On Diversity, Equity, and Inclusion in Computing: Finding Allies in Overrepresented Populations

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Abstract. Participation in science and engineering after the nineteenth century has largely been skewed toward men, computing being no different. However, the history of diversity in computing offers an unexpected insight. Some might assume that there has been a smooth progression from originally a few women in computing to a slightly more representative proportion at the present time. This article reviews the significant and growing body of scholarship that has challenged this linear assumption. In addition to the female pioneers who are now well known, there were many women who made the transition from hand calculators to computer operators at the time IFIP was established. An historical analysis of the decrease in the participation of women after their initial dominance shows that the rhetoric of rigorous computing coincides with the decreasing percentage of women. Thus, computing offers important lessons into the way policy and ideology can inadvertently cause a lag in representation for some demographic groups. Based on the author's own experience in fostering an inclusive environment at an engineering school, this paper then describes the challenges and opportunities for programs to enhance diversity and reverse the historical exclusion of certain groups. IFIP has been a leader in incorporating the history of computing into technical education, which can result in creating curricula that foster diversity and make a more inclusive atmosphere by incorporating the arts, broadly conceived, into STEM to create STEAM.

Keywords: STEM education, history of computing, diversity, unearned privilege, stereotype threat, microaggressions, imposter syndrome, STEAM.

1 Introduction

A few years ago, I was working on a grant proposal with two faculty members in the dean's office to support diversity at a university dedicated to science and engineering. Based on my continuing research into diversity, equity, and inclusion (DEI) in science, technology, engineering and mathematics (STEM), I wrote in the rationale that introductory courses negatively impacted all students, but particularly historically excluded groups, such as women, indigenous people, and people of color. Research supported this claim: large lecture courses seem to ratify existing patterns of representation. My collaborators surprised me by suggesting my comment was inaccurate.

As a student, professor, and advisor, I had observed the phenomenon many times. First-year engineering students are admonished to demonstrate their rigor, many receiving failing scores on their midterm exams. Every student feels the stress of gateway courses that seem like an effort to "weed-out" unqualified undergraduates, but members of historically excluded groups are disproportionately affected, reversing efforts to diversify. The resistance to my assertion about the deleterious effects of first-year courses struck me as odd because my university had committed to increasing diversity in engineering. I learned that not everyone was familiar with the processes that conspire to maintain STEM as a field dominated by men with Asian and European roots.

Lessons about diversity in the U.S. are applicable to some extent in a worldwide context. The conversation about diversity in the United States centers around local definitions. Thus, one sees articles about the overrepresentation of white and Asian-American men when compared to these groups' percentage of the population. Certainly, U.S. racial categories are not universally applicable to universities and industries around the world; however, the lessons learned about individuals who are not in the majority – whether it be ethnically, economically, or in national origin – can be applied elsewhere. After all, there is no evidence that abilities are uniform within different groups, and there is no evidence that those groups have different aptitudes for STEM overall. Although racial tensions may seem unique to U.S. history, the U.S. also has a long history of working to overcome prejudice of all types. In addition, racial and gendered attitudes in the U.S. are in part based on science from the age of empires, creating an opportunity to link the effort to end discrimination in the U.S. to the effort to ameliorate the legacy of colonialism in STEM internationally.

Comparing the demographics of the U.S. population to the demographics of STEM professions, one sees how opportunity is unevenly distributed. To be sure, demographic categories are gross generalizations that are best thought of symptoms of underlying inequities. People who understand the spectrum of gender will bristle at the binary separation of populations into men or women. Similarly, given biological research, the eighteenth-century notion that humanity can be reliably divided into four or five discrete categories is laughable. My students from southeast Asia are quick to point out that the assertion that Asians are overrepresented in STEM should not lead people to believe that there are too many Khmer or Burmese students in the university. Even though the demographic categories could be improved, they offer a window into the ways that the opportunity to pursue a career in STEM is not equal for everyone.

This conversation has the potential of upsetting struggling students who feel they have succeeded based on their merits alone. However, it is wrong to expect the members from historically excluded groups do all of the work to promote DEI. To be sure, recent work on promoting diversity in STEM like Dunbar-Hester [1] seeks to bring a positive attitude toward the situation, turning a problem into an opportunity. Diversity benefits all members of the community, not just people from groups that have been historically excluded. The community- and merit-based culture of computing provides a potential for change that might be more difficult to realize in other professions.

When trying to secure allies from current individuals in STEM, it is important to remember they are likely from overrepresented groups. Some express the feeling that they or their peers will have to give up their places so that STEM can be more diverse.

It is important to state upfront, then, that increasing diversity in STEM is not a zero-sum game. The truth is, continuing technological advancement and bringing the benefits of scientific progress to a wider proportion of the world's population have created a demand for workers that is increasingly difficult to fulfill. In 2012, for instance, the U.S. determined that it would be short 1 million STEM professionals in the coming ten years. In other words, as shown in Figure 1, it would be unproductive to replace anyone. Proponents of increasing diversity suggest that the easiest way to recruit more people to STEM is to utilize the pool of untapped talent from students who tend to avoid choosing STEM or leave STEM programs. Even though women and people of color represent more than 70 percent of the workforce, they are only 45% of the workers in STEM. Thus, they represent a "large underutilized source of potential STEM professionals" [2]. Doubling the number of female students, though, is not an ambitious goal when the starting point is so low. The U.S. has relied on policies like retaining international students with restrictive H1b visas, instead of fostering an inclusive environment.

