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RESEARCH ARTICLE

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Engineering ableism: The exclusion and devaluation of engineering students and professionals with physical disabilities and chronic and mental illness

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Abstract

Background: The experiences of students and professionals with disabilities are routinely excluded from scholarly and policy debates about equity in engineering. Emergent research suggests that engineering is particularly ableist, yet systematic accounts of the possible exclusion and devaluation faced by engineers with disabilities are largely missing.

Purpose/Hypothesis: This paper asks, do engineers with disabilities have more negative interpersonal experiences in engineering classrooms and workplaces than those without disabilities? Utilizing a social relational model of disability, I hypothesize that engineers with physical disabilities and chronic and mental illness are more likely to experience exclusion and professional devaluation than their peers and, partly as a result, have lower persistence intentions.

Data/Methods: The paper uses survey data from 1729 students enrolled in eight US engineering programs (American Society for Engineering Education Diversity and Inclusion Survey) and 8321 US-employed engineers (Science, Technology, Engineering, and Math Inclusion Study Survey). Analyses use regression, mediation, and intersectional approaches.

Results: Consistent with expectations, engineering students and professionals with disabilities are less likely than their peers to experience *social inclusion* and *professional respect* at school and work. Students with disabilities are more likely to *intend to leave their engineering programs* and professionals with disabilities are more likely to have *thought about leaving their engineering jobs* compared to peers, and their greater risks of encountering interpersonal bias help account for these differences. Analyses also reveal intersectional variation by gender and race/ethnicity.

Conclusion: These results suggest that engineering harbors widespread ableism across education and work. The findings demand more scholarly

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attention to the social, cultural, and physical barriers that block people with disabilities from full and equal participation in engineering.

KEYWORDS
ableism, disability, engineering work, inclusion, inequality, intersectionality, respect

1 | INTRODUCTION

Engineering education and professional engineering work that does not include robust representation from the very publics it purports to serve are both inherently exclusionary and intellectually and creatively impoverished (Haraway, 1988; Harding, 1998; Slaton et al., 2019; Spingola, 2018). For decades, engineering education scholars and social scientists have documented the marginalization and minoritization of women and people of color in science, technology, engineering, and math (STEM) fields, and more recent work has extended that investigation to include sexual and gender minorities (Beasley, 2011; Cech et al., 2019; Cech & Rothwell, 2018; Freehill, 2012; Xie & Shauman, 2005). However, the experiences and voices of engineering students with disabilities have been comparably absent from research agendas and policy narratives in engineering education, and scholars know little about how engineers with disabilities fare in the workforce (Pearson Weatherton et al., 2017; Slaton, 2013).[1]

Pioneering early research on disability inequality in engineering suggests that engineers with disabilities face a variety of constraints, burdens, stereotypes, and discriminatory treatment in the profession (Chua et al., 2019; Dolmage, 2017; Jurado-Caraballo et al., 2020; Maroto & Pettinicchio, 2014; Pearson Weatherton et al., 2017; Slaton, 2013). Moreover, science and technology studies (STS) scholars argue that STEM broadly and engineering specifically may be particularly hostile to people with disabilities (Lee, 2014; McCall et al., 2020; Slaton et al., 2019). Yet, there has been little broad-level assessment of the experiences of engineers with disabilities across the engineering training and career span.[2]

Weaving together a social relational model of disability with STS theories on cultural notions of embodied expertise, I argue that cultural and relational contexts in engineering which construct certain embodiments as "normal" and "ideal" produce interactional-level disadvantages for engineers with disabilities. I examine three specific domains of disadvantage: lower likelihood of experiencing social inclusion, lack of respect for one's engineering professional abilities, and the impact of these experiences of exclusion and devaluation on engineers' persistence intentions.

Using two survey datasets—one with more than 1700 students enrolled in eight US engineering education programs, and another that includes more than 8000 employed engineers—I compare the experiences of engineering students and professionals with disabilities to other engineering students and professionals in the same programs and types of work. The use of these two datasets in combination offers the potential to tell a more powerful story then either could alone—that bias faced by persons with disabilities is not just a feature of education or of the workforce but is endemic to the interactional norms of the engineering profession more broadly.

Following measurement and data availability, the analyses here attend to three categories of disability: physical disabilities (e.g., ambulatory or walking difficulties, visual, speech, and/or hearing difficulties), chronic illness (e.g., autoimmune disorders, diabetes), and mental health difficulties (e.g., depression, bipolar disorder). Although not available in these data, a growing literature in engineering education addresses the experiences of people with learning disabilities and forms of neurodiversity (i.e., diverse ways of thinking, communicating, and behaving) such as ADHD and autism and has begun to recommend pedagogical shifts that can provide expanded accessibility along these dimensions (Asghar et al., 2017; Chrysochoou et al., 2021; Syharat et al., 2020). Attention to physical disabilities and chronic and mental illness in engineering has lagged in comparison (Bork & Mondisa, 2022; Jensen & Cross, 2021; Spingola, 2018).

[1]Currently, about 15%–20% of the US population has disabilities, which increases to 50% among adults over 75 years old (Pearson Weatherton et al., 2017; Svyantek, 2018).

[2]Following much of Disability Studies scholarship, and per National Center on Disability and Journalism guidelines (https://ncdj.org/style-guide/), I use person-first language (i.e., "people with disabilities" rather than "disabled persons"), which positions emphasis on the person before the condition. Some disability advocates and scholars prefer to use "disabled" as an identifying adjective (McCall et al, 2020; Sinclair, 2013), in particular because it emphasizes the ways that structural and cultural environments act upon individuals in *dis*-abling ways. However, outside of Disability Studies, this can be misinterpreted as a medicalized framing of disability.

Using these datasets, this study asks, do engineering students and engineering professionals with physical disabilities, chronic illness, and mental health difficulties experience less social inclusion than their peers, net of variation along other demographic axes? Are engineers with disabilities less likely than their peers to feel that their engineering work is respected? And, does this devaluation and exclusion lead engineering students and engineering professionals with disabilities to be more likely to intend to leave their engineering programs or engineering jobs than their peers (holding constant variability in career stage and other demographic measures)? In supplemental analysis, I examine intersectional patterns in these results by gender, race/ethnicity, class background, age, and engineering subfield.

This study both responds to and underscores the need for robust, rich, multimethod research on the experiences of engineering students and engineering professionals with disabilities and the patterns of disadvantage that are perpetuated in these institutional and organizational contexts. Beyond documenting these potential patterns of disadvantage, this study advances theoretical work on inequality in engineering by examining whether those with physical and mental health difficulties are targets of similar forms of mistreatment as documented along other sociodemographic axes like gender, race, and sexual identity. The paper's conclusion discusses the implications of these findings for engineering education and the engineering workforce.

2 | BACKGROUND

Although often medicalized in Euro-western contexts, disability is not a natural or inevitable designation; it is a socially constructed status (Altman, 2001; Slaton, 2013; Turner, 2001; Williams, 2001). I join engineering education scholars like Pearson Weatherton and colleagues (2017), Slaton (2013), and Riley (2013) in eschewing the medical model of disability, which frames the disadvantages faced by people with disabilities as emerging from their limitations in otherwise fair and well-functioning physical and social environments (Altman, 2001; Kutner, 2007; Wasserman et al., 2011).

In contrast, this research utilizes a social relational model of disability (Owens, 2015; Thomas, 2004b).[3] Such a model rejects biologically deterministic deficit perspectives and understands disabilities instead as outcomes of social and structural environments with physical, cultural, and organizational arrangements that *dis*-able some people but not others (Owens, 2015; Thomas, 2004a, 2004b). The social relational model "understands disability to be those restrictions of activity that result from the exercise of the power to exclude: disability only comes into being when restrictions of activities are socially imposed" (Thomas, 2004b, p. 29). This framework leaves room for the corporeal realities of physical, intellectual, or psychological restrictions on activities and experiences, but anchors the differential treatment that people with restrictions may face firmly within sociocultural and structural processes of oppression (Owens, 2015).

The social reality of disability encompasses "considerable variation in experience of impairment by large numbers of people" who nonetheless "share common conditions of exclusion, marginalization, and disadvantage" (Williams, 2001, p. 17).[4] The umbrella term "disability" captures a broad range of experiences and embodiments, which can include atypical physical embodiments; structural, functional, or learning atypicalities; chronic sickness; and mental health difficulties (Dolmage, 2017; Kutner, 2007). This term also includes experiences that may be more noticeable or "knowable" to others (e.g., ambulatory differences) and those that may be more "hidden" (e.g., some mental health difficulties) (Maroto & Pettinicchio, 2014). The present study examines the experiences of people with physical disabilities, those with chronic illness, and those with mental health conditions; other scholars have included within this umbrella other categories of disability not able to be measured here, including types of neurodiversity and learning difficulties (e.g., Lee, 2014).

