Enhancing equity and inclusivity in engineering education for diverse undergraduate students: a systematic literature review

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Abstract

Historically, higher education systems have prioritized access and enrollment over equitable outcomes, often overlooking how policies and practices affect diverse student groups. As a result, measures of effectiveness have focused more on participation than on equity in academic performance, retention rate, and degree completion rate across racial and cultural groups. In response, equity and inclusivity have become central priorities in engineering education over the past two decades, emphasizing fair access to resources, opportunities, and academic success for students. This systematic literature review synthesizes research published between 2000 and 2024 to examine strategies that promote equitable and inclusive learning environments for diverse undergraduate engineering students. A comprehensive search across six major databases—Google Scholar, ASEE PEER, IEEE Xplore, Scopus, Compendex, and INSPEC—yielded 902 studies, of which 43 met the inclusion criteria following the PRISMA-guided screening and established review protocols.

The analysis identified five key themes: (1) mentorship programs that strengthen belonging and academic success; (2) diversity initiatives that reshape institutional culture and engineering student participation; (3) inclusive teaching practices that improve engagement and reduce achievement gaps; (4) inclusive curriculum designs that incorporate diverse cultural perspectives; and (5) efforts to address implicit bias in teaching and assessment. Collectively, this review underscores the significant impact of implementing coordinated, multi-level equity strategies and initiatives to address criticisms of the higher education system's lack of minority

representation. Additionally, study findings underscore the need for sustained institutional commitment to support diverse historically marginalized student groups in engineering fields. Findings also indicate a growing scholarly emphasis on equity-focused engineering education. This review highlights the importance of coordinated, multi-level interventions and sustained institutional commitment to address persistent inequities and strengthen diversity in engineering education.

Keywords: engineering education equity, inclusivity, PRISMA framework, systematic literature review, engineering students

1. Introduction

Higher education institutions in the United States increasingly recognize the importance of fostering an inclusive learning culture within engineering education. This shift is essential not only for broadening the field of engineering but also for ensuring that engineering education is accessible to all. Engineering education systems (such as engineering curriculum and pedagogy, engineering instructors, students' demographics and support services, industry partnerships, technology integration, assessment and evaluation systems, policies and governance, accreditation and quality standards) play an important role in preparing students for careers in both industry and academia by equipping them with the technical expertise and practical experience necessary to drive technological advancement. Stakeholders— including engineering administrators, educators, and industry professionals—collaborate to provide students with the skills needed to contribute to innovation in teaching that fuels economic growth [4], [6], enhance healthcare through technology [8], [12], improve national security systems [26], [37], and promote sound resource management [4], [6]. As a result, engineering graduates bring sought-after expertise to a wide spectrum of sectors in the American job market. However, research

reveals a significant underrepresentation of certain groups—specifically women, racial and ethnic minorities, and individuals from low-income backgrounds—in engineering fields within U.S. higher education institutions due to a lack of inclusive engineering systems in undergraduate learning environments [4], [51], [54]. This lack of representation limits the diversity of perspectives and experiences in the engineering field and perpetuates systemic inequalities.

In recent decades, the principles of equity and inclusivity in education have gained prominence. Addressing the underrepresentation of minorities in engineering education requires a multifaceted approach, including government initiatives, such as funding and support aimed at improving diversity and access to higher education [9], [49], [32], equity action plans [44], [53], teacher diversity [10], and inclusive teaching practices [33], [46]. These efforts aim to build on existing diversity initiatives by implementing new strategies that provide equal access to resources and academic rigor for all students, regardless of their backgrounds. For example, Halkiyo's [17] study emphasizes the importance of effective instructional design for international students in engineering fields. The findings suggest that inclusive instructional design, which considers the unique educational and cultural backgrounds of international students, can help create a more integrated engineering curriculum and inclusive learning environment for undergraduate engineering students. Further, such effective instructional design for engineering courses and curriculum ensures that all students have equal access to educational opportunities and resources, ultimately helping to bridge the gap in representation among different demographic students in engineering classrooms.

Another inclusive education approach is art-integrated learning to foster critical thinking skills in inclusive classrooms, where students with and without disabilities learn side by side [52]. The

group of students with disabilities is diverse. The only thing they have in common is disability that prevents them from taking advantage of the general engineering curriculum without specialized support. One innovative teaching method is integrating content with artistic forms, such as creative expression through photography and diagrams, and learning content standards are taught and assessed equitably in and through the arts in the maker spaces [52]. This arts integration approach encourages engineering faculty to employ hands-on activities that not only develop critical thinking skills but also enhance engineering students' abilities to observe and respond to the needs of their peers in learning [16], [52].

Furthermore, integrating culturally relevant content into the curricula as proposed by Ladson-Billings [57] is another effective strategy for enhancing equity and inclusivity. Culturally responsive instruction creates a more equitable educational environment for historically marginalized and non-marginalized student groups [13], [39] [58]. Despite the growing awareness of the need for equity and inclusivity in engineering education, there remains a gap in understanding the specific impact of initiatives, such as mentorship programs on creating a supportive learning environment and addressing historical social injustices [18], [30], [35], [40], [41]. Additionally, the transformative potential of equity and inclusivity initiatives, as well as their direct impact on student outcomes and the development of a more diverse engineering workforce. To address these gaps, this systematic review of reviews seeks to comprehensively explore the necessity and impact of promoting equity and inclusivity in engineering education for undergraduate students from diverse backgrounds. By systematically synthesizing and analyzing the existing literature, this study seeks to identify the strategies and interventions employed by engineering educators to enhance educational equity and inclusivity. The study was guided by two research questions: (1) What are the strategies and initiatives that promote equity

and inclusivity in engineering education for diverse undergraduate students, and (2) how do equity and inclusivity initiatives impact student learning outcomes and the development of a diverse engineering workforce?