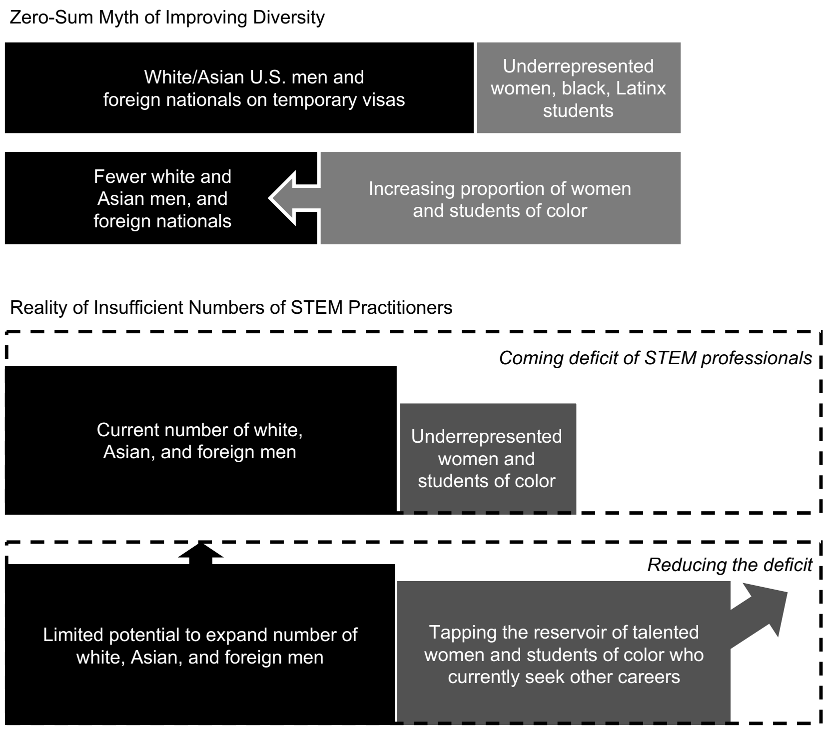

Fig. 1. Increasing diversity in STEM is sometimes thought of a zero-sum game. However, there are not enough students and professionals in STEM fields.

Although this paper focuses on university experiences, the implications of these ideas are clear in other contexts. In fact, fostering an inclusive environment will improve research and working conditions for everyone. A workplace environment where all can be included is one where ideas are shared more openly, bringing about more successful outcomes. This paper begins with an historical overview of diversity with an emphasis on women in computing. Counter to some people's expectations, the underrepresentation of women in computing was not something experienced in its early days, going a long way to dispel the notion that it is somehow natural that women are not interesting in computing. Finally, the paper provides an overview of some current ideas about DEI in STEM as a starting point for those who might wish to help create a more inclusive environment.

2 The Decline of Diversity in Computing

When IFIP was established in 1960, computer science and computer engineering were barely recognized as fields. Although this was a different age in terms of diversity in the workplace, computing was actually a field that had a healthy presence of women. As the workplace overall became more diverse, though, STEM generally and fields related to computing specifically have been outliers. Women and people of color are no longer the underrepresented minority overall, but STEM student populations and workforces have persistently failed to diversify.

2.1 Initial Diversity in Computing

Surprisingly, at time IFIP was founded, the percentage of women in computing had reached a high point and would soon start to decline. As has been noted by Light and others, the electronic devices that took the place of women also "would take their name": the legions of women who had made calculations by hand [3]. In spite of this, the female "human computers" were experts in setting up problems who had an important role in the early days of electronic computing. Six women, for instance, were part of the first team that programmed ENIAC. When the project was transferred to Aberdeen, Abbate says at least seven more women joined the team. Two followed the leaders who went on to create UNIVAC [4]. Of course, while working on UNIVAC, Hopper would go on to pave the way for computing by inventing the software compiler.

As electronic computers became more widespread, some of the women who had been doing calculations by hand continued their work, preparing equations so that they could be fed into machines. They taught classes about computing, and they also had an influence on programming. Abbate notes that the women who worked on ENIAC invented break points (a technique of inserting stops in a program for debugging), they created a system to visualize the timing of digital analysis, and they adapted techniques from applied mathematics to computerize numerical analysis [4]. Even so, women received little recognition for their work. Abbate suggests that the erasure of the women was mirrored by many of their male counterparts; the machine and its inventors took center stage at a time when hardware seemed more important than the programmers who made it function. As pointed out by Ensmenger [5], the reason for this is partly one of methodology: a "bias in the traditional emphasis of the history of *computing* on the history of the *computer*." Because few women had the opportunity to create machines, the mistaken impression that there were no women involved arose.

Shortly before IFIP was founded, computing jobs were increasingly located in private companies, and there is (perhaps unexpectedly) evidence that women were welcome. In 1956, the U.S. Labor Department noted that some industrial laboratories hire women for computing groups exclusively, others at a high percentage. Abbate points to a 1957 brochure to recruit women to IBM. Entitled "My Fair Ladies," the brochure claimed that a job at IBM would give a woman a "highly important position" that would allow her to use her "talents and aptitudes." Abbate also refers to a 1963 advertisement promoting English Electric's software services entitled "Why pick a woman to pep up your accounting department?" The fashionable woman in the advertisement, pensively chewing on a pen, "simultaneously positioned female programmers both as eye candy for male managers and as competent, no-nonsense technical experts" [4]. Despite this implicit bias, Abbate notes that the advertisement claims women are competent and possess a "logical flair" for writing programs.