Additionally, disability experiences are not monolithic. Disability status is entwined with other axes of social difference and disadvantage, such as gender, race/ethnicity, age, and class (Brown, 2021; Collins & Bilge, 2020; Lee, 2014). Experiences of social exclusion and devaluation among persons with disabilities may differ across sociodemographic axes. Even the diagnosis of chronic illness and validation of physical and emotional pain are inflected with gendered,

[3]Disability Studies is an interdisciplinary field that draws on a variety of critical theoretical frameworks to interrogate how disability is constructed within institutional and social contexts (Freedman, Dotger, & Song, 2020; Jurado-Caraballo et al., 2020). It theorizes the "social interpretation of disability through examining the cultural, political, and economic contexts that structures and gives meaning to disability" (Gabel 2005, p. 2).

[4]This definition, and my operationalization below, includes under the umbrella of "disability" people who themselves might not identify as having a disability (e.g., someone with leukemia). The case for doing so is motivated by the shared experiences of socially- and environmentally- produced exclusions of persons under that umbrella (Wasserman et al., 2011); it rests on the common ground created by experiences of oppression, stigma, and exclusion, the shared fight for access, and the common desire for more affirming representations (Dolmage, 2017).

racialized, ageist, and classist beliefs (Garb, 2021). As such, this study also attends to intersectional variation in the experiences of persons with disabilities in engineering education and the workforce.

2.1 | Ableism in US higher education and the workforce

Decades of research have documented the ways higher education produces systemic inequalities for students with disabilities. In the United States, 19.4% of college students identify as having some form of disability (Freedman et al., 2020). Notably, institutional counts may seriously under-represent the number of students with disabilities. One study found that only about a third of incoming college students with disabilities informed their institutions of their disability status (NCES, 2022). Colleges are under a legal obligation to provide necessary adjustments for students with disabilities. The 1990 ADA, for example, requires schools receiving federal funding to grant students participation and provide “reasonable accommodations” (Freedman et al., 2020; Maroto & Pettinicchio, 2014). Yet these are often ineffective, under-funded, and contested by those in power (Groen et al., 2018; Pearson Weatherton et al., 2017). Post-secondary students with disabilities face disadvantages in terms of completion rates and time to degree. Students with disabilities have a 25% longer average degree completion time than students without disabilities, and only about one-third of students with disabilities graduate within 6 years (Dolmage, 2017). Partly as a result, students with disabilities have approximately 60% more student load debt on average than their peers (Dolmage, 2017).

These disparities are driven by ableism endemic to higher education. Ableism is the cultural and institutional valuation of specific versions of bodies and minds—ones perceived as free from “faults”—which marginalizes mental, emotional, physical, or ambulatory differences and frames such differences as deviant (Brown, 2021). Ableism incudes the practices, structures, and social relations that “presume able bodiedness, and by doing so, construct [people with disabilities] as marginalized ‘others’ (Chouinard, 1997, p. 380)” (cited in Williams & Mavin, 2012, p. 171).

As Dolmage (2017) argues, “few cultural institutions do a better job at promoting ableism” than higher education, where the culture of achievement “encourages students and teachers alike to accentuate abilities, valorize perfection, and stigmatize anything that hints at intellectual or physical weakness” (p. 2). In this context, many students with disabilities are hesitant to disclose their status to university disability services offices for fear of stigmatization by professors and fellow students (Freedman et al., 2020). Further, because most disability services offices require “proof” of status through medical, psychological, and/or cognitive testing, gaining access to legally granted (though often inadequate) resources requires that students prove their membership in a stigmatized group. Even when needed adjustments are secured, students must then renegotiate this access with instructors and classmates every term (Beckwith, 2019; Freedman et al., 2020). These types of accommodation structures help to *construct* the disability of those students who need or use them (Sang et al., 2022).

Recent research has also documented systematic discrimination and bias faced by employees with disabilities in the workforce. Job seekers with disabilities are disadvantaged in obtaining employment: in 2018, for example, 74% of people without disabilities aged 16–64 in the United States were employed, compared to only 30% of people with disabilities (Blaser & Ladner, 2020). And, the overall employment rate of people with disabilities has actually declined since the passage of the 1973 ADA (Maroto & Pettinicchio, 2014). Experimental and audit studies and analyses of large-scale administrative and survey data further reveal that workers with physical and mental health restrictions face institutional and organizational barriers such as hiring discrimination (Jurado-Caraballo et al., 2020; Procknow & Rocco, 2016). A Norwegian audit study found, for example, that job applicants who used a wheelchair were 48% less likely to be invited to a job interview than identical applicants who did not use a wheelchair (Bjørnshagen & Ugreninov, 2021).

Once employed, workers with disabilities tend to be crowded into employment sectors and occupational fields with more limited educational and skill requirements and are less likely than similarly educated and experienced workers to be employed in highly-paid professional occupations (Maroto & Pettinicchio, 2014). For example, people with disabilities occupy only 3.6% of tenure-line faculty positions at US institutions (Dolmage, 2017). In addition to experiences of overt discrimination, workers with disabilities often report interpersonal biases such as exclusionary, resentful, or paternalistic behaviors by colleagues (Jurado-Caraballo et al., 2020; Ren et al., 2008). These inequities exist across the spectrum of disabilities, but previous research has found that exclusionary treatment is especially pronounced for workers with mental health conditions (Maroto & Pettinicchio, 2014), who are more likely to be stigmatized as unpredictable, unstable, and/or unreliable (Ren et al., 2008).

These literatures provide a useful backdrop for understanding the contexts in which engineering students and engineering professionals with disabilities study and work. Yet, very little scholarship has focused explicitly on the interpersonal environments people with disabilities encounter in engineering.

2.2 | Investigating how ableism manifests in engineering education and professional work

Emergent research suggests that people with disabilities face various constraints, burdens, and biases in STEM generally and engineering specifically (Chua et al., 2019; Pearson Weatherton et al., 2017; Slaton et al., 2019; Williams, 2001). Research on K–12 education suggests that students with disabilities face formidable barriers related to a lack of access to environmental and pedagogical adjustments and the bias of teachers and students (Lee, 2014, 2022; NCES, 2022). Once in higher education, college students with disabilities are just as likely to enter engineering programs as their peers but face difficulties securing necessary classroom adjustments and graduate with engineering degrees at lower rates (e.g., Alvarez et al., 2018; Hood et al., 1997). Early disabilities scholarship in STEM education suggests that students with disabilities may also encounter prejudicial treatment from STEM classmates and professors (Wasserman et al., 2011). This can include stigma by faculty and students in response to requests for accessibility-related changes to physical spaces and pedagogical practices (McCall et al., 2020), or discouragement to pursue engineering-related courses of study at all (Lee, 2014).

Inequalities may be just as prevalent in the engineering workforce. Suggesting the systemic dissuasion of engineering graduates with disabilities from engineering jobs, only 65% of engineering or science graduates with disabilities are employed in STEM jobs, versus 85% of graduates without disabilities (Pearson Weatherton et al., 2017). While there has been no social science research to my knowledge that has explicitly attended to the experiences of employed engineers with disabilities, the processes of ableism that drive stigmatization and exclusion of people with disabilities in engineering education is likely present in the engineering workforce as well (Brown, 2021; Gay, 2004).

Taking seriously the social-relational model's attention to social exclusion and devaluation as forms of oppression, I focus on the interpersonal disadvantages engineers with disabilities may encounter in classrooms and workplaces. Such interpersonal disadvantages are likely rooted in ableist physical, temporal, and epistemic norms of engineering education and engineering work (Slaton et al., 2019). Longstanding beliefs in the professional culture of engineering about competence and excellence privilege some forms of embodiment over others (Blair-Loy & Cech, 2022; Slaton, 2013). "Engineering functions as an ableist enterprise on the basis of essential notions of intellect, drive, and self-discipline that center on bodily 'normalcy'" (Slaton, 2013, p. 5). Ableism is also rooted in related "ideal worker" norms that pervade engineering education and practice which presume that full-time, intensive work is the only route to "successful" careers in engineering and equate physical and psychological endurance with substantive skill and professional dedication (Sang et al., 2022). Moreover, people with disabilities have routinely been perceived in engineering as a population that engineers should aim to "help" or "fix" through product or process design, rather than a population to be included as full and equal participants in the enterprise of engineering (Spingola, 2018).

In this study, I investigate three potential dimensions of interpersonal bias. The first is whether engineering students and engineering professionals with disabilities experience *less social inclusion* among their classmates and coworkers. Social inclusion is the experience of being fully accepted by and incorporated into the informal interpersonal community of peers in an interactional space (Attell et al., 2017; Koster et al., 2009). Social exclusion is the absence of this acceptance and incorporation.