2. Methodology

We conceptualized a Systematic Literature Review (SLR) in engineering education as a structured and methodological approach to identifying, evaluating, and synthesizing research evidence on a specific engineering topic or research question. Unlike traditional narrative reviews, SRLs follow a rigorous, pre-defined protocol that minimizes bias, ensures transparency, and allows reproducibility of findings. We used the PRISMA framework to guide our SRL study process in achieving these objectives. This framework has four phases: (1) identification, where all study datasets including articles were retrieved from selected databases using search terms and Boolean operators; (2) screening, wherein all collected datasets of the study were screened by study selection criteria following predefined inclusion and exclusion criteria; (3) eligibility, is the phase where the initially identified and screened datasets are further evaluated to determine whether they meet predefined criteria for inclusion in the final analysis; and (4) inclusion, wherein the final study dataset included in the review process are analyzed and synthesized to answer a set of research questions. This study followed an SLR protocol guided by the PRISMA 2020 checklists [42]. The SLR protocol was developed to ensure a structured and transparent approach to the literature search and data collection, as presented in Appendix Table 1. This SLR protocol contained information, including search terms, sources of databases, study objective, eligibility criteria, study section process, and data collection, extraction, and synthesis methods. The review aimed to explore strategies and interventions that promote equity and inclusivity in engineering education for undergraduate students.

2.1. Data Collection

Data were collected from five primary databases: Google Scholar, ASEE PEER, IEEE Xplore, Compendex, and Scopus. These databases were chosen for their comprehensive coverage and compatibility with library tools, e.g., easily connect the records with Zotero library, and help to download and export the records along with study characteristics, such as names of authors, publication year, abstracts, number of citations, publisher, etc. In addition, these databases help the researchers to readily download and export such study features from several types of studies, such as articles, books, and conference papers to reference management tools, e.g., Microsoft Excel. A total of six search terms were used, including "equity," "inclusivity," "education equity in engineering," "inclusion in engineering," "equity in engineering education," and "inclusivity in engineering education" to collect literature mentioned in published articles' titles, abstracts, or keywords. Search strategies varied across databases, employing a combination of search terms and Boolean operators to refine the results. For example, Scopus data were retrieved on 30th July 2023 using search strings: *TITLE-ABS-KEY ((equity AND in AND engineering OR inclusivity) AND (education AND equity OR inclusive)) AND (limit-to (subject area, "engineering")) AND (limit-to (doctype, "article") OR limit-to (doctype, "chapter book") OR limit-to (doctype, "conference paper") OR limit-to (doctype, "book")) AND (limit-to (exact keyword, "equity") OR limit-to (exact keyword, "engineering education") OR limit-to (exact keyword, "students") OR limit-to (exact keyword, "inclusion")) AND (limit-to (language, "English")). Furthermore, we added articles meeting all inclusion criteria and eliminated articles that did not meet one of the exclusion criteria, as presented in Table 2.*

Table 2 SLR Study selection of literature using inclusion-exclusion criteria

Criteria	Decision
When the predefined keywords exist as a whole or at least in the title, keywords, or abstract section of the paper	Inclusion
When the articles had to be conducted and published in the engineering fields.	Inclusion
Papers that present pieces of evidence of the contribution to engineering education equity and inclusivity	Inclusion
The paper should be written in the English language	Inclusion
The paper had to be published between 2000 and April 2024	Inclusion
The paper had to be full-length and restricted to journal articles, theses, conference proceedings, and book chapters	Inclusion
Papers that are pre-prints, reports, and web-page blogs	Exclusion
Papers that are duplicated within search documents	Exclusion

The general screening processes and the flow of selecting relevant literature are presented in Figure 1. In the identification stage, a total of 902 records were retrieved through comprehensive database searching (588 from Scopus, 38 from IEEE Xplore, six from ASEE PEER, 128 from Compendex and INSPEC/Engineering Village, and 142 from Google Scholar, i.e., using an advanced search technique). After removing works of literature such as gray literature, webpage blogs, extended abstracts, preprint papers, and reports, the number of literatures was reduced to 730 records, which were retained for further title analysis. Furthermore, during the screening stage, the reviewers performed two tasks: (1) the duplication of the recorded dataset was checked

and excluded 239 publications, and (2) the first iteration of the screening process examined the title of each article, which excluded 72 irrelevant records to the review topic. In addition, the review work identified six non-English records and excluded them from further review consideration. This process resulted in 413 records that fulfill the eligibility criteria for further abstract review. Upon reading the abstracts, 299 articles unrelated to the review's topic and goals were excluded, leaving 114 articles for full-text reading. From these, 71 articles were discarded because they did not pertain to engineering fields or discuss the importance of learning initiatives and practices to enhance education equity and inclusivity. In the end, 43 publications that fulfilled all inclusion criteria remained in the review, specifically focusing on education equity and inclusivity.

