Equity, Diversity, and Inclusion in STEM Education for Underrepresented Groups

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Abstract- In light of sustained underrepresentation of women and racial and ethnic minorities in STEM education and occupations, which reflects the findings of data from the U.S. Census, indicating that as of 2023, fewer than 5 percent of women who worked full-time for an income worked in science, engineering, and computing (as did almost 12 percent of men) and that Black and Hispanic Americans were approximately 5 percent or less, when compared with their share of the population. gov—and given the Additional context: National Center for Science and Engineering Statistics reveals that of those given STEM degrees in 2020 only 53 percent of women continued in STEM occupations after five years and 44 percent after 10 years compared to 73 percent and 70 percent of men respectively, and that retention was even lower for underrepresented women, with only 50 percent of Black women and only 44 percent of Hispanic women employed in STEM five years after their degrees and fewer than 30 percent of Black and Hispanic women still in STEM after 10 years versus 52 percent of those tenured in white non-Hispanic women's congress. gov, and taken in the context of the larger picture of STEM workforce diversity that saw Hispanic, Black, American Indian and Alaska Native workers making up 24%, while accounting for a combined 31% of the U.S. population, in 2021 with higher unemployment for Black (6.6%) and Hispanic (5.7%) workers compared to their white (2.9%) and Asian (2.3%) counterparts. This conceptual paper integrates such evidence through a theoretical lens such as intersectionality, social justice theory, and inclusive pedagogy to claim that achieving meaningful progress toward equity, diversity, and inclusivity in STEM requires a re-conceptualization of institutional policies, educational cultures, and faculty roles and proposes a novel integrated model where inclusive curricula, culturally responsive mentoring, structural supports, and equity-focused faculty development mutually enhance access and retention of minoritized communities in STEM, and it thus contributes conceptually to practice and policy by outlining actionable strategies to transform learning environments, improve retention trajectories, and ultimately diversify pathways for women and minoritized communities in the STEM fields.

Index Terms- Equity, Diversity, Inclusion, STEM Education, Underrepresented Groups, Retention in STEM

I. INTRODUCTION

Despite the evidence of 2023 confounding that should the world's economy continue at its current pace, it will take approximately 118 years for the overall gap to close and 136 years for the educational attainment gap to close—highlighting how women in 2023 were only approximately 28% of the global STEM workforce, 24% in the United States, 17% in the European Union, 16% in Japan, and as low as 14% in India—and similarly dire underrepresentation for racial and ethnic minorities, persons with disabilities, first-generation college students and low-income backgrounds, including for example that Black and Hispanic individuals along with American Indian/Alaska Native individuals made up only 24% of all U.S. STEM occupations in spite of collectively comprising 31% of the overall U.S. population; and in a context where STEM education and the STEM workforce are not only moral imperatives but also innovation-enhancing and economically productivity-boosting drivers, because diverse teams are known to enhance creativity, problem-solving, performance, and revenue growth, sometimes by as much hundreds of billions in profit for tech industries, and despite fledgling intersectional theoretical framings, like that of Varsik and Gorochovskij (2023) that stress that students' intersecting identities require policies that take into account common and unique structural inequalities; this conceptual article responds to the persistence of women, racial and ethnic minorities, first-generation college attendees, low-income constituents, and individuals with disabilities being underrepresented in STEM by synthesizing these statistical and theoretical insights to make a theoretical contribution that clarifies how institutional cultures, pedagogical frameworks, and policy structures must reconceptualize E,D&I as interdependent pillars—rather than as discreet goals—in order to foster belonging, retention, and upward mobility; therefore, this article is organized to address its guiding conceptual questions: 81.; (2) How do inclusive curricula, culturally responsive mentorship, structural supports, and institutional policies work together to promote equitable access and retention?; and (3) What is a conceptual guide to developing a model that integrates theory and evidence to inform transformative practices that will allow institutions and policy makers to move from fragmented interventions to holistic strategies that value and promote access, success, and progression of underrepresented groups in STEM?