The social exclusion of people with disabilities has been well-documented in the US population in general (Kutner, 2007). In this article, I am interested in whether differential experiences of social inclusion play out within both engineering classrooms and workplace contexts. I expect that engineering students and professionals with physical disabilities, chronic illness, and mental health difficulties will be less likely than their peers to report being included in the social networks of their classmates and colleagues (e.g., to say that they do not feel they "fit in" with peers). Such exclusion may be the result of direct or indirect marginalization by peers at school or work. It may also be due in part to self-isolation among students and professionals with disabilities out of fear of stigmatization within ableist interactional spaces (Ren et al., 2008).

Past research has connected experiences of social exclusion with lower senses of self-efficacy and belonging (Groen et al., 2018; Pearson Weatherton et al., 2017). Social exclusion also has important career consequences: engineering students and professionals who are less well-integrated among their classmates and co-workers are more likely to miss out on informal learning and collaboration opportunities and other forms of social capital (Cech & Rothwell, 2018; Ragins & Cornwell, 2001). In other words, social inclusion is not just a matter of having friends in class or at work; it is a pipeline of career skills and opportunities as well.

Second, beyond social inclusion, ableism in engineering classrooms and workplaces may manifest in *less respect of the professional capabilities* of engineers with disabilities. Professional respect (or its absence, professional devaluation) is the recognition (or dismissal) of one's skills, abilities, and potential as an engineer (Cech, 2022; Cech & Rothwell, 2018). STS and engineering education scholars have argued that the judgment of technical competence in engineering is entwined with assessments of bodily and mental "typicality" (Jensen & Cross, 2021; McCall et al., 2020; Slaton, 2013; Slaton et al., 2019). Notions of engineering skills have assumptions about "capable" bodies and minds built into them (Riley, 2013). For example, to be perceived as proficient at circuit design in an electrical engineering lab, students are expected to have the manual dexterity to manipulate centimeter-long resistors and capacitors, the visual acuity to see small details up close, and the ambulatory ability to move freely around the lab. Demonstrating that one understands the workings of a circuit is often conflated with the physical act of circuit-making. In such instances, a lack of visual sharpness or physical mobility may be interpreted as inadequate engineering knowledge. Further, illness of the body or mind contradicts notions of engineers as disembodied enactors of technical expertise—notions that code engineers without disabilities as "neutral" and thus more objective and skilled at engineering tasks (Slaton, 2013).

As a result of this interplay between ableist stereotypes and cultural notions of engineering competence, I suspect that engineering students and professionals with disabilities will have less access than their classmates and coworkers to respect and acknowledgement of their engineering capabilities.[5]

Past research has shown that experiences of social exclusion and professional devaluation undermine the likelihood that marginalized group members will intend to continue in engineering in the future (Beasley, 2011; Cech & Rothwell, 2018; Dryburgh, 1999; Posselt, 2020). These disadvantages, in addition to the structural and social challenges of seeking and ensuring necessary accommodations, likely have implications for engineering students' interest in continuing in engineering, and professionals' plans to stay in engineering work long term. I thus attend to variations in engineering students' and engineering professionals' *persistence intentions*, and whether their greater exposure to social exclusion and devaluation helps account for differences in these intentions.

As described below, I investigate these potential dimensions of interpersonal bias using two large survey datasets. Most prior scholarship on engineers with disabilities has involved theoretical, interview, and/or focus group-based research (e.g., McCall et al., 2020; Pearson Weatherton et al., 2017; Riley, 2013; Slaton, 2013). Such work has provided urgently needed elevation of the voices and perspectives of people with disabilities through ethnographic, interview, and autobiographical accounts. In addition to these rich narrative- and case study-based insights, it is important to document systemic patterns of disadvantage for students and professionals with disabilities as they manifest across the engineering profession. Accordingly, the goal of this article is to provide a high-level account of systematic interpersonal disadvantages faced by engineering students and engineering professionals with disabilities. Although quantitative assessments of disadvantage that compare the experiences of marginalized groups with their otherwise similar majority group peers are sometimes culturally perceived as more "convincing" in policy debates about organizational and structural change, this study should be understood as an important companion to qualitative and phenomenological narratives of lived experiences, not a replacement for them (Garcia et al., 2018; Kellam & Jennings, 2021). Additionally, my use of quantitative analyses and demographic categories is not meant to uncritically align with positivist understandings of statistical analysis as perfect reflections of reality or to reify socially constructed categories (Gillborn et al., 2018). I align with reflexive QuantCrit approaches to quantitative methods that aim to "chart the wider structures within which individuals live their everyday experiences and to highlight the structural barriers and inequalities" that differently (dis)advantaged groups navigate (Gillborn et al., 2018, p. 160).

Furthermore, while this study focuses on experiences of interpersonal bias, it is important to recognize that, co-occurring with these potentialities for negative treatment, symbolic meanings entwined with disability are often expressed and experienced as positive, self-efficacious senses of identity that are foundational for disability community subcultures (e.g., ASL Deaf community connections through shared linguistic and cultural similarities) (Brown, 2021; Dolmage, 2017; Kutner, 2007). Such subcultures work to suppress deficit-based narratives and advocate for the inclusion of people with disabilities in policy and social change conversations (Chua et al., 2019; Kutner, 2007; McCall et al., 2020).

[5]Following prior work (Cech, 2022), I conceptualize social inclusion and exclusion, and professional respect and devaluation, as spectrums of experiences within interactional environments. Both are assessed relationally, such that systematically lower reports of inclusionary treatment among one group compared to others indicates that the former group is more likely to experience exclusion.

2.2.1 | Positionality statement

I conduct this research as a white, queer, cisgender woman with training in sociology and engineering who does not currently experience physical disabilities, chronic illness, or mental health issues, but who experienced past periods of mental health difficulties, especially as an undergraduate engineering student. My professional motivation to investigate potential bias faced by engineers and engineering students with disabilities is rooted in my broader commitment to understanding and documenting structural and cultural mechanisms of inequality in engineering specifically and STEM broadly. I am personally motivated to conduct this research because my maternal grandmother, who lost her sight as a result of a degenerative disease, was excluded from the technical work of her employer, and then excluded from employment altogether, on the basis of her visual impairment.

3 | METHODS

The analyses below utilize two datasets: a survey of students from eight US engineering programs and a survey of engineers employed in the United States who are members of 21 STEM-related professional societies. Both surveys contain questions capturing experiences of social in/exclusion, (dis)respect, and persistence intentions that are tailored to the school or workplace context as appropriate.

3.1 | Survey of engineering students: American Society for Engineering Education-Diversity and Inclusion Survey

The American Society for Engineering Education-Diversity and Inclusion Survey (ASEE-DIS) includes data from 1729 students enrolled in one of eight US engineering programs (PIs: Stephanie Farrell, Rocio Chavela Guerra, Erin Cech, Tom Waidzunas, and Adrienne Minerick). Engineering programs were recruited into the study via a survey of engineering deans and program directors. In Fall 2015, researchers sent survey invitations to all deans and program directors affiliated with ASEE's Engineering Deans' Council and Engineering Technology Council. Ninety deans and program directors participated in the survey (response rate: 23%). From the subsample of deans who were willing to allow the research team to administer a survey to their undergraduate engineering students, the team selected eight programs that varied in size, geographic region, funding structure, and target student population. Specifically, the sample includes students enrolled in engineering programs at a small private college, a midsized public school, and a large public university in the northeast; a midsized public school and a small technical school in the midwest; a small catholic school in the west; and two large public universities in the south. To protect respondent confidentiality, the names of the schools included in the study are not provided. The ASEE-DIS was approved by the IRBs at each principal investigator's institution.

The ASEE-DIS asked undergraduate engineering students a range of questions about their experiences with engineering peers, their thoughts about the engineering profession, and their future career plans. The school-specific sample sizes ranged from 82 students (School No. S101) to 909 students (School No. S109). Response rates ranged from 4% to 45%, with an average response rate of 16.5%.[6] Although 2575 students began the survey, I use the 1729 respondents who passed the attention filters. Attention filters significantly improve the quality of the data by excluding respondents who did not carefully attend to the questions. For example, the survey included a check that was worded as follows: "As a consistency check, please choose 'Almost every day' for this question." Respondents who chose something other than "almost every day" for this response were coded as having failed the attention filter. I ran supplemental analyses with the full sample without the filters and this produced the same patterns of significance.

Given that an engineering program's participation in the study required the dean of that program to at least nominally support the goals of the study, I suspect that the leadership—and subsequently the programs included in the study—are more committed to diversity and inclusion efforts on average than is typical in US engineering programs. As a result, the patterns of disability status disadvantages documented here may be conservative estimates of patterns in US engineering education more broadly.

