In Frontiers in Education. 755471) Front Media SA. 2022;6. ttps://doi.org/10.3389/feduc.2021.755471.
16. Campbell-Montalvo R, Kersaint G, Smith CA, Puccia E, Skvoretz J, Wao H, Martin JP, MacDonald G, Lee R. How stereotypes and relationships influence women and underrepresented minority students' fit in engineering. J Res Sci Teach. 2022;59(4):656–92. ttps://doi.org/10.1002/tea.21740.
17. Casper AA, Atadero RA, Abdallah AR, Siller T. Bringing social justice context into civil engineering courses for first-year and third-year students. J Civil Eng Educ. 2024;150(2):04023013. ttps://doi.org/10.1061/JCEECD.EIENG-1857.
18. Casper AA, Atadero RA, Hedayati-Mehdiabadi A, Baker DW. Linking engineering students' professional identity development to diversity and working inclusively in technical courses. J Civil Eng Educ. 2021;147(4):04021012. ttps://doi.org/10.1061/(ASCE)EI.2643-9115.0000052.
19. Chang YJ, Wang TY, Chen SF, Liao RH. Student engineers as agents of change: combining social inclusion in the professional development of electrical and computer engineering students. Systemic Pract Action Res. 2011;24:237–45. ttps://doi.org/10.1007/s11213-010-9183-3.
20. Chrysochoou M, Zaghi AE, Syharat CM, Motaref S, Jang S, Bagtzoglou A, Wakeman CA. (2021, July). Redesigning engineering education for neurodiversity: New standards for inclusive courses. In 2021 ASEE Virtual Annual Conference Content Access. ttps://doi.org/10.18260/1-2--37647
21. Dennehy TC, Dasgupta N. (2017). Female peer mentors early in college increase women's positive academic experiences and retention in engineering. Proceedings of the National Academy of Sciences, 114(23), 5964–5969. ttps://doi.org/10.1073/pnas.1613117114
22. Edmondson A. Psychological safety and learning behavior in work teams. Adm Sci Q. 1999;44(2):350–83. ttps://doi.org/10.2307/2666999.
23. Florian L, Black-Hawkins K. Exploring inclusive pedagogy. Br Edu Res J. 2011;37(5):813–28. ttps://doi.org/10.1080/01411926.2010.501096.
24. Freeman TM, Anderman LH, Jensen JM. Sense of belonging in college freshmen at the classroom and campus levels. J Experimental Educ. 2007;75(3):203–20. ttps://doi.org/10.3200/JEXE.75.3.203-220.
25. Garcia V, Golding P, Golding D, Torres-Catanach I, Cuvelier N, Cholewa C, Mendoza KA, Conference. & Exposition. ttps://doi.org/10.18260/1-2--41618
26. Gatz J, Kelly AM, Bugallo MF. (2018, January). The power of peer mentoring of undergraduate women in engineering: Fostering persistence through academic and social integration. In Proceedings of the 2018 American Society for Engineering Education Annual Conference & Exposition. ttps://doi.org/10.18260/1-2--31119
27. Gay G. Preparing for culturally responsive teaching. J Teacher Educ. 2002;53(2):106–16. ttps://doi.org/10.1177/0022487102053002003.
28. Geisinger BN, Raman DR. Why they leave: Understanding student attrition from engineering majors. Int J Eng Educ. 2013;29(4):914–25.
29. Godwin A, Perkins H, DeAngelo L, McChesney E, Kaufman-Ortiz K, Dorvé-Lewis G, Conrique B. Belonging in engineering for Black, Latinx, and Indigenous Students: Promising results from an educational intervention in an introductory programming course. IEEE Trans Educ. 2023. ttps://doi.org/10.1109/TE.2023.3312628.
30. Good C, Rattan A, Dweck CS. Why do women opt out? Sense of belonging and women's representation in mathematics. J Personal Soc Psychol. 2012;102(4):700–17. ttps://doi.org/10.1037/a0026659.
31. Goodenow C. The psychological sense of school membership among adolescents: Scale development and educational correlates. Psychol Sch. 1993;30(1):79–90. ttps://doi.org/10.1002/1520-6807(199301)30.:1%3C79::AID-PITS2310300113%3E3.0.CO;2-X.
32. Gorski PC. Rethinking the role of culture in educational equity: From cultural competence to equity literacy. Multicultural Perspect. 2016;18(4):221–6. ttps://doi.org/10.1080/15210960.2016.1228344.