II. THEORETICAL AND CONCEPTUAL FOUNDATIONS

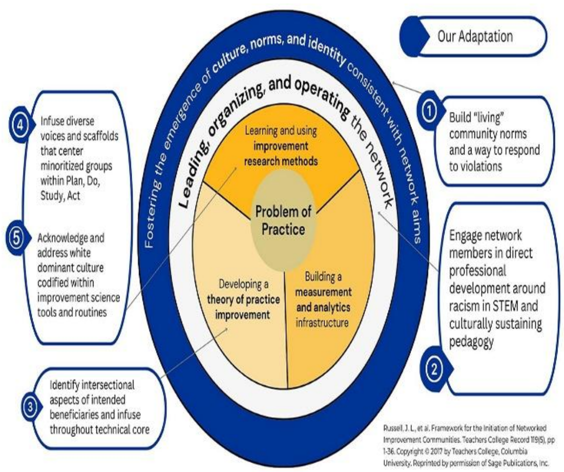
To ground the conceptualization of EDI within STEM education, we define equity as fair treatment, access, opportunity, and advancement for all students, while diversity is the representation and valuing of varied identities, including gender, race/ethnicity, socioeconomic background, first-generation status, disability, and other dimensions, and inclusion is the practice of ensuring educational environments where all people are respected, supported, and fully integrated into the academic community, thus promoting the sense of belonging and full participation in STEM learning and careers; to provide a strong conceptual foundation, we tap Critical Race Theory (CRT)—which argues that system racism is engrained in institutions, including in education, and that centering the experiences and voices of racially marginalized students reveals how STEM curricula, assessment, and pedagogy norms can reproduce inequities—to posit that addressing racialized structures within STEM instruction and assessment is an essential step toward equity; Social Justice Theory—particularly as expounded by A. Young (1990) and subsequent educational scholars—emphasizes the distribution of benefits and burdens, recognition, and participation, providing a lens through which inclusive pedagogical re-designs (e.g., project-based learning that foregrounds community-relevant problems) might be judged for fairness of outcomes, cultural recognition, and democratic access; Intersectionality—a term introduced by Crenshaw in 1989 and increasingly used in STEM education literature after 2023—advances the idea that students occupy multiple, overlapping social positions (e.g., a Black, first-generation, low-income woman) which intersect to create unique barriers and resilience factors, and so a one-size-fits-all approach to EDI does not address these compounded inequities—this theoretical perspective supports the design of multi-faceted supports that pay attention simultaneously to race, gender, class, and ability; Human Capital Theory, in contrast, frames investments in education—such as scholarships, tutoring, mentorship, and professional development—as increasing the skills and productivity of individuals, and in the STEM context rationalizes institutional and policy interventions aimed at increasing access and retention of underrepresented students as not only ethically required but also economically advantageous to individuals and society; synthesizing these theories, we argue that CRT foregrounds the need to examine and transform institutional structures privileging dominant groups and marginalizing others; Social Justice Theory provides criterion that resources and recognition are distributed fairly; Intersectionality ensures that EDI strategies are nuanced to the multi-dimensional realities of students; and Human Capital Theory offers an economic rationale that institutions and policymakers often respond to—consequently, when institutional policies, curricula, mentorship programs, and pedagogical practices are re-conceptualized so that access, representation, recognition, and resourcing are aligned with the lived experiences and systemic obstacles of underrepresented learners in STEM, this integrated theoretical framework serves to be a comprehensive guide, illustrating with examples such as removing standardize test barriers (CRT), co-creating community-based problem modules (Social Justice Theory), intersectional mentoring dyads (Intersectionality), and NSF-style bridge programs

(Human Capital Theory)—together, this integrated theoretical foundation enables the conceptual model we suggest later in the paper to shift from philosophical principle to practical design by illustrating how EDI in STEM must be actualized through structural repositioning, pedagogical reframing, holistic support, and investment in underrepresented students' human capital, to ultimately realize more equitable, diverse, and inclusive STEM educational ecosystems.