[6]Approximate response rate [RR] by school: School S101: n=82, RR=18%; School S108: n=233, RR=7%; School S109: n=909, RR=45%; School S110: n=128, RR=4%; School S114: n=215, RR=30%; School S116: n=290, RR=7%; School S117: n=620, RR=11%; School S120=98, RR=8%.

3.2 | Survey of engineering professionals: STEM Inclusion Study survey

My analysis of the experiences of employed engineers uses data from a survey of STEM professionals who were members of one of 21 STEM professional societies (PIs: Erin Cech and Tom Waidzunas). The names of these societies are not specified to protect respondent confidentiality; they include five national flagship disciplinary societies in engineering, eight national flagship disciplinary societies in the natural and physical sciences and mathematics, two interdisciplinary STEM societies, three teaching-focused STEM societies, and two demographic-focused professional societies. Over 25,000 full-time STEM professionals participated in the survey, including over 8000 employed engineers. Working with professional society leadership, the research team distributed the survey to either the entire population of the US-based employed membership of each society or, for larger societies, a random sample of members. Surveys were fielded between winter 2017 and spring 2019. The average response rate was 20.1%, which is typical of surveys in the workforce (NSSE, 2016). The STEM Inclusion Study (SIS) survey was approved by the IRBs at each principal investigator's institution. Respondents could end the survey at any time and participation was voluntary.

The SIS survey asked respondents a variety of questions about the climate in their workplace, their experiences with colleagues, and their future plans. The measures used in this analysis are either replications of existing validated survey items or items designed and pre-tested by the research team (Cech, 2022). The survey included skip logics that could accommodate retired members, student members, and members who worked in non-STEM jobs; the analyses here only include data from respondents who were employed full-time in an engineering job in the United States at the time of survey participation ($n = 8231$).

3.3 | Operationalization

3.3.1 | Disability measures

Consistent with the social relational model of disability, which centers respondents' experiences in their environments, disability status is assessed in both surveys with questions that ask about respondents' physical, mental health, and chronic illness restrictions.[7] Specifically, questions in both the ASEE-DIS and SIS surveys asked respondents whether they experienced any of the following: "vison difficulties beyond what can be corrected by eyeglasses or contacts"; "hearing difficulties beyond what can be corrected with hearing aids"; "speaking difficulties"; "walking difficulties"; "chronic illnesses"; or "mental health difficulties" (respondents could mark all that apply) or "none of the above." I present the means for each of these items in Tables 1 and 2. Measures of learning disabilities or neurodiversity were not available in these surveys. For the remainder of the analysis, and to protect confidentiality for groups that are especially small in number, I recoded these into three categories: experiencing *physical disability*, which includes hearing, vision, speaking, and walking difficulties; *chronic illness*, a single-item measure indicating whether respondents reported experiencing chronic illness, and *mental illness*, a single-item measure indicating whether respondents reported experiencing mental health difficulties. Supplemental analysis conducted separately for hearing, vision, speech, and walking difficulties indicated that the patterns for these disaggregated measures were consistent with those for the aggregated physical disability measure.

3.3.2 | Social inclusion measures

Each survey included two social inclusion measures tailored to the context of that population. In the ASEE-DIS, one measure asked, "how accepted do you feel by the following: students in your engineering/engineering technology classes" (1 = not accepted at all to 4 = very accepted). The second measure asked how frequently the students "stayed home from school because you did not feel welcome" (1 = never to 4 = at least once per week). Student social inclusion measures were adopted to the engineering context from student inclusion and exclusion measures from NCES' Educational Longitudinal Survey (2022).

[7]As Blaser and Ladner (2020) note, although questions that explicitly ask respondents whether they identify as having disabilit(ies) allow for more direct identification of disability status, such measures can strongly underestimate disability prevalence because of the social stigma of the label "disabled."

TABLE 1 Means and standard deviations for disability status and demographic and subfield measures for engineering students (ASEE-DIS data, $n = 1729$).

Variable	Mean	SD
Physical disability	0.112	0.315
Vision difficulties	0.088	0.283
Hearing difficulties	0.007	0.083
Speaking difficulties	0.024	0.153
Walking difficulties	0.008	0.092
Chronic illness	0.029	0.169
Mental illness	0.089	0.285
Women	0.330	0.470
Men	0.661	0.319
Gender nonbinary	0.009	0.091
White	0.800	0.400
Latinx	0.040	0.197
Asian	0.149	0.357
Black	0.034	0.181
Native American	0.015	0.123
Another race/ethnicity	0.019	0.136
LGBTQ	0.084	0.228
Socioeconomic background	2.559	1.265
First generation college student	0.156	0.036
Aerospace engineering	0.046	0.210
Chemical engineering	0.121	0.326
Electrical and computer engineering	0.173	0.378
Mechanical engineering	0.304	0.460
Biological engineering	0.064	0.244
Industrial engineering	0.044	0.205
Other engineering specialty	0.248	0.390

Note: Means and standard deviations among engineering students from the ASEE-DIS. Respondents could select more than one race/ethnicity and could identify with more than one form of disability. Men's and women's gender categories include both cisgender and transgender respondents.
Abbreviations: ASEE-DIS, American Society for Engineering Education-Diversity and Inclusion Survey; LGBTQ, lesbian, gay, bisexual, and/or transgender; SD, standard deviation.

In the SIS survey, engineering professionals were asked the extent to which they agree that "overall, I feel I 'fit in' with other people in my workplace" (1 = strongly disagree to 5 = strongly agree). This measure assesses their overall sense of belonging among their co-workers. Then, to tap their experiences of social in/exclusion in collegial interactions, respondents were asked whether they agreed that "when my co-workers get together socially at lunch or after work I am usually included in the invitation" (1 = strongly disagree to 5 = strongly agree). These SIS measures were replications of social inclusion measures from SHRM's 2008 National Survey of the Changing Workforce (2008).

3.3.3 | Professional respect measures

In the ASEE-DIS data, experiences of having one's engineering work respected were measured through two questions in the context of their engineering classes: "my peers respect me for the work that I do" (1 = strongly disagree to 5 = strongly agree) and "my schoolwork is respected" (1 = strongly disagree to 5 = strongly agree). The SIS survey

TABLE 2 Means and standard deviations for disability status and demographic and subfield measures for engineering professionals (SIS data, $n = 8231$).

Variable	Mean	SD
Physical disability	0.072	0.163
Vision difficulties	0.047	0.197
Hearing difficulties	0.010	0.098
Speaking difficulties	0.003	0.054
Walking difficulties	0.018	0.114
Chronic illness	0.065	0.225
Mental illness	0.040	0.164
Women	0.232	0.422
Men	0.761	0.437
Gender nonbinary	0.008	0.019
White	0.780	0.414
Latinx	0.074	0.261
Asian	0.101	0.302
Black	0.021	0.143
NAAPI	0.010	0.100
Another race/ethnicity	0.022	0.197
LGBTQ	0.032	0.177
University/college employment sector	0.210	0.407
For-profit employment sector	0.539	0.499
K–12 employment sector	0.002	0.050
Other employment sector	0.239	0.426
Highest degree	0.674	0.469
Average age	48.211	13.746
Aerospace engineering	0.149	0.356
Chemical engineering	0.095	0.293
Civil engineering	0.123	0.329
Industrial engineering	0.029	0.166
Electrical and computer engineering	0.034	0.181
Mechanical engineering	0.174	0.379
Biological engineering	0.011	0.028
Materials science and engineering	0.064	0.244
Other engineering specialty	0.355	0.256

Note: Means and standard deviations among engineering professionals from the SIS survey. Respondents could select more than one race/ethnicity and could identify with more than one form of disability. Men's and women's gender categories include both cisgender and transgender respondents.
Abbreviations: LGBTQ, lesbian, gay, bisexual, and/or transgender; NAAPI, Native American and Pacific Islander; SD, standard deviation; SIS, STEM Inclusion Study.

asked similar questions about the respect engineers received from their colleagues: whether they agree that "my colleagues treat me as an equally skilled professional" and that "my work is respected" (1 = strongly disagree to 5 = strongly agree). These professional respect measures were developed and pretested for the SIS survey using cognitive interviews and content validity testing with a panel of substantive experts. Refer to Cech (2022) for details on reliability and validity testing. These same measures were adapted for engineering student populations for the ASEE-DIS.

3.3.4 | Persistence measures

Finally, students and professionals were asked questions related to their intentions to stay or leave their engineering pathway or their current engineering job. Engineering students in the ASEE-DIS were asked "how likely is it that you will be an engineer in five years?" (1 = very unlikely to 5 = very likely). This ASEE-DIS measure is a replication of the persistence intentions measure from Cech et al. (2011).