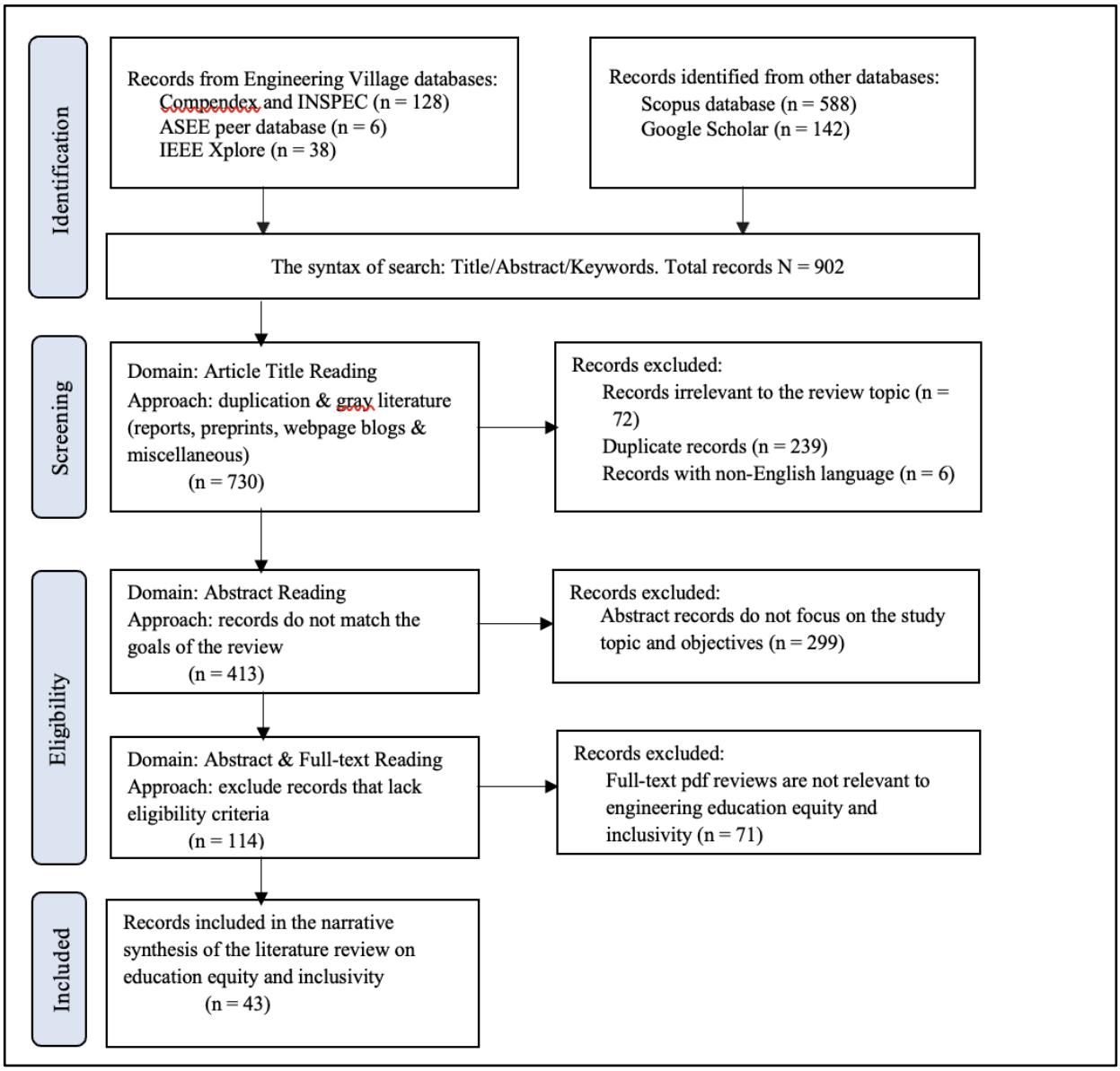

Figure 1 PRISMA flow diagram for the database search of publications for systematic literature reviews

2.2. Data Analysis

This study utilized qualitative content analysis to examine the 43 identified publications, aiming to summarize the existing evidence and generate new insights/ knowledge production by synthesizing multiple articles. To achieve this, the reviewers followed a structured five-step process to synthesize the literature and derive meaningful insights from publications. In the first

step, both reviewers independently read and created scholarly summaries from a sample of twenty-one publications. Each reviewer documented the following information for each article, including the title, list of authors, abstract, keywords, year of publication, study purpose, research design and context, publication outlet, document types (e.g., conference proceedings, journal paper, book), research methods employed, and research findings. The summaries from both reviewers were then compared to confirm that the records were consistent.

In the second step, the reviewers collaborated to inductively generate codes that captured common patterns across twenty-one publications. This process resulted in the identification of thirteen distinct codes. In the third step, the remaining twenty-two publications were reviewed independently by both reviewers to capture scholarly summaries of information as before, as well as map each article to the nineteen codes generated in the previous step. If an article does not fit into any existing codes, the reviewers can propose new codes as necessary. The fourth step involved further analysis of codes generated in the second and third steps, and grouped into five emergent themes: mentorship interventions, diversity initiatives, inclusive teaching practices, implicit bias in learning, and inclusive curriculum.

In the final step of the systematic literature review data analysis, we assessed the inter-rater reliability between two reviewers in categorizing selected articles into themes. Both reviewers independently evaluated the literature using a binary rating system, marking articles as either satisfactory (1) or unsatisfactory (0). This assessment utilized Cohen's Kappa statistics to evaluate the reliability of the analysis. Out of 41 articles reviewed, the analysis yielded a Cohen's Kappa value of 1.00, indicating complete agreement between reviewers.

3. Results

3.1 Publication trends in scholarly research related to equity and inclusivity in engineering education

An analysis of publication trends related to engineering education equity and inclusivity from 2021 to April 1, 2024, reveals a significant increase in scholarly activity, indicating a burgeoning interest in the subject. Key peaks in publication activity were observed in 2015, 2020, and 2022, with the highest levels recorded in 2020 and 2022, as illustrated in Figure 1. These spikes likely reflect heightened academic engagement in response to societal movements advocating for diversity and inclusion.