33. Griful-Freixenet J, Struyven K, Vantieghem W, Gheysens E. Exploring the interrelationship between Universal Design for Learning (UDL) and Differentiated Instruction (DI): A systematic review. Educational Res Rev. 2017;29:100306. ttps://doi.org/10.1016/j.edurev.2019.100306.
34. Hain A, Zaghi AE, Taylor CL, Conference ASEE, Exposition. ttps://doi.org/10.18260/1-2--29969
35. Harteveld C, Javvaji N, Machado T, Zastavker YV, Bennett V, Abdoun T. (2020, October). Gaming4all: reflecting on diversity, equity, and inclusion for game-based engineering education. In 2020 IEEE Frontiers in Education Conference (FIE) (pp. 1–9). IEEE. ttps://doi.org/10.1109/FIE44824.2020.9274176
36. Hartman H, Forin T, Sukumaran B, Farrell S, Bhavsar P, Jahan K, Macey D. Strategies for improving diversity and inclusion in an engineering department. J Prof Issues Eng Educ Pract. 2019;145(2):04018016. ttps://doi.org/10.1061/(ASCE)EI.1943-5541.0000404.
37. Hazari Z, Sonnert G, Sadler PM, Shanahan M-C. Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. J Res Sci Teach. 2010;47(8):978–1003. ttps://doi.org/10.1002/tea.20363.
38. Honra JR. Enhancing high school biology education students' transdisciplinary thinking through design thinking. J Experimental Educ. 2025a;1–17. ttps://doi.org/10.1080/00220973.2025.2606241.
39. Honra JR. Understanding the influence of biomimetic projects on transdisciplinary thinking in biology education. Innovations Educ Teach Int. 2025b;1–15. ttps://doi.org/10.1080/14703297.2025.2512386.
40. Honra JR, Monterola SLC. Enhancing biology students' cognitive flexibility through problem-based learning moderated by transdisciplinary thinking. J Educational Res. 2025;119(1):129–39. ttps://doi.org/10.1080/00220671.2025.2525245.
41. Jensen KJ, Cross KJ. Engineering stress culture: Relationships among mental health, engineering identity, and sense of inclusion. J Eng Educ. 2021;110(2):371–92. ttps://doi.org/10.1002/jee.20391.
42. Ladson-Billings G. But that's just good teaching! The case for culturally relevant pedagogy. Theory Into Pract. 1995;34(3):159–65. ttps://doi.org/10.1080/00405849509543675.
43. Ladson-Billings G. Culturally relevant pedagogy 2.0: aka the Remix. Harv Educational Rev. 2014;84(1):74–84. ttps://doi.org/10.17763/haer.84.1.p2rj131485484751.

44. Ladson-Billings G, Tate WF, IV. Toward a critical race theory of education. Teachers Coll Record. 1995;97(1):47–68.
45. Lancaster S, Walden S, Trytten D, Murphy T. (2005, June). The contribution of office hours type interactions to female student satisfaction with the educational experience in engineering. In 2005 Annual Conference (pp. 10-1268). ttps://doi.org/10.18260/1-2--14225
46. Lea SJ, Stephenson D, Troy J. Higher education students' attitudes to student-centred learning: Beyond 'educational bulimia'? Stud High Educ. 2003;28(3):321–34. ttps://doi.org/10.1080/03075070309293.
47. Leyva LA, McNeill RT, Balmer BR, Marshall BL, King VE, Alley ZD. Black queer students' counter-stories of invisibility in undergraduate STEM as a white, cisheteropatriarchal space. Am Educ Res J. 2022;59(5):863–904. ttps://doi.org/10.3102/00028312221096455.
48. Leyva LA, McNeill RT, Duran A. A queer of color challenge to neutrality in undergraduate STEM pedagogy as a White, cisheteropatriarchal space. J Women Minor Sci Eng. 2022;28(2):79–94. ttps://doi.org/10.1615/JWomenMinorScienEng.2022036586.
49. Liptow EE, Chen KC, Parent R, Duerr J, Henson D, Conference ASEE. & Exposition. ttps://doi.org/10.18260/p.26439
50. Ludi S, Huenerfauth M, Hanson V, Rajendra Palan N, Conn P. (2018, February). Teaching inclusive thinking to undergraduate students in computing programs. In Proceedings of the 49th ACM technical symposium on computer science education (pp. 717–722). ttps://doi.org/10.1145/3159450.3159512
51. Luthi KT, Kar M. Equity in engineering education: The experiences of non-traditional students in introductory engineering courses with peer learning support. ASEE 2022 Annual Conf. 2022. ttps://doi.org/10.18260/1-2--41955.