From this base, one would expect to see only a greater participation in computing from women as the 1960s drew on, given the general attention toward civil rights and, specifically, anti-discrimination legislation in the U.S. Quite the reverse would turn out to be true. One of the key moments in the development of modern computing was the creation of time-sharing systems, where multiple users could work simultaneously on a single mainframe, helping to create the notion of a community. This turn from individualistic problem-solving to communities of practitioners is often lauded as a pivotal shift in computing, but given the social norms of the 1960s, not all parts of the change were positive. Some of the key work in time-sharing was done at Dartmouth University, which was at the time a single-sex university. Joy Lisi Rankin has pointed out that, as one might have predicted, the university's computer center employed women. However, the student programmers and their achievements demonstrated what Rankin describes as a "macho computing culture" [6]. Even when Dartmouth became coeducational, female students tended to avoid the computing center. As Rankin notes, the social world reinforced the growing norm of computing as a privileged domain. Seven of the nine secondary schools working with Dartmouth before 1967 were all-male, private schools. Interestingly, Rankin notes, the teachers who supervised the high school students were also male, even at a time when teaching was assumed to be a profession dominated by women [6]. Despite the initial prominence of women, access to computing was mediated through gender and class biases of this time.

This transformation of computing into a male field is now well documented. Mar Hicks has noted how programmers in the U.K. computer industry were once thought of as skilled professionals when the work seemed less valuable, but when men learned how precious computing would be, it soon became a management position, where women were underrepresented [7]. This attitude was reinforced by policies that required women to have college degrees at a time when there were not so many women in college, as memorably depicted in the book *Hidden Figures* by Margo Shetterly [8] and in the film, particularly as portrayed by Janelle Monáe [9]. Abbate notes that a college degree was not a useful prerequisite; policy makers thought of it as an indicator of general intelligence and not of skill in computing. Abbate writes, "given the economic and class barriers to attending college during this period, it could not be assumed that only those with a degree had the ability to think" [4]. This had the perhaps unintended consequence of decreasing access to the profession of computing.

This policy did not reflect experience. Abbate points out that education was not found to be a good proxy of intelligence; in 1968, she writes, General Electric in Albany, New York created a program to prepare black residents for jobs in computing even if they did not have college degrees. The organizers found that some of the students who did not complete high school were still at the top of program participants. Evidence of how relaxing the requirement that computing professionals must have a college degree could change the field, though, did not result in a new policy. Abbate surmises, "Accepting black high-school dropouts as potentially talented programmers might have threatened the privileged status of technical skill." As a result, larger social forces contributed to a bias against addressing exclusion, even though the people enforcing the policy might have thought they were making merit-based decisions.

A computing expert in the 1970s and beyond might think it was natural, however unfortunate, that there were so few women in computing. It would be hard for most professionals from this period to say that groups were actively excluded from computing – but even so, Abbate, Rankin, Hicks, and other scholars have demonstrated how policy rather than personal interest created a palpable bias that resulted in a community that decreased in diversity and was less inclusive.

2.2 Creating Underrepresentation

Around the time when IFIP was founded, only about a third of college degrees in any field were earned by women. Although women would continue to have important roles in computing in the 1970s and beyond, their presence would peak around 1985 and then go into decline. As a marker of the erasure of the initial diversity in computing, no women were invited to the 1968 Garmisch conference where the term "software engineering" was coined. Their absence "should give us pause," Abbate says, who then proposes several well-known women who conceivably could have been invited [4]. Paradoxically, the women's and civil rights movements seemed to have resulted in a backlash against diversity in engineering in particular, computing specifically.

As shown in Figure 2, science, law, medicine, and engineering saw fewer than 15% women in 1950. The women's movement, along with a more general attention to civil rights in the U.S., made the lack of diversity unpalatable in many fields. Due to antidiscrimination legislation (such as the 1964 Title IX of the U.S. Civil Rights Act), a resolution by Association of American Medical Colleges (AAMC) to foster diversity, and the general spirit of feminism, some professions began to change. For instance, medical programs actively began to mentor and recruit women, with the result that today men and women are nearly equally represented in medical school [10]. A similar trend can be seen in law. As a result, membership in these professions is closer to national demographics of the professional class overall. This trend is even more troubling because engineers are only one constituent in a modern engineering project; they must work with managers, investors, government officials, residents. STEM students who are not used to diverse environments will find themselves unprepared for a multi-unit enterprise where demographics match national averages.

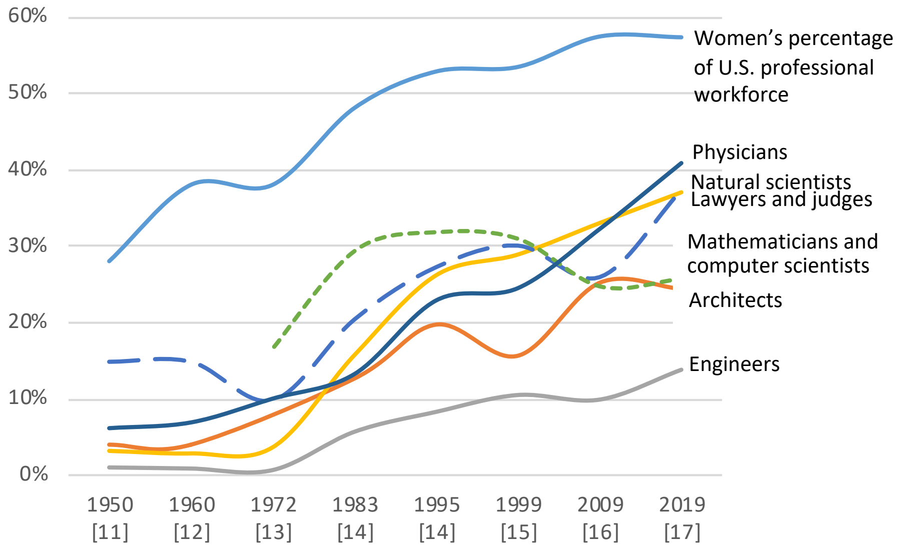

Fig. 2. Since 1950, the percentage of women in the U.S. professional workforce has doubled, growing from 28% to 57%. Despite an initial increase, computing has declined in diversity.