Tapping into their considerations of leaving their engineering job, SIS respondents were asked how frequently they have "thought about leaving your current job" (1 = never to 5 = almost every day). This measure of turnover intentions is a replication of the measure used in the 2008 National Survey of the Changing Workforce. Because this question does not assess respondents' persistence in engineering specifically, I conduct supplemental analyses controlling for engineers' satisfaction with their job ("overall, how satisfied are you with your job," 1 = very unsatisfied to 5 = very satisfied) to understand whether there are differences in intentions to leave one's engineering work by disability status even among people who are similarly satisfied with their job.

3.3.5 | Controls

ASEE-DIS data

Several controls for demographic characteristics are included in the engineering student models. I control for racial/ethnic category(ies) students identify with (respondents could choose multiple): Hispanic/Latinx, Black, Asian, Native American or Pacific Islander, white, and other racial/ethnic category (1 = yes, 0 = no); self-reported socio-economic status (SES): "what would you say is the economic class of your family growing up": "working class" = 1, "lower-middle class" = 2, "middle class" = 3, "upper-middle class" = 4, "upper class" = 5; and whether respondents are first-generation college students—specifically, students were asked, "Are you the first person in your immediate family (parents/guardians, siblings) to attend college?" (1 = yes, 0 = no). I measured gender with a question asking: "how do you currently describe yourself": "Male," "Female," "Transgender Male," "Transgender Female," "Something else," or "I don't know how to answer." Respondents who answered as male or transgender male were coded as men, those who answered female or transgender female were coded as women, and those who indicated "something else" or "I don't know how to answer" were coded as gender nonbinary. I also include a measure of whether respondents identify as lesbian, gay, bisexual, and/or transgender (LGBTQ) (1 = yes, 0 = no). Refer to Cech and Rothwell (2018) for detailed information on LGBTQ status and gender identity variable construction. Each model also includes indicators for students' engineering subfield (aerospace engineering, chemical engineering, civil engineering, mechanical engineering, electrical and computer engineering, bioengineering, industrial engineering, or other) and an indicator for which of the eight schools students were enrolled in.

SIS data

Models using the SIS data include a number of demographic controls: race/ethnicity (respondents could choose multiple): Hispanic/Latinx, Black, Asian, Native American/Pacific Islander, white, and other racial/ethnic category (1 = yes, 0 = no); age (in years); and whether respondents were born outside of the United States (1 = yes, 0 = no). I included measures of respondents' gender identity (measured in the SIS survey the same way as in the student data: women [including cisgender and transgender-identifying women], men [cisgender and transgender], and gender nonbinary), and for LGBTQ status (1 = yes, 0 = no). Refer to Cech and Waidzunas (2021) for a detailed description of the coding of LGBTQ status. The models also control for respondents' employment sector (university/college, for-profit, non-profit, K–12, or other); their highest degree (0 = BS, 1 = masters, 2 = PhD); engineering subfield (aerospace engineering, chemical engineering, civil engineering, mechanical engineering, electrical and computer engineering, bioengineering, industrial engineering, materials science and engineering, and other); and indicators for the professional society from which respondents were recruited.

3.4 | Analytic approach

Tables 1 and 2 present the means and standard errors on each measure for the engineering students in the ASEE-DIS data and the engineering professionals in the SIS data, respectively. To produce the bar graphs in Figures 1–6, I used ordinary least squares (OLS) regression models to predict each of the outcome variables with disability status and the controls listed above (Gordon, 2020). OLS regression models help assess differences in experiences by disability status while accounting for variability along other axes. To account for the distribution of students by school, and of engineers

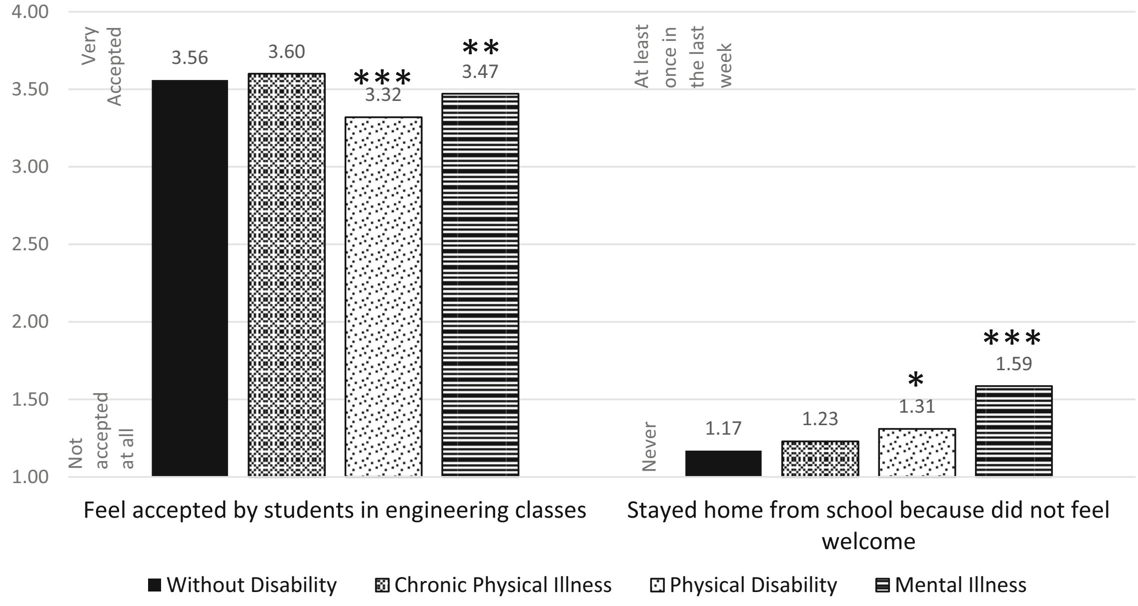

FIGURE 1 Engineering students' experiences of social inclusion. Predicted means on experiences of social inclusion for each category, holding constant variation by demographics, subfield, school, and other controls listed in Table 1. Values produced by margins command following ordinary least squares regression models predicting each outcome. Asterisks indicate significant variation from respondents without disabilities. Both measures use a 1 to 4 scale. ***$p < .001$; **$p < .01$; *$p < .05$. American Society for Engineering Education-Diversity and Inclusion Survey data, $n = 1729$.

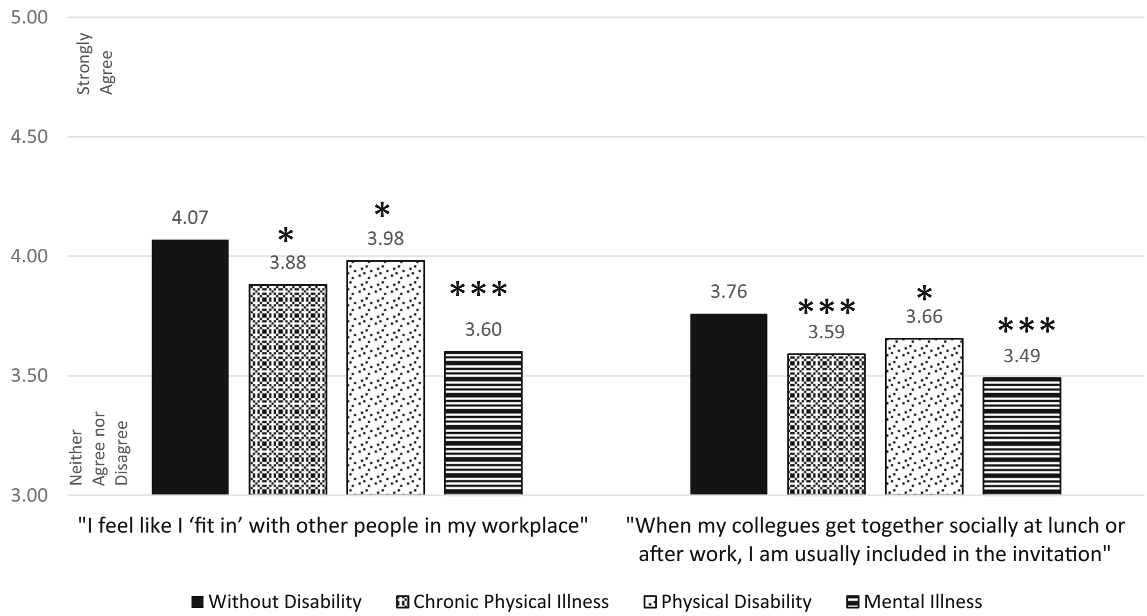

FIGURE 2 Engineering professionals' experiences of social inclusion. Predicted means on experiences of social inclusion for each category, holding constant variation by demographics, subfield, professional society, and other controls listed in Table 2. Values produced by margins command following ordinary least squares regression models. Asterisks indicate significant variation from respondents without disabilities. ***$p < .001$; **$p < .01$; *$p < .05$. STEM Inclusion Study survey data, $n = 8231$.