52. McGee EO, Bentley L. The equity ethic: Black and Latinx college students reengineering their STEM careers toward justice-oriented causes. Am J Educ. 2017;124(1):1–36. ttps://doi.org/10.1086/693954.
53. Morton TR, Gee DS, Woodson AN. Being vs. becoming: Transcending STEM identity development through Afropessimism, moving toward a Black X consciousness in STEM. J Negro Educ. 2019;88(3):327–42. ttps://doi.org/10.7709/jnegroeducation.88.3.0327.
54. Morton TR, Nkrumah T. A day of reckoning for the white academy: Reframing success for African American women in STEM. Cult Sci Edu. 2021;16(2):485–94. ttps://doi.org/10.1007/s11422-020-10004-w.
55. Morton TR, Parsons EC. #BlackGirlMagic: The identity conceptualization of Black women in undergraduate STEM education. Sci Educ. 2018;102(6):1363–93. ttps://doi.org/10.1002/sce.21477.
56. Motaref S. (2022, August). Strength-based projects in the mechanics of materials course to enhance inclusivity and engagement. In 2022 ASEE Annual Conference & Exposition. ttps://doi.org/10.18260/1-2--41896
57. Murphy MC, Dweck CS. A culture of genius: How an organization's lay theory shapes people's trust, belonging, and performance. Pers Soc Psychol Bull. 2010;36(3):283–96. ttps://doi.org/10.1177/0146167209347386.
58. National Academies of Sciences, Engineering, and Medicine. Advancing Antiracism, Diversity, Equity, and Inclusion in STEMM Organizations: Beyond Broadening Participation. National Academies; 2023. ttps://doi.org/10.17226/26803.
59. National Academy of Engineering. Changing the Conversation: Messages for Improving Public Understanding of Engineering. National Academies; 2008. ttps://doi.org/10.17226/12187.
60. National Center for Educational Statistics. (n.d.). https://nces.ed.gov/programs/digest/current_tables.asp
61. Newell MH, Resto-Fernández MC, MacCarthy MF. (2021). Integrating disability studies into an engineering service-learning curriculum. ASEE Annual Conference. ASEE.
62. Rahhal T, Ayllon ME. (2021, January). Understanding the impact of a diversity and inclusion oriented curriculum in short-term study abroad programs for undergraduate engineering students. In 2021 CoNECD. ttps://doi.org/10.18260/1-2--36133
63. Rao K, Meo G. Using universal design for learning to design standards-based lessons. SAGE Open. 2016;6(4):1–12. ttps://doi.org/10.1177/2158244016680688.
64. Rayford T, Ruedas-Gracia N, Goldstein M, Schimpf C, Hebert L, Escamilla L, Zavala J, Conference. & Exposition. ttps://doi.org/10.18260/1-2--40697
65. Riley D, Claris L. (2009). From persistence to resistance: Pedagogies of liberation for inclusive science and engineering. Int J Gend Sci Technol, 1(1). https://genderandset.open.ac.uk/index.php/genderandset/article/view/25
66. Rodriguez SL, Blaney JM. We're the unicorns in STEM: Understanding how academic and social experiences influence sense of belonging for Latina undergraduate students. J Divers High Educ. 2021;14(3):441–55. ttps://doi.org/10.1037/dhe0000176.
67. Rodriguez SL, Doran EE, Friedensen RE, Martínez-Podolsky E, Hengesteg PS. Inclusion & marginalization: How perceptions of design thinking pedagogy influence computer, electrical, and software engineering identity. Int J Educ Math Sci Technol. 2020;8(4):304–17. ttps://doi.org/10.46328/ijemst.v8i4.952.
68. Ryan RM, Deci EL. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. Am Psychol. 2000;55(1):68–78. ttps://doi.org/10.1037/0003-066X.55.1.68.
69. Schlossberg NK. Marginality and mattering: Key issues in building community. New Dir Student Serv. 1989;48:5–15.
70. Secules S, Gupta A, Elby A, Tanu E. Supporting the narrative agency of a marginalized engineering student. J Eng Educ. 2018;107(2):186–218. ttps://doi.org/10.1002/jee.20201.