Contemporaneous with the civil rights movement, computing saw an environment that was hostile to diversity. As noted by Dunbar-Hester [1], the cultural values of the open-source movement included a "tenacious devotion to free speech" that "provided a fertile ground for confrontation and hostile speech – including sexist speech – to flourish." At the same time that open-source and maker communities seem to be divested from politics, asserting instead an individualistic mindset that has personal benefits, Dunbar-Hester reminds us that progressive politics are unwelcome in these communities. Nonetheless, Dunbar-Hester points out the many ways that feminists and others have taken advantage of the community-based protocols of these groups, which rely on consensus and participation, to create spaces that support DEI. She cites groups like LinuxChix, Debian Woman, Ubuntu Women, the Geek Feminist project, and PyLadies as groups that strive to make a welcoming environment.

When engineering fields in general became dominated by men, it may have seemed proper to "fix" computer science by making it seem more like other engineering fields. As Abbate describes, the "crisis" that software engineering was expected to resolve did not go away when the masculinist rhetoric of rigor and technical merit were infused into the profession. Indeed, by devaluing "the aspects of software production that rely on stereotypically feminine skills of communication and personal interaction," a whole new series of problems developed. By 1990, evaluators of the field noted that practitioners were too closely focused on technical issues, economics, and rationality. Failures resulted because computing professionals were unable to communicate with their clients and understand their needs and constraints – let alone the unintended social consequences of their work. The interpersonal or "soft" skills, which Abbate describes sardonically as "elusive," were the values once imparted as part of a liberal education before the invention of specialized education for computing. The study of culture and the resulting sense of citizenship it should impart were the casualties of software engineering reforms in the name of rigor.

Certainly, the early generations of computer science professionals had not shied away from the arts and sciences, but they were not graduates of computer science programs because they did not yet exist. Even as other professions began to address diversity, computing's effort to become more like engineering unfortunately changed the path one took to become a computing professional. By the 1990s, the liberal arts had been devalued in computing education, and diversity was on a downward trend.

2.3 Bringing Diversity Back

In 1991, Ellen Spertus wrote a report about women's experiences based in part on her online data collection while she was an undergraduate student at MIT [18]. She reports some disappointing experiences but also makes positive assertions: her mentors at MIT were supportive of her effort, and the deficit of trained computer professionals was leading to efforts to improve recruiting of women.

The efforts to reverse the historical exclusion of groups in computing that began in the 1990s, however, should actually be described as *returning* diversity to computing. In spite of efforts by educators and admissions staff, a study by the U.S. National Science Foundation did not find much improvement in the early days of the 21st century. Undergraduate enrollments in STEM seemed to be following existing trends. Although first-year college students nationwide are nearly evenly split between genders and reflect the ethnic diversity of the country well, significant gender and racial differences in the sciences persisted. In math, statistics, and computer science, 1.4 percent of women were interested, as compared to 5.2 percent of men. The difference was much greater in engineering overall. In terms of race, Asian students were more than twice as likely than other groups to choose a major in engineering (15.0 percent of all first-year students) or in math, statistics, or computer science (5.6 percent) [19]. If one is committed to the idea that gender or race do not somehow give a student a biological advantage, then social biases must be considered.

Some students, faculty, and administrators believe that STEM fields are already quite diverse. Even though the STEM workforce has drawn traditionally from white and Asian men, universities claim they meet diversity goals with international students and by incrementally increasing the number of women [20]. Classrooms might seem diverse due to a diversity of national origins, for instance, masking the absence of other demographic groups. I remember one student who attended a DEI program I organized only because he wanted to make the point that at our university there were not enough white men and increasing the number of white men would improve diversity. He asked us to notice that most people in our classrooms were not white men.

The social encouragement (or discouragement) is even more pronounced when one figures in recent data from the College Board, the company that administers the SAT. When a high-school student signs up to take the SAT, the College Board asks pointed questions that can show prospective students' preparation for and interest in college majors. In the past decade, the College Board found that the proportion of college-bound students from historically excluded groups had never been higher, as was the percentage of black and Hispanic students who surpassed the College Board's benchmark for college readiness [21]. Differences in the math portion of the SAT, although they varied as much as 200 points between races, were not so different between genders of each race. In fact, as shown in Figure 3, the College Board found that women were slightly more prepared in terms of mathematics than their male classmates – about 50 percent of each group having four or more years of math that included calculus and AP or honors classes – and yet men were much more likely to say they would study engineering or computer science when they were getting ready to take the SAT. Thus, the persistent lack of diversity must be seen as a contradiction to the increasing preparation and interest of those from groups that have been historically excluded.

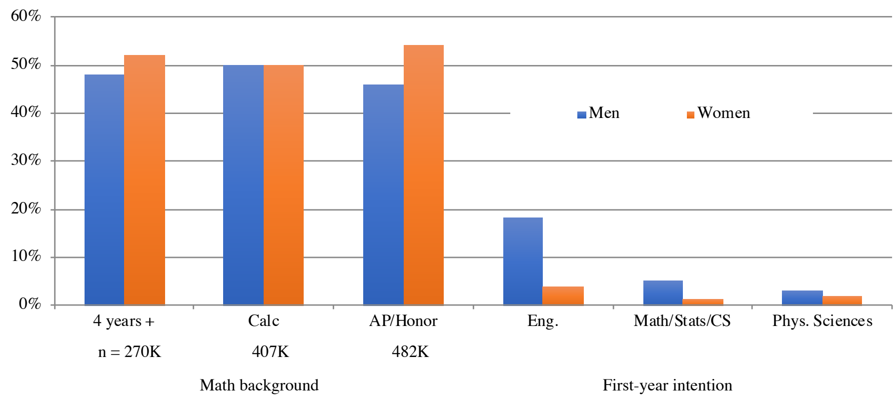

Fig. 3. The College Board found that men and women have similar preparation for STEM majors. Nevertheless, men outnumber women in their intention of studying STEM.