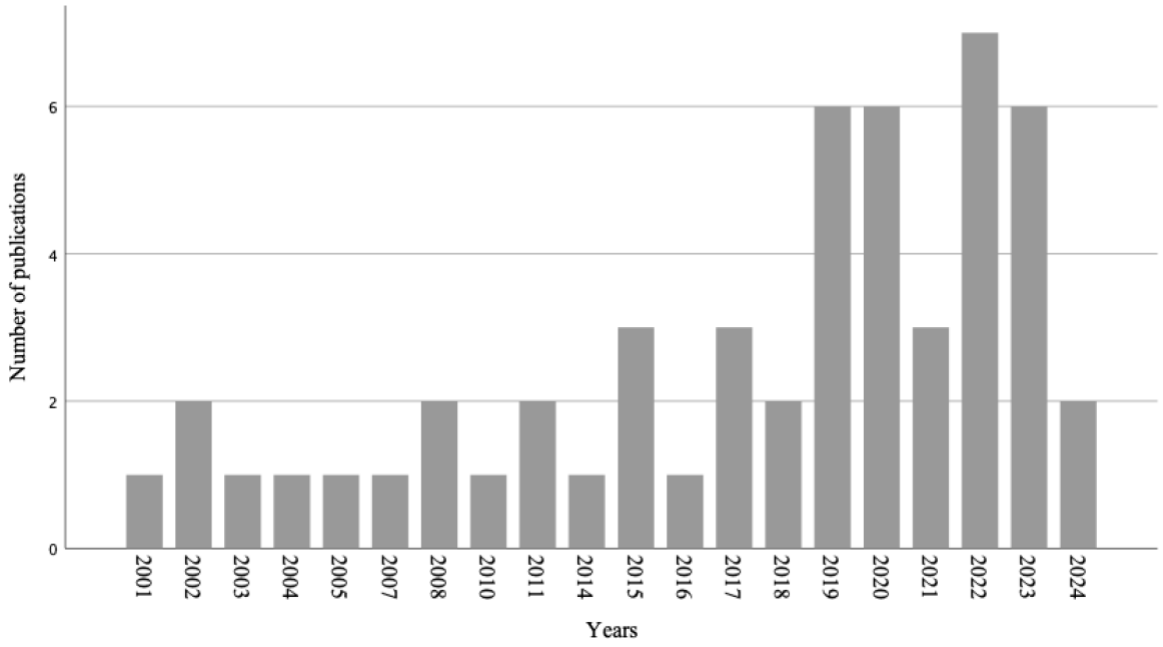

Figure 1 Number of final selected publications in engineering education equity and inclusivity by year

Conversely, the data highlights years with minimal to no publications, suggesting fluctuations in research focus and external influences (e.g., funding constraints) on academic priorities. Thus, in this SLR study, the trends indicate a positive trajectory in scholarly engagement with equity and inclusivity in engineering education, while also highlighting the need for continued focus and support in this area of research, which is essential for fostering diverse learning environments.

4. Findings and Discussions

This study synthesized 43 studies published between 2000 and 2024 to identify strategies and interventions used to advance equity and inclusivity in undergraduate engineering education and to examine how these approaches are conceptualized in the literature. Guided by the CRP lens of Ladson-Billings [57], the review revealed five interconnected themes: mentorship interventions, diversity initiatives, inclusive teaching practices, implicit biases, and inclusive curriculum designs. Together, these themes illustrate how engineering teachers conceptualize and operationalize equity and inclusivity through practices that contribute to undergraduate engineering students' academic achievement, cultural competence, and critical awareness.

Theme 1: Mentorship interventions

This theme captures insights from twelve articles that explore the significance of mentorship interventions within engineering education. Eight of these articles highlight the critical role of how mentorship interventions function in advancing educational equity, particularly for diverse student backgrounds [12], [14], [16], [19], [20], [24], [29], [31]. These studies underscore the importance of providing structured guidance, access to resources, and relational support as a mechanism to improve academic achievement, strengthen cultural identity, identity development, self-efficacy, and increase sense of belonging for historically marginalized and minoritized engineering students. The remaining studies focus on mentorship initiatives intentionally

designed to address inequities in access to academic networks and institutional support. For example, Ewing et al. [11] show how structured faculty–student mentorship can mitigate disparities in access to academic resources for historically racially marginalized students (e.g., Black students). Additionally, beyond benefiting historically underrepresented students—success in their academic coursework, identity and self-efficacy development, and a stronger sense of belonging—mentorship encourages faculty to reflect on and improve instructional materials and practices. Similarly, works by Ogle et al. [10] and Thomas et al. [13] highlight how targeted mentorship initiatives (e.g., programs offering equity-focused resources for minoritized engineering students) help institutions respond to the specific challenges these students face. Luchini-Colbry & McDaniel [18] further illustrate how mentorship interventions help to build a more inclusive culture through enriching supportive relationships and expanding access to opportunities for students who have been historically excluded and racially marginalized from education systems.

Theme 2: Diversity initiatives

We reviewed ten articles under the theme of diversity initiatives to examine how diversity initiatives function as institutional strategies to enrich equity and inclusivity within engineering education. Four of these articles primarily focused on how diversity initiatives, such as DEI programs, inclusive recruitment efforts, and culturally responsive student support structures contribute to engineering education equity [15], [17], [25], [27], as well as the challenges engineering teachers face, particularly in navigating bias, institutional resistance, and the complexities of creating equitable learning environments, where all students can thrive [33], [36]. These findings underscore the importance of cultural humility and intentional bias-management practices in supporting diverse students in multicultural learning environments.

Similarly, the AAMC IDEAS learning initiatives, aim to create inclusive environments, ensure equitable advancement opportunities, and increase the representation and participation of STEM students from diverse backgrounds [22], [23]. Such initiatives not only foster a diverse and inclusive learning community— e.g., increasing the presence of international students alongside domestic students in U.S. higher education —but also enrich educational experiences by exposing students to broader perspectives, reshaping institutional culture, reducing cultural barriers, and making students from diverse backgrounds feel valued and included, e.g., black women in engineering, black students, and international students in mainstream culture.

Theme 3: Inclusive teaching practices

Inclusive teaching practices is identified as a central strategy to improve engineering education equity and inclusivity. We categorized five articles under this theme that collectively emphasize the importance of inclusive teaching practices that address students' learning needs regardless of their background, have equal access to learning opportunities [16], [21], [26], [28], [31].