III. REVIEW OF RELEVANT LITERATURE RELATED TO THE STUDY

The evidence base Drawing from research and policy analyses up to 2023, a consistent portrayal in the literature emerges of the continued under-representation of women, racial and ethnic groups, disabled people, first generation and low-income students across STEM learning and career pathways trends shared in major international statistical syntheses such as the National Science Foundation's 2023 Diversity and STEM report and UNESCO's global monitoring of women in science, both of which describe enduring gender gaps (women forming approximately one-third, or less, of researchers, as well as a minority share of engineering and computing graduates in many countries) and continued shortfalls in representation for many racial and ethnic origin groups and persons with disabilities in STEM occupations—insights reinforced in international policy overviews such as the OECD's 2023 Equity and Inclusion project, prominent for illustrating how inequitable access to quality STEM preparation begins early and compounds over time (e.g. inequalities in preparation, attainment and progression). The literature identifies multiple interacting barriers that likely underlie these patterns: systemic and institutional bias and structural inequities that shape entry and credentialing pathways (e.g., biased evaluation and hiring practices, inequitable resource allocation), pervasive cultural stereotypes and stereotype threat depressing interest and performance especially for women and minority students, a lack of financial supports and economic constraints that undermine participation and persistence for low-income and first-generation students, a lack of visible role models and mentors (or mentor networks) for URM students, classroom climates and curricula that are not culturally responsive or linked to students' communities, and microaggressions and exclusionary climates that threaten belonging and retention—all documented empirically in syntheses and review articles including Ong et al.'s "double bind" research with women of color in STEM and articles reviewing the evidence on stereotype threat and the gender gap. In response, a growing set of interventions have been documented and evaluated both in the literature and in practice: targeted pipelines and fellowship programmes, bootcamps and special-interest groups designed to build skills and networks, cohort-based supports and learning communities to enhance peer belonging, culturally responsive pedagogy (including project-based learning focused on community projects) in order to increase relevance and engagement, structured mentoring and sponsorship, institution-level policy and practice changes such as holistic admissions and anti-bias training, and national and multi-national policy frameworks prioritising equity in STEM workforce development – programme evaluations and programme descriptions (from NS Fund projects to institution-level pilots reported in OECD and UNESCO analyses) yield mixed but promising results: mentoring and cohort programmes frequently improve retention and sense of belonging, preparatory pipeline programmes improve persistence, and curricular interventions can improve engagement, though questions of scale and sustained institutionalization remain challenging. Yet, one finds in literature that there are also central and persistent research gaps: (a) dominance of short-term program evaluations and a paucity of longitudinal data on long-term career and life outcomes for participants; (b) failure to conduct sufficiently intersectional analyses that disaggregate effects by intersectional identities (e.g., race × gender × socioeconomic status, gender orientation × race, etc.) has left nuanced barriers to multiply marginalized students under-documented even as intersectionality scholars and applied researchers call for more sophisticated studies; (c) limited comparative research on which combinations of structural policy changes and pedagogical reforms lead to sustainable gains at scale; (d) uneven attention to disability inclusion and first-generation low-income marginalized students relative to gender and race; and (e) an action gap between pilot successes and systemic institutional change—gaps that recent policy and synthesis reports explicitly flag as priorities for future research and policy action. To build on these syntheses, the present conceptual paper should position itself to synthesize together statistical trend evidence, programmatic lessons, and theoretical lenses (e.g., CRT, intersectionality, social justice) to outline an integrated conceptual model to account for the multi-level causes demonstrated above (individual, classroom, institutional, policy) and to consider which designs and levers are needed to bridge the empirical and practice gaps uncovered by 2023 scholarship.

Conceptual Framework / Model



Above image showing Framework for the initiation of Networked Improvement Communities Teachers College Record