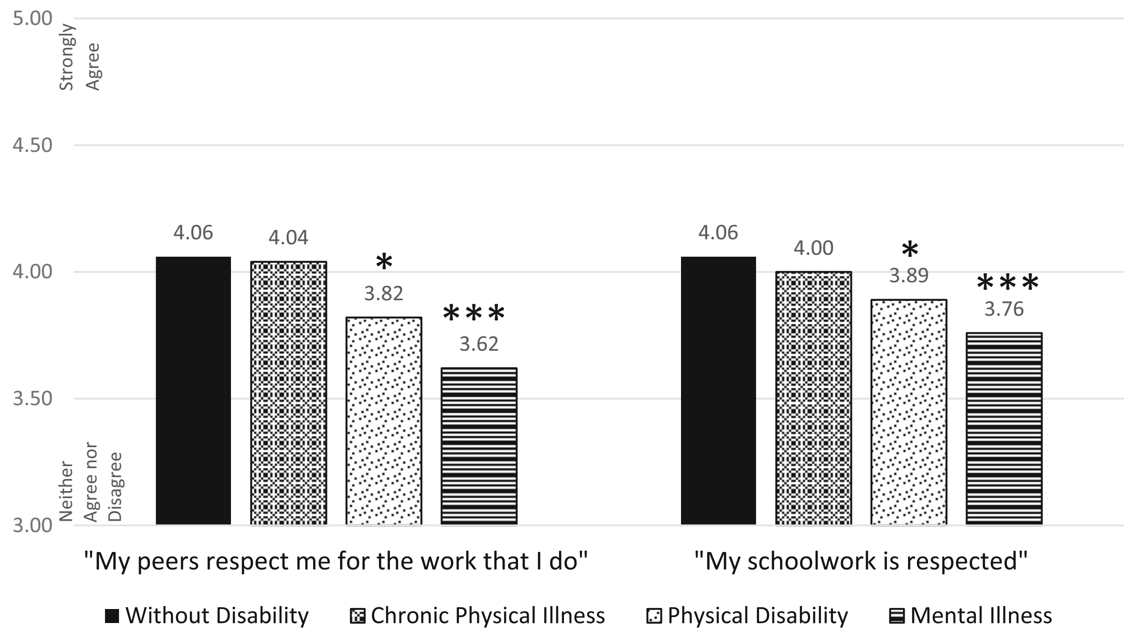

FIGURE 3 Engineering students' experiences of professional respect. Predicted means on professional respect measures for each category, holding constant variation by demographics, subfield, school, and other controls listed in Table 1. Values produced by margins command following ordinary least squares regression models predicting each outcome. Asterisks indicate significant variation from respondents without disabilities. ***$p < .001$; **$p < .01$; *$p < .05$. American Society for Engineering Education-Diversity and Inclusion Survey data, $N = 1729$.

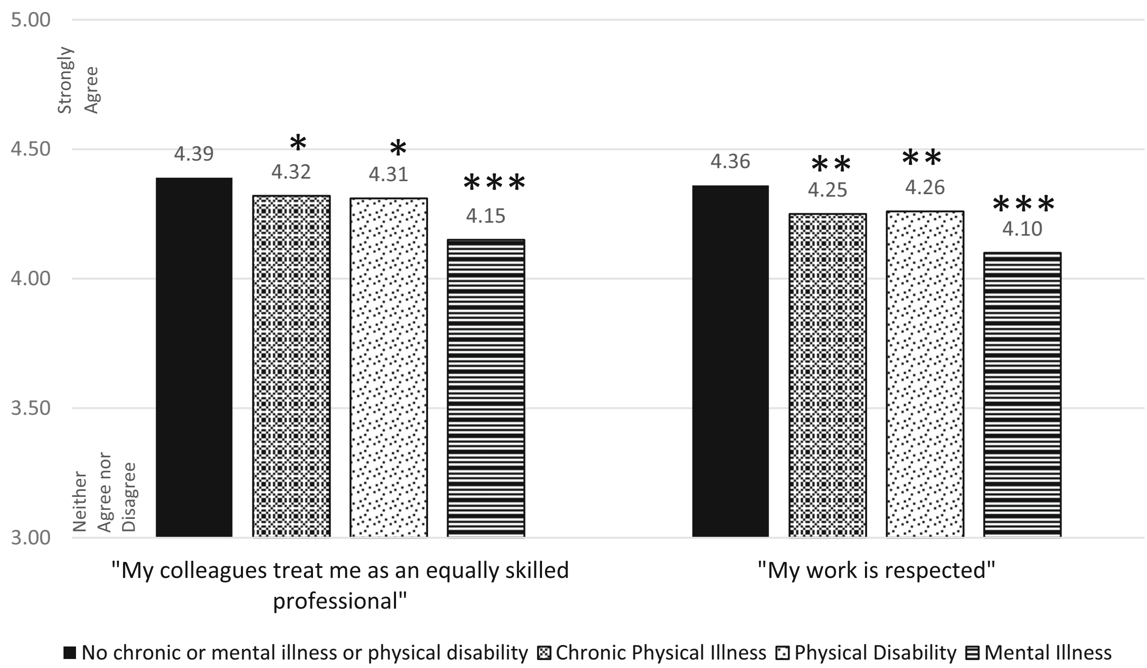

FIGURE 4 Engineering professionals' experiences of professional respect. Predicted means on professional respect measures for each category, holding constant variation by demographics, subfield, professional society, and other controls listed in Table 2. Values produced by margins command following ordinary least squares regression models. Asterisks indicate significant variation from respondents without disabilities. ***$p < .001$; **$p < .01$; *$p < .05$. STEM Inclusion Study survey data, $n = 8231$.

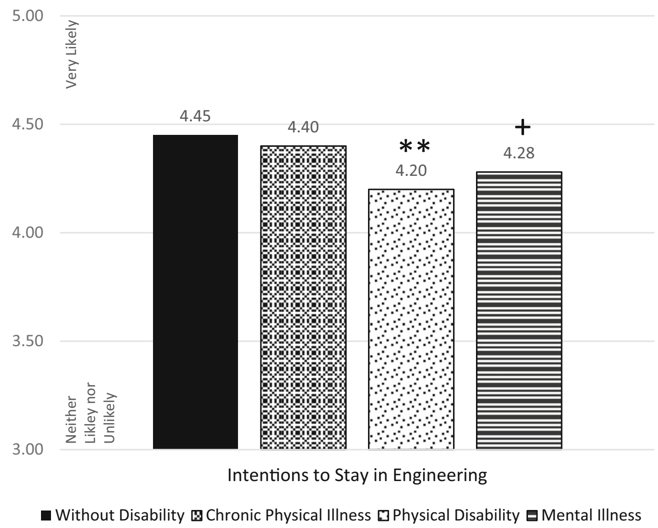

FIGURE 5 Engineering students' intentions to stay in engineering. Predicted means on intentions to stay in engineering for each category, holding constant variation by demographics, subfield, school, and other controls listed in Table 1. Values produced by margins command following ordinary least squares regression models predicting each outcome. Asterisks indicate significant variation from respondents without disabilities. $^{+}p < .10$; $^{**}p < .01$. American Society for Engineering Education-Diversity and Inclusion Survey data, $n = 1729$.

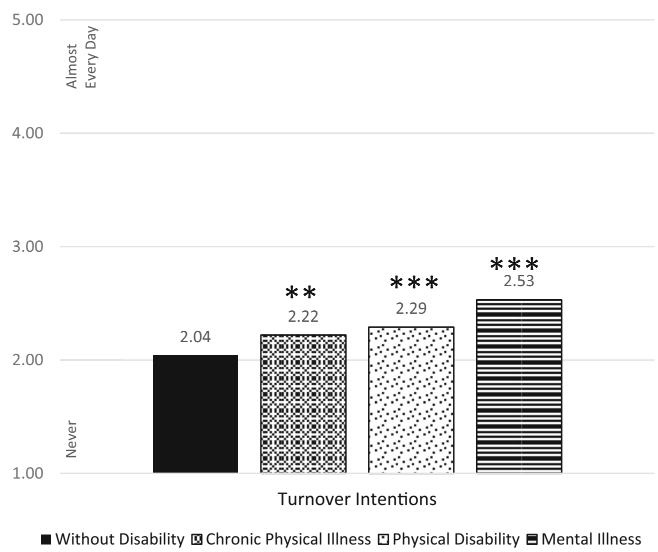

FIGURE 6 Engineering professionals' frequency of thinking about leaving their job. Predicted means on the frequency of thinking about leaving one's engineering job for each category, holding constant variation by demographics, subfield, professional society, and other controls listed in Table 2. Values produced by margins command following ordinary least squares regression models. Asterisks indicate significant variation from respondents without disabilities. $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$. STEM Inclusion Study survey data, $n = 8231$.

by professional society, models include controls for the school and professional society, respectively, from which respondents were recruited.[8] To avoid potential multicollinearity issues, OLS regression models were run separately with one disability status indicator at a time.[9]

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[8]Because the number of schools and professional societies is below the standard threshold of 25 for appropriate use of hierarchical modeling approaches (Gill & Torres, 2020), I use controls for each school/society in the models. Alternative models ran with robust standard errors clustered by school and society produced the same patterns of results as those presented here.