Furthermore, these studies demonstrated that inclusive teaching practices (e.g., multimodal instruction, effective instructional design, active learning, culturally relevant pedagogy, and flexible assessment) were shown to increase student participation, reduce performance gaps, reduce learning gaps, and foster a sense of belonging. This underscores that when engineering teachers incorporate inclusive teaching practices into their instructional material design, they help create a more inclusive and equitable educational landscape that support the academic achievements of students, regardless of their students' prior backgrounds. Halkiyo [20] provides a clear example of this impact. By piloting research-based inclusive instructional lessons in engineering courses, Halkiyo found that such practices effectively reach diverse student populations and advance educational equity within the field. The study highlights that adopting

inclusive teaching methods enables engineering educators to create learning environments that value and respect students' diverse identities and experiences. This approach not only increases student engagement but also enriches their overall learning experience. Furthermore, incorporating research-based multimodal teaching practices and active learning strategies into engineering curricula has been shown to deepen student engagement and strengthen connections among students from different backgrounds. These practices help bridge experiences between mainstream learners (e.g., White students) and racially marginalized groups, such as Black students and women in engineering, thereby contributing to improved academic outcomes and more inclusive classroom climates.

Theme 4: Adapt the inclusive curriculum design

This theme synthesizes twelve studies that examine how inclusive engineering curriculum design contributes to equity and inclusivity for diverse groups of undergraduate engineering students. Six studies highlight the challenges associated with creating inclusive curricula, including institutional constraints, limited faculty preparation, and the difficulty of integrating diverse perspectives into traditionally technical content [19], [22], [23], [24], [30], [31]. The remaining studies emphasize the importance of embedding inclusive content into engineering teaching and learning to ensure that curricula reflect the experiences, histories, and cultural backgrounds of all students [17], [19], [21], [25], [27], [34]. The findings highlight developing curriculum content that reflects diverse perspectives and experiences, is shown to enhances students' connection to course material. This approach not only boosts student participation and deepens their understanding of engineering concepts but also enriches an inclusive learning environment and fosters global perspectives among engineering students. Inclusive curriculum design ensures that all students' learning needs are addressed and prevents content from being biased toward certain

groups at the expense of others. Additionally, inclusive engineering curriculum content reflected through integrating topics, examples, and materials that reflect variety of cultural backgrounds, including traditions, histories, scientific approaches, and perspectives of students enable engineering students to absorb or gain knowledge within familiar contexts, which the efforts contribute into engineering education equity as the curriculum recognize both mainstream and racialized minoritized students' cultural context, prior educational experiences and backgrounds. Further, inclusive engineering curriculum design embrace varied of students' cultural backgrounds and experiences, broadens understanding in course contents, and prepares racially marginalized students (e.g., women students in engineering) to thrive in multicultural education and reinforces the efforts of bridging the learning gap between mainstream students and racially historically marginalized student groups.

Theme 5: Implicit bias in engineering classroom

We reviewed twelve articles examining how implicit biases and cultural awareness influence the educational experiences of diverse engineering students in learning environments. Collectively, these studies reveal that engineering teachers' unconscious stereotypes, assumptions, and attitudes impact engineering classroom culture, instructional practices and students' academic trajectories [14], [16], [19], [21], [24], [26], [27], [29], [31], [33], [34], [37]. Across these studies, implicit bias is shown to affect grading practices, advising relationships, classroom interactions, and educators' perceptions of students' abilities. When educators do not critically examine their assumptions or deficit-based thinking, these biases can create inequitable learning conditions that disproportionately disadvantage students from racially and socioeconomically marginalized backgrounds. Several studies emphasize the importance of culturally responsive curriculum design and reflective teaching practices as strategies to mitigate the effects of implicit

bias. A curriculum informed by local cultural knowledge and community resources not only aligns with academic goals but also carries cultural relevance that supports students' identity development and sense of belonging. Such approaches help cultivate socially responsible and culturally aware engineering graduates who are prepared to navigate multicultural professional environments.

Self-reflection is highlighted as a critical component of equitable teaching. When engineering educators actively examine how their beliefs and behaviors influence student experiences, they are better positioned to foster culturally aware and inclusive classroom environments. For example, Lomotey and Smith [27] found that implicit bias toward students of color in higher education is associated with lower expectations, harsher grading, and increased dropout rates among racially marginalized groups, including Latina/o and Black engineering students. Similarly, Salehi et al. [36] emphasized the need for intentional strategies to recognize and challenge implicit biases in engineering education. The collective findings demonstrate that equitable teaching requires engineering educators to acknowledge and address their implicit biases. By increasing cultural awareness and actively challenging biased assumptions in engineering classroom, engineering teachers can create a more inclusive environment where all students—particularly those from socioeconomically and racially marginalized backgrounds—feel valued and supported.

5. Discussion

The purpose of this systematic review was to identify and interpret the strategies and initiatives that promote equity and inclusivity in undergraduate engineering education systems. The five findings that emerged—mentorship interventions, diversity initiatives, inclusive teaching

practices, inclusive curriculum design, and addressing implicit bias—collectively demonstrate that equity in engineering education is advanced through intentional, culturally responsive, and structurally embedded practices, which are detailed as follows.