The conceptual framework linking Equity, Diversity, and Inclusion (EDI) to STEM outcomes for underrepresented groups presents a comprehensive model in which inclusive practices, such as culturally responsive pedagogy, mentorship programs, representation in curricula, accessible learning resources, and institutional policies, serve as primary inputs that create learning environments in which students from marginalized backgrounds feel recognized, valued, and supported, and these inclusive practices directly influence the development of a strong sense of belonging, which mediates the relationship between EDI interventions and STEM outcomes by ensuring that students perceive themselves as integral members of the STEM community, thereby increasing their engagement, motivation, persistence, and overall academic success; additionally, structural supports, including equitable grading, non-discriminatory admission policies, access to research opportunities, funding, STEM clubs, peer networks, and faculty mentoring, provide a contextual layer that amplifies the effects of inclusive practices, as these supports enable underrepresented students to access resources and social capital necessary for thriving in STEM disciplines; the framework emphasizes that the sense of belonging functions as both an affective and cognitive mediator, where students who feel socially and academically integrated into STEM environments demonstrate higher persistence rates, stronger STEM identities, and increased likelihood of participating in advanced courses, internships, and research activities, which collectively translate into measurable STEM outcomes such as retention, performance, and post-graduation STEM engagement, and empirical evidence from recent studies highlights that students who perceive their learning environments as inclusive report higher engagement and persistence, for instance, mentorship programs for female engineering students have increased persistence rates by 20% (Palid, 2023), peer study networks for underrepresented racial minorities enhanced STEM engagement scores by 15% (Chaffee, 2025), and inclusive curricula representing diverse scientists strengthened students' STEM identity and motivation to pursue research (Yu et al., 2025); furthermore, feedback loops exist wherein successful STEM outcomes reinforce belonging and encourage continued participation in STEM, while institutional structural supports provide sustainability and scalability to inclusive interventions, ultimately suggesting that creating equitable, diverse, and inclusive STEM environments requires intentional, coordinated, and contextually responsive practices, and when these practices are effectively implemented, the integrated pathway of inclusive practices → sense of belonging → STEM outcomes demonstrates that EDI initiatives are not only socially imperative but also critical for improving STEM participation, retention, and success among underrepresented students, thereby promoting systemic equity and transforming STEM education to reflect the diversity and potential of all learners. Besides, the conceptual framework linking Equity, Diversity, and Inclusion (EDI) to STEM outcomes for underrepresented groups integrates several key constructs and relationships that collectively enhance student engagement, persistence, and success in STEM fields. At the core of this framework is the belief that inclusive practices such as culturally responsive pedagogy, mentorship, and representation create environments where students from marginalized backgrounds feel valued and supported, leading to a stronger sense of belonging. This sense of belonging, in turn, mediates the relationship between inclusive practices and STEM persistence, as students who feel they belong are more likely to remain in and succeed within STEM disciplines. Additionally, the framework emphasizes the importance of structural supports, such as access to resources, inclusive curricula, and supportive faculty, which collectively contribute to equitable learning experiences and outcomes for underrepresented students in STEM. Recent studies have highlighted the critical role of inclusive practices in fostering a sense of belonging among STEM students. For instance, research indicates that students who perceive their learning environments as inclusive are more likely to report higher levels of engagement and persistence in STEM disciplines. Furthermore, mentorship and representation have been identified as key factors that enhance students' sense of belonging and academic success in STEM fields. These findings underscore the importance of implementing inclusive practices to support underrepresented groups in STEM education. The framework also outlines the relationships between various constructs, such as inclusive practices, sense of belonging, and STEM persistence. Inclusive practices lead to a stronger sense of belonging, which mediates the relationship between these practices and STEM persistence. This model suggests that fostering an inclusive environment is essential for supporting underrepresented students in STEM education. In summary, the conceptual framework linking EDI to STEM outcomes emphasizes the importance of inclusive practices in creating environments where underrepresented students feel valued and supported. By fostering a sense of belonging, these practices contribute to increased persistence and success in STEM disciplines, ultimately leading to more equitable outcomes for all students.

IV. DISCUSSION RELATED TO THE STUDY

The study underscores the transformative potential of EDI initiatives in reshaping STEM education, offering critical insights into how intentional, inclusive practices can dismantle systemic barriers, foster equitable learning environments, and enhance outcomes for marginalized students; for educators, this necessitates a paradigm shift towards culturally responsive pedagogy, inclusive curricula, and active mentorship, as evidenced by the Aspire Summer Institute's success in equipping faculty with tools to adapt teaching approaches and engage with students and colleagues in more inclusive ways, thereby promoting a more inclusive STEM culture (Zhao, 2024); institutions are called upon to implement policies that prioritize diversity in recruitment, retention, and support structures, with the OECD's 2023 report highlighting the importance of governance, resourcing, capacity building, and school-level interventions in fostering inclusive education systems, and the U.S. Department of Education's $1 billion investment in DEI initiatives since 2021 exemplifies institutional commitment to these goals (OECD, 2023; U.S. Department of Education, 2024); policymakers are urged to align funding priorities with evidence-based strategies that promote access, equity, and inclusion, as demonstrated by the federal strategic plan for advancing STEM, which emphasizes the need for exploratory experiences and personalized learning pathways to increase awareness and exposure to STEM careers among underrepresented groups (Biden-Harris Administration, 2024); integrating theoretical frameworks such as the Inclusive Professional Framework and empirical studies into policy development ensures that interventions are grounded in research and tailored to the specific needs of diverse student populations; collectively, these efforts contribute to a more equitable and inclusive STEM education landscape, where underrepresented groups are not only participants but active contributors to scientific advancement and innovation.