Although about 50% of students who start in STEM do not finish, the attrition of students of color is higher than 75%. The overrepresentation of white and Asian students widens at higher degree levels [22]. This phenomenon has been called a "leaky pipeline." Some blame falls on the first-year experience. Abbate notes that the tradition of getting rid of what was seen as an excess of students through "daunting workloads" started in the 1980s; these caused people to drop out who have less experience or confidence (i.e., women). The study of a bottleneck course, Calculus 1, by Colorado State researchers surveyed more than 2,000 students. They found that women were 50% more likely to switch out of the required sequence (and leave STEM). In addition, they discovered that confidence levels in men after the course were much higher than women. Based on their understanding of the students, this lack of confidence was not a matter of ability but self-perception [23]. Given the strong preferences some STEM educators have for this sort of first-year experience, it will be difficult to ameliorate the effects.

As historian of science Londa Schiebinger asserts, broader changes in gender-based social expectations from many domains are required to correct underlying causes of inequality. It is not natural or necessary for some groups to be underrepresented in STEM. Schiebinger likes to point out that in 17th century Germany, a higher percentage of astronomers were women (14 percent) than there are today (5 percent) [24]. She points to well-known studies that show men are reviewed more favorably than women in hiring and promotion. Recognizing that there have been many efforts since the 1950s to improve opportunities for women, Schiebinger downplays efforts to “fix the women,” supposedly making them better prepared for STEM. Seeing women as the problem, Schiebinger writes, is not the best or only way to change inequality [25]. Cultural assumptions about classrooms, research labs, and academic departments – not to mention everyday life – work against all women, and especially in STEM.

To Schiebinger, though, it is not so difficult to accept unfairness in STEM and work to become conscious of it. A bigger challenge is thinking about how research results can be improved by ameliorating bias. As seen in Figure 4, Schiebinger is not alone in this regard. In the 21st century, compelling arguments have been made to increase diversity in STEM. Removing bias in STEM makes improvements for all.

Benefits of improving diversity in STEM	
Better knowledge	Improve epistemology, eliminating gendered metaphors to understand scientific concepts [25, 26]
Cultural competency	Prepare students for diverse workplaces [27]
Improved innovation	Challenge preconceptions about users of technology and recipients of medicine [25, 27]
Social justice	Provide access to well-paid, prestigious jobs [26]
Talented workforce	Utilize the best thinkers; intelligence and insight are distributed evenly among all demographics [26]

Fig. 4. The arguments for supporting diversity have been well articulated [25, 26, 27]. Notably, diversity benefits professions and society as a whole, not just historically excluded groups.

3 Becoming an Ally who Fosters DEI in STEM

In his famous 1902 book *Souls of Black Folk,* W. E. B. DuBois asks, what does it feel like to be a problem? As the first African-American to earn a Ph.D. from Harvard, DuBois was often asked about what was then referred to as the “Negro Problem”: what to do for the 3.5 million formerly enslaved people after the Civil War. As he describes, this terminology is a small insult to someone who is trying to be a public professional [28]. As DuBois might remind us, it is important to think about how others hear the conversation about DEI in STEM if one wishes to have a positive impact.

These days, it is common to hear members of a male-dominated STEM extracurricular club state that they would welcome any woman who volunteered to participate. People from overrepresented groups seem mystified as to why their environments lack diversity. In the past twenty years, many people interested in equity have developed a rich palate of concepts and best practices. It is beyond the scope of this article to discuss each fully, but this section will provide a brief overview of the concepts and terms that are helpful to people who seek to foster an inclusive environment.

3.1 Unearned Privilege

The concept of "unearned privilege" can be used to understand how disparities in representation in STEM are symptoms of problems that affect many people. Macintosh invokes a metaphor of an "invisible, weightless knapsack of special provisions, maps, passports, codebooks, visas, clothes, tools, and blank checks" to describe the unacknowledged advantage a member of a majority group can draw on [29]. The items in the backpack provide dominance in social settings, but this is not the only impact; Macintosh points out that the idea that one's skin color will not be a factor in judgements about you or the expectations that people around you will treat you equitably "should be the norm in any decent society." STEM policy and programs have not been designed well to improve representation of marginalized groups and, as described below, may in fact reinforce preexisting inequalities.

This concept of unearned privilege does not suggest that obstacles to careers in STEM that white women face, for instance, are the same as Latino men, nor that all Latino men and white women will find less success than white and Asian men. Similarly, one should not suppose that white and Asian men find it easy to gain their achievements in STEM. The concept of unearned privilege suggests, though, that some groups have more confidence that the educational and industrial environment will work for them: someone without a backpack will not see the same success from the same amount of effort as someone with a backpack. Science and engineering, after all, require intense preparation that causes most students uncertainty and doubt. It would not be surprising, then, that those who feel that their effort will not yield meaningful results would leave STEM and seek a career in a field that needs their technical skills and analytical ability but offers less intense identity-based challenges, such as financial analysis or medicine, which have been more successful in promoting DEI in the past 60 years.