The first theme highlights mentorship interventions as a foundational equity strategy that supports historically marginalized, and racially profiled students' academic performance, engineering identity development, and sense of belonging. This aligns with existing research showing that mentorship improves retention and persistence for underrepresented students in STEM by providing access to social capital, academic networks, and culturally responsive support systems [11], [25]. The reviewed studies reinforce that mentorship is not merely supplemental; it is a structural mechanism that counters inequities in access to learning resources and opportunities. By strengthening engineering identity and validating students lived experiences, mentorship directly addresses barriers that disproportionately affect racially minoritized, first-generation, and low-income engineering students. This finding underscores that mentorship programs are essential for creating inclusive engineering pathways where all students can envision themselves as capable contributors to engineering fields and innovations. The second finding demonstrates that diversity initiatives—such as DEI programs (e.g., ensure diverse cultural backgrounds, including race, ethnicity, gender and sexual orientation into engineering education ecosystems; and address systematic barriers that prevent full participation in educational opportunities, ensuring all students, especially those from historically marginalized groups, have the support they need to succeed), inclusive recruitment, and culturally responsive student support—play a critical role in reshaping institutional culture. These initiatives align with broader literature emphasizing that representation, inclusive policies, and culturally aware institutional practices are necessary for equitable participation in STEM

[20], [38]. The reviewed studies show that diversity initiatives not only increase access for historically marginalized groups but also enhance the learning environment for all students by broadening perspectives and reducing cultural barriers. However, the challenges identified—such as teachers' resistance to design culturally responsive learning environments, systemic racism, stereotypical assumptions, institutional inertia, and unaddressed biases—mirror findings in the engineering education literature that structural change requires sustained commitment and cultural humility.

The third theme identifies inclusive teaching practices as a central mechanism for promoting equitable learning outcomes for engineering students. The reviewed studies show that multimodal instruction, active learning, culturally relevant pedagogy, and flexible assessment reduce performance gaps, increase active participations and sense of belonging into engineering fields—findings consistent with STEM education research [33], [34], [50] demonstrating that active and inclusive pedagogies improve learning outcomes for underrepresented students. Importantly, such inclusive teaching practices help efforts to validate students' cultural identities and encourage them to contribute their perspectives into engineering design and innovation, which aligns with CRP's emphasis on academic success, cultural competence, and critical consciousness. This finding matters because it demonstrates that equity is enacted not only through institutional programs but also through everyday instructional activities and decisions that shape engineering students' engagement and learning. This reflect that equity is enacted not only through engineering programs but also through engineering pedagogy.

Finding 4 highlights that inclusive curriculum design is a powerful lever for engineering education equity when it reflects diverse engineering students' cultural backgrounds, integrates culturally relevant examples, histories, and value prior educational cultures. This finding aligns

with research showing that inclusive curricula increase student motivation, deepen conceptual understanding, and reduce feelings of isolation among students of color [17], [21]. The reviewed studies highlight that inclusive curriculum design helps students connect engineering concepts to real-world contexts that resonate with their cultural and community experiences. This matters because curriculum is often the most rigid component of engineering education system; when it becomes more inclusive, it signals a shift toward valuing diverse. Finding five highlights the pervasive influence of implicit bias on engineering students' educational experiences. Previous works has shown that unexamined assumptions and deficit-based thinking can negatively affect engineering students' grading, advising, classroom interactions, and perceptions of students' abilities [58]. The reviewed studies reinforce that addressing implicit bias is essential for creating equitable learning environments, as biases disproportionately harm students from racially and socioeconomically marginalized backgrounds. These findings matter because they reveal that even well-intentioned teachers can unintentionally perpetuate inequities unless they engage in ongoing self-reflection and culturally responsive practice.

While the five findings are presented separately, they are deeply interconnected and often reinforce one another. For example, mentorship interventions (finding 1) frequently appeared as a necessary foundation for the success of diversity initiatives (finding 2), as students who felt supported and affirmed were more likely to engage with institutional programs. Inclusive teaching practices (finding 3) and inclusive curriculum design (finding 4) work together to create learning environments where students' cultural identities are recognized and valued, which in turn strengthens the effectiveness of mentorship and diversity efforts. Addressing implicit bias (finding 5) is essential across all findings, as unexamined assumptions can undermine even the most well-designed equity initiatives. When students experience culturally responsive teaching,

inclusive curricula, and bias-aware engineering teachers, they report greater motivation, persistence, and connection to learning. Together, these interconnected strategies illustrate that promoting equity and inclusivity in undergraduate engineering education requires a holistic, multi-level approach that integrates interpersonal support, pedagogical practices, curriculum design, and institutional transformation.

6. Study Limitations and Future Directions

Although this systematic review provides a comprehensive synthesis of strategies and initiatives that promote equity and inclusivity in undergraduate engineering education, several limitations should be acknowledged. First, the review included studies published between 2000 and 2024, which may have excluded earlier foundational work or very recent publications not yet indexed in major databases. As equity-focused engineering education research continues to grow rapidly, the field may evolve in ways not fully captured in this timeframe. Second, the review relied on published peer-reviewed literature, which may introduce publication bias by underrepresenting innovative practices, community-based initiatives, or institutional programs that are documented only in reports, dissertations, or internal evaluations. Third, the included studies varied widely in methodological rigor, context, and sample characteristics, which limits the ability to generalize findings across all engineering programs. Finally, because the review synthesized studies conducted primarily in U.S. and Western higher education contexts, the findings may not fully represent the experiences or needs of engineering students in non-Western, Global South, or resource-constrained settings.

These limitations point to several important directions for future research. First, more empirical studies are needed to examine how equity-oriented strategies—such as mentorship, inclusive

teaching, and culturally responsive curricula—operate across diverse institutional types, including community colleges, minority-serving institutions, and international engineering programs. Second, future work should employ longitudinal and mixed-methods designs to better understand how equity initiatives influence students' academic trajectories, identity development, and long-term persistence in engineering. Third, researchers should explore how intersectional identities (e.g., race, gender, socioeconomic status, disability, immigration background) shape students' experiences with equity-focused interventions, as current studies often examine these identities in isolation. Fourth, there is a need for research that centers the voices of students, faculty, and community partners to better understand how equity strategies are experienced and enacted in practice. Finally, future scholarship should investigate institutional and structural barriers that limit the implementation of equity initiatives, as well as the organizational conditions that enable sustainable, systemic change in engineering education.