[9]Specifically, the VIF of chronic illness is above the threshold of five in several models with all three indicators of disability status. As noted in the discussion, this suggests the need for further research into how the co-occurrence of multiple forms of disability shape engineers' educational and work experiences.

The bars themselves represent predicted means for respondents with physical disabilities, respondents with chronic illness, respondents with mental illness, and respondents who did not report any of these, holding all other axes of variation constant. The significance of each disability status measure is based on the coefficient estimates produced by the OLS regression models and is indicated by asterisks above each bar (two-tailed tests; $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$). To produce these values, I used OLS regression models to predict the outcome measure with the focal disability status indicator and controls listed above. Margin values were calculated from the resulting regression equations for people with or without the focal disability category, holding the values for all other control measures at their mean. While the raw averages for each subgroup show the same patterns as the predicted means in Figures 1–6, raw averages are more difficult to interpret because of the potential confounding variation by other demographic measures, engineering subfields, etc. As such, I present predicted means that control for possible variation along these potentially confounding factors. Respondents with more than one category of disability are represented by the combination of relevant bars. As recommended, I used multiple imputation (the MI chained technique in Stata 16 with 20 imputations) to handle missing data (Allison, 2002).

I assess potential intersectional variability in these patterns by disability status. Specifically, I reran the OLS models for each outcome with interaction terms between gender and disability status (e.g., women × physical disabilities, gender nonbinary × physical disabilities) (Cho et al., 2013). I then reran the models with interaction terms between each racial/ethnic category and disability status and then with interaction terms between disability status and SES and age. To assess possible subfield variation, I ran all models with interaction terms between disability status and engineering subfield.

Finally, to test for possible mediation effects of exclusion and devaluation on the relationships between disability status and persistence intentions, I utilize structural equation modeling (SEM). SEM is a useful tool for testing whether part of the statistical relationship between two factors (i.e., disability status and persistence intentions) can be accounted for by systematic variation along a third factor (here, exclusion and devaluation) (Byrne, 2013). Tables 3 and 4 present the direct effects of disability status on persistence intentions and the indirect (mediating) effects of disability status on persistence intentions *through* each of the exclusion and devaluation measures.

4 | RESULTS

Tables 1 and 2 provide means for the disability status measures and other relevant controls for engineering students (ASEE-DIS data) and engineering professionals (SIS data), respectively. A sizeable proportion of engineering students have some form of disability: more than 1 in 10 engineering students have a physical disability, including 9% with vision difficulties, 1% with hearing difficulties, 2% with speaking difficulties, and 1% with walking difficulties. Three percent have chronic illness. Paralleling the rising concern over mental health issues in higher education (Bork & Mondisa, 2022; Dolmage, 2017), 1 in 11 students (9%) experience mental health difficulties. This is generally consistent with national-level data that finds that 19% of college students in the United States have some form of disability (Jensen & Cross, 2021; McCall et al., 2020).

Possibly reflecting factors related to attrition between engineering education and the engineering workforce (Pearson Weatherton et al., 2017), the proportion of engineers with physical disabilities is somewhat lower among professionals than students. Seven percent of engineers reported a physical disability, including 5% with vision difficulties, 1% with hearing difficulties, 0.3% with speaking difficulties, and 2% with walking difficulties. The rate of chronic illness among professional engineers is more than double that of engineering students (at 7%), which may be partly driven by the differential in average age between students and professionals and the onset of many chronic illnesses (e.g., multiple sclerosis) after age 40 (Zola, 1993). A smaller proportion of employed engineers than engineering students (4% vs. 9%) report mental health issues. This may be the result of people with mental illness being disproportionately more likely to leave engineering before entering the workforce, or that mental illness disclosure is less stigmatized among younger cohorts.

4.1 | Differential experiences of social inclusion

Figures 1–6 present bar graphs representing predicted means for engineers with chronic illness, physical disabilities, and mental illness (the patterned bars in each figure), compared to respondents who did not report any of these (solid bars). The predicted means hold constant potential variability in each outcome by engineering subfield and along the other sociodemographic controls listed in Tables 1 and 2. Asterisks represent the two-tailed significance levels of each disability status measure compared to respondents who did not report restrictions.

TABLE 3 Structural equation model coefficient estimates and standard errors (SE) for direct and indirect effects of disability status, inclusion, and respect measures on persistence intentions among engineering students (ASEE-DIS data, $n = 1729$).

	Direct effect of disability status → persistence intentions		Direct effect of inclusion or respect → persistence intentions		Indirect effect of disability status on persistence intentions via inclusion or respect measure		SRMR (S) and RMSEA (R) statistics
	Coefficient	SE	Coefficient	SE	Coefficient	SE	
Physical disabilities							
Mediators: Inclusion							
Mediator: Feel accepted	−0.294**	0.099	0.201***	0.052	−0.022⁺	0.073	$S = 0.013$ and $R = 0.034$
Mediator: Stayed home, not welcome	−0.236**	0.089	−0.122**	0.046	−0.028*	0.012	$S = 0.014$ and $R = 0.036$
Mediators: Respect							
Mediator: Classmates treat with respect	−0.242**	0.090	0.113**	0.035	−0.025*	0.011	$S = 0.013$ and $R = 0.033$
Mediator: Work is respected	−0.242**	0.090	0.141***	0.036	−0.027*	0.011	$S = 0.010$ and $R = 0.022$
Chronic illness							
Mediators: Inclusion							
Mediator: Feel accepted	−0.166	0.189	0.167**	0.054	0.003	0.017	$S = 0.015$ and $R = 0.039$
Mediator: Stayed home, not welcome	−0.012	0.172	−0.086⁺	0.051	−0.014	0.013	$S = 0.014$ and $R = 0.035$
Mediators: Respect							
Mediator: Classmates treat with respect	−0.019	0.172	0.100**	0.036	0.002	0.013	$S = 0.014$ and $R = 0.041$
Mediator: Work is respected	−0.011	0.171	0.151***	0.036	−0.006	0.019	$S = 0.012$ and $R = 0.029$
Mental health difficulties							
Mediators: Inclusion							
Mediator: Feel accepted	−0.173	0.107	0.182***	0.051	−0.047**	0.017	$S = 0.015$ and $R = 0.042$
Mediator: Stayed home, not welcome	−0.154	0.101	−0.105*	0.045	−0.047*	0.021	$S = 0.013$ and $R = 0.032$
Mediators: Respect							
Mediator: Classmates treat with respect	−0.158	0.022	0.096**	0.034	−0.043*	0.017	$S = 0.014$ and $R = 0.039$
Mediator: Work is respected	−0.142	0.099	0.145***	0.036	−0.049**	0.016	$S = 0.011$ and $R = 0.024$

Note: ***$p < .001$; ** $p < .01$; * $p < .05$; $^{+}p < .10$ (two-tailed test); Each row represents coefficients from a separate structural equation model. All models include standard controls for gender, race/ethnicity, first-generation status, SES, and school. Indirect effects are calculated as $A * B$, where $A =$ the direct effect between disability status and the inclusion/respect measure, and $B =$ the direct effect between the inclusion/respect measure and persistence intentions. Fit statistics: SRMR (standardized root mean squared residual) is a standardized measure of the average squared difference between the residuals of the sample covariances and the residuals of the estimated covariances. An SRMR of less than 0.08 is considered a good fit (Hooper et al., 2008). The RMSEA (root mean square error of approximation) is also provided for context, but it is important to note that RMSEA favors parsimonious models. Because the models used here maximize the inclusion of measures to control for potential conflating factors rather than seeking to maximize parsimony, RMSEA is a less informative measure of fit. Abbreviations: ASEE-DIS, American Society for Engineering Education-Diversity and Inclusion Survey; SES, socio-economic status.