Some might say that unearned privilege is simply a euphemism for sexism or racism, and perhaps it is. The goal of using this term, though, is to broaden the understanding of racism and sexism beyond being kind and respectful to people from different demographic groups to provide a better understanding how erasing inequity requires more than politeness. It is helpful to qualify the word "privilege" with "unearned" for another reason. The white and Asian men who predominate STEM in U.S. universities and industries are not always individuals who have economic or political advantages. In my own experience, many students in the overrepresented groups were, in fact, from backgrounds that are often called underprivileged, in the sense of lower-income. Calling a student "privileged" whose parents left his home country and made many sacrifices so that he could study engineering – and who likely worked one or more jobs while he did so – is likely to earn the retort that "I am not privileged." Care must be taken in this conversation, especially when asking current engineers and educators to support it.

3.2 Stereotype Threat

The term stereotype threat was coined by Claude Steele to help understand performance differentials between overrepresented and underrepresented groups [30]. At every stage of testing in schools, lower scores are earned by historically excluded groups, such as women or students of color. This was startling to Steele and his associates because the comparatively poor performance could not be attributed to lack of kills or preparation. "The underperformance phenomenon documents lower performance by these groups at each level of skill – that is, when skill and preparation … are essentially held constant" [31]. Through more research, Steele learned to describe the cause of this phenomenon.

In one article, Steele likens the additional cognitive load on a member of an historically excluded group to a person who is late to a dinner party. Although the other guests are unconcerned about the lateness, the late person feels ill at ease and is preoccupied with unnecessary tasks in a vain effort to compensate. To Steele, this analogy explains the performance differential: during an assessment, some of a student's effort is wasted on worrying whether the student will confirm the stereotype or, at least, be perceived as confirming it. This phenomenon was also demonstrated among other historically excluded groups.

The performance differential is frequently seen with challenging assessments, so Steele developed a methodology to reveal the involvement of stereotypes. The team recruits students who have mathematical ability and believe mathematics is important to their future plans. These students are asked to complete a challenging assessment, but one group receives different instructions than the other. In the first group, students are told that they are going to take a difficult mathematics assessment that many female students find difficult. In the second group, the instructions are simpler: just do your best. Steele and his associates found that in the first group, where the fear of a stereotype was activated, the performance gap between overrepresented and underrepresented students increased dramatically. In this way, Steele has shown how what should be an objective assessment does in fact exhibit bias. All students have similar background preparation, they are all answering the same questions, and they are all sitting at a similar desk. Nevertheless, perceptions of bias can vary the outcome depending on one's demographic membership. This challenges the assumption that test scores can be the basis of merit-based decision-making.

There is some good news in this research: Steele found that an awareness of stereotype threat is a good way to overcome it. However, there is a potential downside as well. Programs to provide simpler curricula or offer extra help to students who are already committed to success in STEM may backfire if they unintentionally reinforce the stereotype. Challenging problems and meaningful support are the best help for students from historically excluded groups if they are determined to succeed. Overall, Steele says, educators should emphasize the expandability of the human mind: no one is born with a natural ability to solve math and engineering problems. Instead, people can learn.

3.3 Imposter Syndrome

Imposter syndrome is the feeling that one's accomplishments do not come from one's ability. The phenomenon was first noticed in 1978 by psychologists Clance and Imes among women with exemplary credentials, who internally and inexplicably create various scenarios that negate "any external evidence that contradicts their belief that they are, in reality, unintelligent" [32]. Men are likely to believe their success is an intrinsic characteristic, whereas women attribute their success to luck, accident, or hard work in order to compensate for what they think is their lack of natural ability. This is not unique to STEM fields. In the context of STEM education, though, it helps to explain performance differentials and why students do not persist in their degree programs or careers.

The feeling that one's abilities are substandard and that only the kind graces of mentors and professors allow a student to continue can be debilitating. The sensation is worsened by the first-year weed-out pedagogy. Students typically receive very low grades in their initial assessments. Those who have friends or family who have attended engineering school before know that it is not uncommon to receive a score below 50% on the first exam; they know that it is traditional in many schools for the professor to "curve" students at the end of the term on a range from A to C even though their term averages are much lower. It seems as if this is a way for faculty to impress upon students the importance of rigorous thinking and encourage them to try harder.

Students I have spoken to have been gratified to learn the name for imposter syndrome because it matches their experience. Imagine the feelings of members of historically excluded groups in this situation. They are already feeling as if they may have made a poor career choice. They have been told that rigorous thinking is important and they believe that they must succeed on their own merits. Everyone then receives devastatingly low scores on early assessments. Some students will feel that their poor scores are evidence that they are unable to master the material. Even though those around them are having similar experiences, those in underrepresented demographics already feel the deck is stacked against them. They may develop defensive habits, like coming to class late or refusing to hand in homework, while they consider other options, with the result that they do not learn any of the course material. The feeling of their overrepresented peers – that everything will be ok at the end of the term – is not an adequate motivation for students from historically excluded groups to move forward. In this context, a student may feel simply that they are allowed to pass a class where the evidence clearly showed they failed because of the desire to diversify engineering.

Imposter syndrome can be demonstrated empirically. For instance, in a study of data gathered about 1,143 students in astronomy (40% women) [33], women report fear of that their lack of knowledge will be discovered and other symptoms of imposter syndrome. This is unfortunate for many reasons, but among graduate students, it is particularly upsetting because they are the most knowledgeable about their topics. By asking other questions, researchers found that those who reported imposter syndrome were also likely to report an unwelcome environment and lack of mentorship.

As was seen before, social factors and not ability are the cause of this factor that stymies efforts to diversify. Dunbar-Hester [1] notes that this topic was a common theme in the free software conferences for social change. At the workshops devoted to diversity she attended, Dunbar-Hester noted that people can overcome the feeling that they are imposter by "claiming more authority in the face of these feelings." In other words, an alternative social environment can improve diversity in STEM.