7. Conclusion

This systematic review identified five key strategies that promote equity and inclusivity in undergraduate engineering education: mentorship interventions, diversity initiatives, inclusive teaching practices, inclusive curriculum design, and addressing implicit bias. Together, these findings show that equity is strengthened when students receive culturally responsive support, encounter inclusive pedagogies, and learn within curricula that reflect diverse perspectives. The review also demonstrates that institutional efforts—such as DEI programs and bias-aware teaching—are essential for reducing structural barriers that disproportionately affect marginalized students. Overall, the evidence indicates that promoting equity in engineering education requires coordinated, multi-level approaches that integrate relational support, inclusive

instruction, and culturally relevant curriculum design. These strategies collectively help create learning environments where all students can participate, persist, and succeed in engineering.

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Appendix Table 1. Systematic Literature Review Protocol.

Section and topic	*Item*	*Checklist item*
Title	1	Enhancing Equity and Inclusivity in Engineering Education for Diverse Undergraduate Students: Systematic Review of Reviews.
Objective	2	Explore the necessity and strategies for promoting equity and inclusivity in engineering education, with a specific focus on undergraduate students from diverse backgrounds. RQ: (1) what are the strategies and initiatives that promote equity and inclusivity in engineering education for diverse undergraduate students, and (2) how do equity and inclusivity initiatives efforts impact student outcomes and the development of a diverse engineering workforce?
Search terms	3	'Education equity and inclusivity' 'equity and inclusivity in engineering' 'inclusion in engineering' 'equity' 'education equity in engineering' 'inclusion in engineering' 'equity in engineering education' 'inclusivity in engineering education'
Eligibility criteria	4	Year limit-years will be considered 2000 - April 1st, 2024, language limit: English; publication type limit: conference, article, reports, review articles & book chapter. Also, we excluded duplication of records, studies scope not

		centered on engineering education equity and inclusivity, work-in-progress, reports, if full-text is not available, and if the abstract is not available
Information sources	5	Google Scholar, Scopus database, ASEE PEER, and IEEE Xplore, Compedex Engineering Village databases.
Study selection process	6	Based on the review protocol development, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) tool will be used to collect systematic review data. Two researchers will work independently on searching and reviewing articles for selection: (1) screening (e.g., by reading the title + abstract, the researcher will check the inclusion and exclusion criteria), (2) downloading the full text–read and check whether the content coverage of each topic related to my topic or not, and (3) eligibility criteria will be considered to include articles in the systematic reviews (e.g., only considering qualitative papers). Any disagreement between reviews during conducting systematic review (e.g., on inclusion and classification) will be discussed until a consensus is reached.
Data collection process, extraction, and synthesis	7	Reviewers will collect data from online databases such as Google Scholar, Scopus database, ASEE PEER, and IEEE Xplore. Then, the reviewers will screen articles based on the titles and abstracts of the records. The articles that were not related to research goals and/or do not meet preliminary eligibility criteria will be excluded. Then the reviewers will continue to perform eligibility criteria by carefully screening the full text of the remaining articles. Furthermore, the reviewers will extract the following information from each article: study location, objectives, methods, sample size, and results using Microsoft Excel. Finally, the summary of the findings will be compiled and reported in the form of a SLR manuscript.

Data extraction, synthesis, and writing up	8	During each step of the systematic review process, advice and guidance will be obtained from the advisor and/or dissertation committee members.
Reviewers	9	1. Xxxx: Engineering Education 2. Xxxx: Engineering Education

Appendix Table 2: Classification of the reviewed literature based on specific themes

Authors (year of publication)	*Title*	*Theme*
Ogle, J. H., Bolding, C. W., Lloyd, J. A., & Wade, L. C. (2020)	Developing inclusive engineers: Teaching peer-mentors principles of equity and inclusion	Mentorship interventions
Thomas, K. M., Willis, L. A., & Davis, J. (2007)	Mentoring minority graduate students: Issues and strategies for institutions, faculty, and students.	
Sutherland, C., Mohammadi, A., & Harris, J. (2022)	Undergraduate mentors' perspectives on equity-oriented STEM outreach.	
Ewing, R., Freeman, M., Barrie, S., Bell, A., O'Connor, D., Waugh, F., & Sykes, C. (2008)	Building community in academic settings: The importance of flexibility in a structured mentoring program	
Luchini-Colbry, K., & McDaniels, M. (2020)	Equity, Inclusion, and Ethics: Adapting a Mentoring Curriculum to Develop an Ethics Workshop for Engineering Students.	
Single, P. B., & Single, R. M. (2005)	E-mentoring for social equity: review of research to inform program development. Mentoring & Tutoring: Partnership in Learning	
Gatta, M., & Trigg, M. (2001)	Bridging the gap: gender equity in science, engineering and technology. Rutgers University, Center for Women and Work	

Perez-Felkner, L., Shore, C., Dickens, T., & Yang, M. D. (2020)	Engineering resilience through research mentorship: Manufacturing pathways to careers.	
Williams, M., Keita, N., & Flores, L. Y. (2022)	An integrative pathway for success: undergraduate research, access, and mentorship in STEM. In Mapping the Future of Undergraduate Career Education	
Roland, K. A. (2008)	Educating for inclusion: Community building through mentorship and citizenship.	
Palid, O., Cashdollar, S., Deangelo, S., Chu, C., & Bates, M. (2023)	Inclusion in practice: a systematic review of diversity-focused STEM programming in the United States.	
Ravishankar, S., Spencer-Drakes, T. C., Fernandes, I. H., Hayes, M. I., Coopwood, S., Spencer, I., & Neal, S. E. (2024).	Empowering STEM students: A university-wide mentorship program fostering retention and belonging.	
Walden, S. E., Trytten, D. A., & Shehab, R. L. (2018)	Based recommendations for creating an inclusive culture for diversity and equity in engineering education.	
Rambo-Hernandez, K. E., Morris, M. L., Casper, A. M. A., Hensel, R. A., Schwartz, J. C., & Atadero, R. A. (2019)	Examining the effects of equity, inclusion, and diversity activities in first-year engineering classes	Diversity initiatives
Pellissier, R., Siluk, F., Flynn, C., & Kanaan, M. (2022)	Approaching equity, diversity, inclusion, and social justice education as imperative to engineering curricula.	
Armanios, D. E., Christian, S. J., Rooney, A. F., McElwee, M. L., Moore, J. D., Nock, D., ... & Wang, G. J. (2021)	Diversity, Equity, and inclusion in civil and environmental engineering education: Social justice in a changing climate.	