71. Seymour E, Hunter AB, editors. (2019). Talking about leaving revisited: Persistence, relocation, and loss in undergraduate STEM education. Springer. ttps://doi.org/10.1007/978-3-030-25304-2
72. Slaton AE. (2015). Meritocracy, technocracy, democracy: Understandings of racial and gender equity in American engineering education. International Perspectives on Engineering Education: Engineering Education and Practice in Context, Volume 1, 171–189. ttps://doi.org/10.1007/978-3-319-16169-3_8
73. Smith CA, Wao H, Kersaint G, Campbell-Montalvo R, Gray-Ray P, Puccia E, MacDonald G. Social capital from professional engineering organizations and the persistence of women and underrepresented minority undergraduates. Front Sociol. 2021;6:671856. ttps://doi.org/10.3389/fsoc.2021.671856.
74. Smucker AD. Exploring the growth of inclusive curriculum: a systematic review of scholar and practitioner perspectives. Int J Incl Educ. 2024;28(12):2750–64. ttps://doi.org/10.1080/13603116.2022.2121988.
75. Solórzano DG, Yosso TJ. Critical race methodology: Counter-storytelling as an analytical framework for education research. Qualitative Inq. 2002;8(1):23–44.
76. Stryker S. (1980). Symbolic interactionism: A social structural version. Benjamin/Cummings.
77. Szczesny S, Salazar A, Casasanta AC, Conference. & Exposition. ttps://doi.org/10.18260/1-2--43628

78. Tanner KD. Structure matters: Twenty-one teaching strategies to promote student engagement and cultivate classroom equity. CBE—Life Sci Educ. 2013;12(3):322–31. ttps://doi.org/10.1187/cbe.13-06-0115.
79. Telang NK, Annaluru RS, Julien C, Santacruz PE, Conference, Exposition. ttps://doi.org/10.18260/1-2--43406
80. Tinto V. Leaving college: Rethinking the causes and cures of student attrition. 2nd ed. University of Chicago Press; 1987.
81. Tripon C. Integrating service-learning in STEM workshops to promote digital skills, problem-solving, and the UN Sustainable Development Goals in education. Social Sci. 2025;14(11):671. ttps://doi.org/10.3390/socsci14110671.
82. Tuchscherer R, Gray CA, Tingerthal J. (2018, July). Examining interventions to increase classroom community and relevancy in an early career engineering course. In ASEE Annual Conference proceedings. ASEE.
83. Valencia RR, editor. The evolution of deficit thinking: Educational thought and practice. Falmer; 1997.
84. Walton GM, Cohen GL. A question of belonging: Race, social fit, and achievement. J Personal Soc Psychol. 2007;92(1):82–96. ttps://doi.org/10.1037/0022-3514.92.1.82.
85. Walton GM, Logel C, Peach JM, Spencer SJ, Zanna MP. Two brief interventions to mitigate a chilly climate transform women's experience, relationships, and achievement in engineering. J Educ Psychol. 2015;107(2):468. ttps://doi.org/10.1037/a0037461.
86. Weaver JP, Decaro MS, Hieb JL, Ralston PA, Conference ASEE. & Exposition. ttps://doi.org/10.18260/p.25818
87. Wenger E. Communities of practice: Learning, meaning, and identity. Cambridge University Press; 1998.
88. Wilson D, Jones D, Bocell F, Crawford J, Kim MJ, Veilleux N, Floyd-Smith T, Bates R, Plett M. Belonging and academic engagement among undergraduate STEM students: A multi-institutional study. Res High Educt. 2015;56(7):750–76. ttps://doi.org/10.1007/s11162-015-9367-x.
89. Wright GB. Student-centered learning in higher education. Int J Teach Learn High Educ. 2011;23(3):92–7. https://files.eric.ed.gov/fulltext/EJ938583.pdf.
90. Yosso TJ. Whose culture has capital? A critical race theory discussion of community cultural wealth. Race Ethn Educ. 2005;8(1):69–91. ttps://doi.org/10.1080/1361332052000341006.
91. Zumbrunn S, McKim C, Buhs E, Hawley LR. Support, belonging, motivation, and engagement in the college classroom: A mixed method study. Instr Sci. 2014;42(5):661–84. ttps://doi.org/10.1007/s11251-014-9310-0.

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