3.4 Microaggressions

The impact of imposter syndrome and stereotype threat can be said to be magnified by microaggressions. Discussing the concept of microaggressions has become an effective way of promoting an inclusive environment at a time when overt bias and threats have become socially unacceptable. In a social justice circle, discussing microaggressions is a way to explain how people who do not think of themselves as prejudiced might nevertheless create adverse environments for members of historically excluded groups.

John F. Dovidio provided some of the theoretical foundation of this concept in his work on averse racism. He and his colleagues note that after the 1960s, white people have modified the appearance that they are racist while at the same time cultivating "a private self-concept of being non-prejudiced" [34]. In the different approaches to understanding racism since that time, Dovidio et al. note that averse racism is expressed by people who are "politically and socially liberal." Instead of blatant racism, these individuals harbor "unconscious negative feelings and beliefs" that are expressed "in subtle, indirect, and often rationalizable ways." In spite of their professed support for equality and righting past wrongs, these people have interior, conflicting notions that are expressed in discomfort or anxiety. In short, they feel an "aversion" against black people, whence the name. It is unlikely that a person perpetrating averse racism will take actions that can readily be identified as racist. At times of ambiguity, though, they might express themselves in ways that can harm black people while at the same time help them to "maintain their self-image as non-prejudiced" [34]. This form of racism has been studied in a variety of contexts, helping to explain biases in hiring as well as problems in intergroup dynamics.

The term "microaggression" has come to be used to describe incidents where averse racism is expressed. Researchers have provided a taxonomy that includes microassaults, microinsults, and microinvalidations [35] or assumptions of inferiority, assumptions of criminality, and exoticization [36]. To the person expressing averse racism, the beliefs they espouse may seem bland or inconsequential. However, to the person experiencing the prejudice, the impact can be severe – especially for individuals who receive signals of averse racism many times throughout the day. Repeatedly experiencing microaggressions can magnify stereotype threat and imposter syndrome, but to the perpetrator, the racism does not exist or it is ambiguous. Calling averse racism a "microaggression" is an effort acknowledge to the perpetrator that what they think may be a minor slight (the "micro" part of the name) is in fact an act of violence (the "aggression" part of the name). Investigators have noted that students are more likely to report microaggressions in the classroom than will faculty [37]. The same research points out that students' greatest complaint is when microaggressions go unchallenged. As with stereotype threat, knowledge about the phenomenon is the best way to combat it.

3.5 Adding the Arts to Create STEAM

The founder of IFIP's Working Group 9.7 (History of Computing) was a proponent of restoring women to computing through the study of history. John A.N. Lee tells a personal anecdote, explaining how he has forgotten the family name of the woman in the computing center who did his calculations, but her work led to his degree. Without her, he later recognized, his graduation would have been delayed for years, but at the time he thought of her as "part of the furniture." He writes that his only excuse is that his colleagues thought the same about women in the computing center [38]. By the time he founded IFIP Working Group 9.7 in 1992, he had championed placing prominent women, like Grace Hopper, into their rightful place.

Lee oversaw a special issue of the *Annals of the History of Computing* dedicated to ENIAC in 1996. Thelma Estrin, one of the contributors to this issue, noted that women's studies and computing were established at roughly the same times and can have an influence on each other. She suggests improving computing education with concepts from women's studies, such as the effort to replace abstract thinking with concrete, practical projects. She writes, "Feminist epistemology, with its dedication to concrete learning, introduces new ideas for gaining knowledge that may make CS more relevant for minority and lower-income students as well as women" [39]. In 1998, WG 9.7 along with IFIP TC 3 adopted the "History in the Computing Curriculum" guidelines. The history of computing "allows students and scholars to explore the thinking and decisions of people as well as the socio-technical dynamics" in computing [40]. Concomitant with the growth of feminist science studies at the end of the 20th century, these scholars began to investigate how bringing the liberal arts back into STEM might improve outcomes in education and research.

This work has proven to have even greater importance when thinking about DEI. When students who have left STEM programs explain their reason in interviews, sometimes they state that their personal interests changed. Digging deeper, though, reveals their unexpected way of defining "personal interests." Listening carefully to these students, one realizes that the concerns they have about STEM seem out of step with the civic-minded personae of so many people who work in STEM fields. One way to counter this mistaken impression of STEM is by adding the arts, which can be broadly conceived as the liberal arts.

Georgette Yakman coined the term STEAM in 2008 [41]. Pointing out the long tradition of educational theory that proposes to develop an individual holistically, Yakman applauds the way that STEM educators have moved away from teaching disciplines as discrete "silos." Instead, Yakman favors an interdisciplinary approach that demonstrates how various fields are interrelated. This is important in an advancing world because transferring knowledge is insufficient when technological devices and scientific knowledge are in constant flux. According to Yakman, only an "integrative education" can help students be "continuously adaptable to the changes and developments of society." Building on the work of holistic educators like Maria Montessori and Rudolph Steiner, Yakman proposes STEAM as a framework for integrative pedagogy.

The foregoing discussion should make clear that Yakman, in terms of computing at any rate, is calling for the *return* of the liberal arts to STEM because they were present from the beginning. With the advent of software engineering and the call for increased rigor in computing, the attention to holistic education faltered. For Yakman, a middle school educator, putting the arts into STEM to create STEAM is important because they explain "how society develops, impacts, is communicated and understood with its attitudes and customs in the past, present and future." According to her definition, the fields of the arts include some obvious candidates, such as the fine arts and literary study. However, she also includes broader studies of humanity on her list, such as psychology, sociology, history, and philosophy. Interestingly, she also includes physical arts – such as sports and dance – as well as the manual arts, or making things, which used to be constrained in the U.S. to vocational training. This echoes Estrin [39] in the effort to improve education with hands-on, practical activities.