Chan, L. S. (2019)	Engineering-Medicine An Introduction.	
Bhatti, H. A. (2021)	Toward “inclusifying” the underrepresented minority in STEM education research.	
Smith, D. G. (2020)	Diversity's promise for higher education: Making it work.	
Mejia, J. A., & Martin, J. P. (2023)	Critical Perspectives on Diversity, Equity, and Inclusion Research in Engineering Education.	
Barger, S. S. (2004)	The impact of international students on domestic students in United States institutions of higher education.	
Palid, O., Cashdollar, S., Deangelo, S., Chu, C., & Bates, M. (2023)	Inclusion in practice: a systematic review of diversity-focused STEM programming in the United States.	
Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014)	Active learning increases student performance in science, engineering, and mathematics.	Inclusive teaching practices
Halkiyo, J. B. (2022)	Enhancing the Equity and Inclusivity of Engineering Education for Diverse Learners through an Innovative Instructional Design, Delivery, and Evaluation: International Students in Focus.	
Dewsbury, B., & Brame, C. J. (2019)	Inclusive teaching.	
Kanvaria, V. K., & Monika, K. (2023)	Promoting Equity in Education: Analyzing the Influence of Technology-Integrated Faculty Development on Inclusive Teaching Practices.	
Croft, B., & Brown, M. (2020)	Inclusive open education: presumptions, principles, and practices.	
Mills, J., & Ayre, M. (2003)	Implementing an inclusive curriculum for women in engineering education.	

Ambrose, S. A., Bridges, M. W., DiPietro, M., Lovett, M. C., & Norman, M. K. (2010)	How learning works: Seven research-based principles for smart teaching.	Inclusive curriculum design
Salminen-Karlsson, M. (2002).	Gender-inclusive computer engineering education: Two attempts at curriculum change	
Farrell, S., Bodnar, C., & Forin, T. (2017)	Using concept mapping to develop inclusive curriculum.	
O'Leary, E. S., Shapiro, C., Toma, S., Sayson, H. W., Levis-Fitzgerald, M., Johnson, T., & Sork, V. L. (2020)	Creating inclusive classrooms by engaging STEM faculty in culturally responsive teaching workshops	
Walkington, J. (2002)	A process for curriculum change in engineering education.	
Mills, J., Ayre, M. E., & Gill, J. (2011)	Gender inclusive engineering education.	
Farrell, S., Forin, T., Jahan, K., Dusseau, R., Bhavsar, P., & Sukumaran, B. (2017)	Developing multiple strategies for an inclusive curriculum in civil engineering.	
Jolly, L., Crosthwaite, C., Brodie, L., Kavanagh, L., & Buys, L. (2011)	The impact of curriculum content in fostering inclusive engineering: data from a national evaluation of the use of EWB projects in first year engineering.	
Shukla, B., Soni, K. M., Sujatha, R., & Hasteer, N. (2023)	Roadmap to inclusive curriculum: a step towards Multidisciplinary Engineering Education for holistic development.	
Wilson, N., Thomson, A., Thomson, A., & Holliman, A. F. (2019)	Understanding inclusive design education.	
Halkiyo, J. B. (2022)	Enhancing the Equity and Inclusivity of Engineering Education for Diverse Learners through an Innovative Instructional Design, Delivery, and Evaluation: International Students in Focus.	

Farrell, S., & Minerick, A. (2018)	Perspective: The stealth of implicit bias in chemical engineering education, its threat to diversity, and what professors can do to promote an inclusive future	Implicit bias in learning
Killpack, T. L., & Melón, L. C. (2016)	Toward inclusive STEM classrooms: what personal role do faculty play?	
Kovaleva, Y., Happonen, A., & Kindsiko, E. (2022, May)	Designing gender-neutral software engineering program. stereotypes, social pressure, and current attitudes based on recent studies.	
Gregory, S. L. (2015)	African American female engineering students' persistence in stereotype-threatening environments: A critical race theory perspective.	
Isaac, S., Kotluk, N., & Tormey, R. (2023)	Educating Engineering Students to Address Bias and Discrimination Within Their Project Teams.	
Lomotey, K., & Smith, W. A. (Eds.). (2023)	The racial crisis in American higher education.	
Meadows, L. A., Sekaquaptewa, D., Paretti, M. C., Pawley, A. L., Jordan, S. S., Chachra, D., & Minerick, A. (2015)	Interactive panel: Improving the experiences of marginalized students on engineering design teams.	
Thacker, I., Copur-Gencturk, Y., & Cimpian, J. R. (2022)	Teacher bias: A discussion with special emphasis on gender and STEM learning.	
Salehi, S., Holmes, N. G., & Wieman, C. (2019)	Exploring bias in mechanical engineering students' perceptions of classmates.	
Buse, K., Hill, C., & Benson, K. (2017)	Establishing the research agenda for increasing the representation of women in engineering and computing.	
Onyeador, I. N., Hudson, S. K. T., & Lewis Jr, N. A. (2021)	Moving beyond implicit bias training: Policy insights for increasing organizational diversity.	
Roberts, P. S., & Wernstedt, K. (2019)	Decision biases and heuristics among emergency managers: just like the public they manage for?	