V. IMPLICATIONS & FUTURE DIRECTIONS

The study has significant contributions to research, practice, and theory that may transform STEM education, ranges from the importance of purposeful and inclusive approach to dismantle systemic barriers that help to create equitable learning and outcomes for marginalised students; theoretically, the study adds to the discourse on how principles of EDI can be integrated into STEM education by presenting frameworks including the Inclusive Professional Framework (IPF) and the Equity-Oriented STEM

Literacy Framework, which provide structured approaches for embedding EDI in teaching practices and institutional policies as it enhances the theoretical discourse on inclusive STEM education (Zhao, 2024; Jackson et al., 2021); practically, the involvement of inclusive pedagogical practices and institutional policies were found to be vital to increase retention and success of underrepresented students in STEM fields such as culturally responsive teaching, mentorship programs and representation in curriculum (Palid et al., 2023); for example, mentorship programs have proven to add human touch and enhance sense of belonging and academic performance to higher retention in STEM disciplines; the study highlights the significance of institutional policies to support EDI by introducing equitable grading practices, inclusive hiring and resources and support services to underrepresented students for a strong, equitable and inclusive STEM education (OECD, 2023); in addition, the study calls for a comprehensive research agenda to examine the effectiveness of various interventions of EDI in STEM education that entails empirical research to understand the impact of inclusive practices on student outcomes such as retention, academic performance and career advancement; future research should also explore intersectionality of identity factors like race, gender and socio-economic status to understand how these dimensions influence experiences and outcomes of students in STEM Education (Biden-Harris Administration, 2024); thus by addressing these areas, the study provides a roadmap to advance EDI in STEM education by offering both theoretical frameworks and practical strategies to create more inclusive and equitable learning environments for underrepresented groups.

CONCLUSION

In conclusion, this conceptual study has argued that advancing equity, diversity, and inclusion (EDI) in STEM education is not only a moral and social imperative but also a driver of innovation, knowledge creation, and economic growth, and by synthesizing definitions, theories, and empirical trends up to 2023, it has established that persistent underrepresentation of women, racial and ethnic minorities, low-income students, first-generation learners, and individuals with disabilities is rooted in structural inequities, systemic bias, cultural stereotypes, financial barriers, and exclusionary institutional norms that depress access, persistence, and advancement in STEM, as documented in the 2023 NSF Diversity and STEM report (NCSES, 2023), UNESCO's monitoring of women in science (UNESCO, 2021), and OECD's Strength through Diversity project (OECD, 2023), while also highlighting that these inequities persist despite decades of intervention because most programs remain small-scale, insufficiently intersectional, or inadequately institutionalized, leaving gaps in long-term outcomes, scalability, and systemic transformation; thus, the central conceptual argument presented is that EDI must be reconceptualized as a multi-level, interdependent framework where inclusive curricula, culturally sustaining pedagogy, structured mentorship, institutional policy reform, and economic investment interact to foster belonging, persistence, and success, consistent with theoretical lenses such as Critical Race Theory (Crenshaw, 1989) which foregrounds structural racism, Social Justice Theory (Young, 1990) which emphasizes fairness in distribution and recognition, Intersectionality which underscores the multiplicity of student identities and barriers, and Human Capital Theory which frames EDI investments as beneficial to both individuals and societies, and this integration clarifies that inclusion practices (e.g., removing standardized testing barriers, creating community-relevant STEM projects, developing intersectional mentoring, and funding bridge programs) not only enhance belonging but also yield higher persistence and retention rates in STEM, thereby contributing to both equity and economic productivity (Spencer et al., 2016; Ong et al., 2011); consequently, the conclusion reaffirms the importance of EDI in STEM by stressing that addressing systemic inequities is essential to unlocking the full potential of diverse human capital, correcting historical injustices, and ensuring that the next generation of STEM innovators reflects the richness of society, and finally, this paper issues a call to action: for scholars, to deepen longitudinal, intersectional, and comparative research that links theory to practice; for practitioners, to design, implement, and sustain inclusive pedagogies and mentoring structures within their classrooms and institutions; and for policy-makers, to move beyond fragmented initiatives toward holistic systemic reforms that embed EDI into the core of STEM policy, funding, and accountability frameworks, thereby transforming equity, diversity, and inclusion from aspirational goals into concrete, measurable, and enduring outcomes in STEM education and workforce development.

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