STEAM is often championed as a means to create innovative scientists and engineers. One famous example of the unexpected technical innovation that comes from the arts was mentioned by Steve Jobs in his 2005 Stanford University commencement address [42]. As he was dropping out of Reed College, he stopped taking required courses and chose courses that interested him. He took a course in calligraphy, learning about serif and sanserif typefaces and proportional spacing. “It was beautiful, historical, artistically subtle in a way that science can’t capture, and I found it fascinating,” he says. At the time, he had little hope studying the western tradition of hand lettering would serve any practical purpose in his life. However, ten years later when he was imagining the Macintosh, he designed a computer that could produce beautiful typography. Today, all consumer electronics use different typefaces. This anecdote demonstrates how an appreciation for history and the arts can inspire technical innovation.

It may be underappreciated, though, how STEAM can support DEI. Some students leaving STEM will say that they wanted to have more time for their so-called creative side, by which they seem to mean that their love for aesthetic experiences felt out of place with the rigorous, algorithmic education in their STEM majors. A student with technical capabilities will successfully develop an interest in photography, for instance, and then abandon a career in STEM altogether. Students in a 6-year preparatory program for STEM, similarly, surprised me by choosing college majors that were only tangentially related to STEM. One, for instance, went on for a major in graphic design. These students, who are obviously very capable, take the basic skills they learn in their foundational courses and become successful. The problem for STEM is, a colleague pointed out to me, that these students are very bright and they can thrive in multiple fields. When faced with negative social pressures, they take their talents elsewhere.

In a way that is somewhat similar, other students will say that their culture or history is important to them, and they do not feel as if their training in STEM has any relationship to their personal identity. For instance, a black student who is studying urban infrastructure proclaimed his dismay that his classes did not address the experience of people of color in cities, even when his courses covered the history of infrastructure in cities. For students with a strong sense of ethnic identity, the way in which a typical STEM curriculum strips away the social realm can be distasteful. The movement of students away from STEM and into other fields should be seen as a failure of the STEM programs and not as evidence that the students were never suited to STEM in the first place. For instance, Donna Riley and Alice L. Pawley write about a Latinx student who chose engineering as an undergraduate major because she felt it would be a field that honored her commitment to social change and because it is an interdisciplinary field that would have allowed her to pursue a variety of interests [43]. After her first year, though, those same values led her to consider a change in major to cultural studies, hoping to learn more about her Latin American heritage. Her desire to maintain positive social change remained intact, but unfortunately the way that culture and ideology are typically absent in STEM education made it seem like an unwelcome choice. The rigid and analytical curricula may be satisfying to some students and employers, but they are not necessarily supportive of DEI.

This does not mean, of course, that hard work and deep learning in STEM must be sacrificed. In creating an interdisciplinary science and technology studies (STS) program inside of a school of engineering, a colleague and I were thinking of students who wanted to pursue careers in science or engineering but at the same time had significant interest in the humanities and social sciences. As members of a department that offered general education courses for engineering students, we built on the general premise of what would later be called STEAM, allowing a student to graduate from an engineering school by taking a minimum of one-third humanities or social science courses and one-third engineering courses along with other students in STEM majors, with the remaining third decided by the student. This kind of curriculum is not suitable for every student; it requires extra thought and planning. Our students went on to typical careers in STEM ranging from medicine to manufacturing.

After 10 years, though, the program showed an unexpected outcome: the percentages of women and non-white students were twice that of the overall student population. In retrospect, the efficacy of our interdisciplinary major in promoting DEI was simple. Students were not dissuaded from taking difficult courses in engineering or science; they stayed in the same classrooms with students in traditional engineering majors. They did appreciate the flexibility to choose more of their own classes, and they enjoyed courses in STS where they could study science and engineering in the context of history, ethics, literature, philosophy, and other fields of the arts. I cannot imagine an entire school of engineering changing its curriculum in this manner, but having an STS major as an option for some students would certainly improve outcomes. Taking some of the features of this program – such as the ability to choose electives, incorporating STEAM, and offering courses that address the social issues related to STEM – would be a benefit as well.

4 Conclusion

It is clear that current STEM pedagogy is successful for many students, including some women and people of color. However, it is also clear that there are other students who are not served well by current thinking in STEM education. If one accepts the premise that talent in STEM is spread throughout the human population and is not confined to white and Asian men alone – as we must – then the current disparities in participation can only be explained by social causes. In order to recruit and retain a larger number of diverse students, it seems unavoidable that the structure and social environment of STEM education must be examined.

The story of computing as a profession is relatively recent, and it is easy to see how its initial freedom from engineering education led to different outcomes. To be sure, the separation of science from the liberal arts is a legacy of the industrial revolution, and C. P. Snow [44] famously decried the “two cultures” split even before IFIP was founded. However, the familiar landscape of universities and workplaces when modern computing was established helps to show how the lack of diversity in computing – and thus in STEM overall – was not inevitable. Likewise, it should be possible to promote policies and cultures that can reverse the trend, as was done in medicine and law.

IFIP was a pioneer in advocating the inclusion of the liberal arts into STEM education. The way that STEAM can promote not just innovative designs but also a more effective workplace should be explored further. In addition, attention to the so-called “soft” skills in engineering will make engineering students more effective in their careers but also less abrasive to their peers. Factoring in time to discuss privilege, stereotype threat, imposter syndrome, and microaggressions to the classroom will make students and professors more efficacious in the promotion of an inclusive environment, improving diversity as a result.

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