Figure 1 presents the means for the two social inclusion measures among engineering students in the ASEE-DIS survey. The first set of bars presents results for the question assessing whether students feel like they are included by their peers. Here, there are clear differences by disability status: compared to their otherwise similar peers in their

TABLE 4 Structural equation model coefficient estimates and standard errors (SE) for direct and indirect effects of disability status, inclusion, and respect on turnover intentions among engineering professionals (SIS data, $n = 8231$).

	Direct effect of disability status → intentions to leave		Direct effect of inclusion or respect → intentions to leave		Indirect effect of disability status on intentions to leave via inclusion or respect measure		SRMR (*S*) and RMSEA (*R*) statistics
	Coefficient	SE	Coefficient	SE	Coefficient	SE	
Physical disabilities							
Mediators: Inclusion							
Mediator: Feel like “fit in”	0.092**	0.028	−0.244***	0.008	0.028***	0.006	$S = 0.032$ and $R = 0.106$
Mediator: Included in social activities	0.098**	0.029	−0.102***	0.007	0.012***	0.003	$S = 0.017$ and $R = 0.054$
Mediators: Respect							
Mediator: Treated as equally skilled professional	0.089***	0.007	−0.232***	0.009	0.025***	0.005	$S = 0.029$ and $R = 0.094$
Mediator: Work is respected	0.078**	0.028	−0.305***	0.009	0.041***	0.008	$S = 0.036$ and $R = 0.119$
Chronic illness							
Mediators: Inclusion							
Mediator: Feel like “fit in”	0.113***	0.030	−0.243***	0.008	0.040***	0.006	$S = 0.032$ and $R = 0.105$
Mediator: Included in social activities	0.123***	0.030	−0.103***	0.007	0.014***	0.003	$S = 0.017$ and $R = 0.054$
Mediators: Respect							
Mediator: Treated as equally skilled professional	0.115***	0.029	−0.232***	0.009	0.032***	0.005	$S = 0.029$ and $R = 0.094$
Mediator: Work is respected	0.114***	0.029	−0.305***	0.009	0.042***	0.007	$S = 0.036$ and $R = 0.119$
Mental health difficulties							
Mediators: Inclusion							
Mediator: Feel like “fit in”	0.346***	0.037	−0.239***	0.008	0.124***	0.009	$S = 0.031$ and $R = 0.104$
Mediator: Included in social activities	0.404***	0.007	−0.101***	0.007	0.025***	0.004	$S = 0.016$ and $R = 0.053$
Mediators: Respect							
Mediator: Treated as equally skilled professional	0.377***	0.038	−0.228***	0.009	0.079***	0.007	$S = 0.028$ and $R = 0.093$
Mediator: Work is respected	0.373***	0.037	−0.302***	0.009	0.109***	0.009	$S = 0.035$ and $R = 0.118$

Note: $^{***}p < .001$; $^{**}p < .01$; $^{*}p < .05$; $^{+}p < .10$ (two-tailed test); Each row represents coefficients from a separate structural equation model. All models include standard controls for gender, race/ethnicity, sector, engineering subfield, and professional society. Indirect effects are calculated as $A * B$, where A = the direct effect between disability status and the inclusion/respect measure, and B = the direct effect between the inclusion/respect measure and turnover intentions. Fit statistics: SRMR (standardized root mean squared residual) is a standardized measure of the average squared difference between the residuals of the sample covariances and the residuals of the estimated covariances. An SRMR of less than 0.08 is considered a good fit (Hooper et al., 2008). The RMSEA (root mean square error of approximation) is also provided for context, but it is important to note that RMSEA favors parsimonious models. Because the models used here maximize the inclusion of measures to control for potential conflating factors rather than seeking to maximize parsimony, RMSEA is a less informative measure of fit.
Abbreviation: SIS, STEM Inclusion Study.

engineering departments, engineering students with physical disabilities and students with mental illness were less likely to say that they feel accepted by their classmates. Similarly, students with physical disabilities and mental illness were significantly more likely than their peers to report that they stayed home from school because they did not feel welcome. Presented another way, while 11% of students without these forms of disability reported staying home from school at some point in the last year because they did not feel welcome, 21% of students with physical disabilities and

35% of students with mental illness did so. There were no significant differences by chronic illness in inclusion experiences among the students in this sample.

Similar social exclusion is evident among engineering professionals in the SIS survey. As indicated by Figure 2, there are significant and negative effects for all three disability status indicators on both measures of social inclusion. Specifically, engineers with chronic illness, physical disability, and mental illness were less likely to report that they feel they fit in with their colleagues and that they are included in social activities, compared to engineering professionals without these disabilities. For instance, 12% of engineers with physical disabilities, 15% of engineers with chronic illness, and 25% of engineers with mental illness reported that they do not feel accepted by their colleagues, compared to only 9% of other engineers.

In sum, these analyses indicate that, compared to their otherwise similar peers, engineers with disabilities were significantly less likely to experience social inclusion in their education programs and workplaces.

4.2 | Differential experiences of professional respect

The disadvantages that people with disabilities may face in engineering are not limited to social inclusion. Figure 3 presents results from the two measures of professional respect among engineering students. Here again, students with physical disabilities and mental illness were significantly less likely to report that they are perceived by their peers as equally skilled students and that their engineering work is respected, compared to other classmates in the same engineering programs. For example, 10% of students with physical disabilities and 15% of students with mental illness disagreed that their work is respected, compared to only 4% of their peers.

Figure 4 presents the results from similar items among engineering professionals. Engineers with chronic illness were marginally less likely than engineers without disabilities to report that they are perceived as equally skilled engineers and were significantly less likely to say that their work is respected. As with students, engineering professionals with physical disabilities and mental illness were less likely than their peers to report that they were perceived as equally skilled professionals or that their work is respected (net of variation by sector, subfield, and other demographics). Among these engineering professionals, 9% of those with physical disabilities, 10% of those with chronic illness, and 15% of those with mental illness disagreed that their peers respect their work, compared to only 5% of other respondents.

4.3 | Exclusion, devaluation, and differential persistence intentions

The final two figures present results on respondents' intentions to stay or leave engineering in the future. Figure 5 provides means on the likelihood that students intend to be an engineer in 5 years. Here, persistence intentions were significantly lower among students with physical disabilities and marginally significantly lower among students with mental illness, compared to their classmates. For instance, 70% percent of engineers without physical disabilities or mental illness said they were very likely to be an engineer in 5 years, compared to only 60% of students with physical disabilities and 59% of those with mental illness.

Figure 6 presents the turnover intentions measure for the sample of employed engineers. Engineering professionals in the SIS were asked how often they think about leaving their job. Engineers with chronic illness, physical disabilities, and mental illness thought about leaving their jobs significantly more frequently than their otherwise similar peers. For instance, a third of those with physical disabilities and chronic illness, and a full 50% of those with mental illness, had thought about leaving their engineering job sometime in the last month, compared to only 25% of their peers. As above, these figures present predicted means that hold constant variability across a variety of other demographic and job-related controls.[10]

The SIS survey did not include an analogous question to the ASEE-DIS asking about respondents' intention to stay in engineering. It could be something about their specific job tasks or organizations, and not experiences as engineers, that lead respondents to intend to leave. As such, I reran the analyses testing turnover intentions among the SIS sample

[10]Across these figures, engineering students and professionals with mental illness experience the biggest disadvantages in inclusion and respect relative to engineers without disabilities. This aligns with research on ableism in the workforce broadly, which suggests that people with mental illness may face particularly acute stigmatization (e.g., Maroto & Pettinicchio, 2014).

controlling for the measure of job satisfaction. The pattern of results remained the same: even among professionals who are similarly satisfied with their jobs, engineers with disabilities think about leaving their work significantly more frequently than engineers without disabilities.

The final set of results uses mediation analysis in SEM to understand whether these differences in persistence intentions by disability status could be partly accounted for by engineers with disabilities' less access to social inclusion and professional respect in their schools and workplaces. As before, these SEMs include the same controls listed in Tables 1 and 2, along with indicators for school and professional society, respectively.

Tables 3 and 4 present results from mediation analyses in SEM for the samples of students and professionals, respectively. Specifically, the tables provide the coefficients, standard errors, and significance levels for the direct effects between disability status and the persistence intentions measures (the first column), the direct effect of inclusion and respect on persistence intentions (the second column), and the indirect effect of disability status on persistence intentions through the inclusion and respect measures (final column). The tables also provide SRMR and RMSEA fit statistics for each SEM.

In Table 3, the indirect effects of the inclusion and respect measures (the third column) are significant and negative among students with physical disabilities and students with mental illness, indicating that part of the reason that these students have lower persistence intentions than students without physical disability or mental illness is because they are less likely to encounter professional respect and social inclusion in their engineering programs.

Table 4 presents results from the mediation analysis for engineering professionals. Here, the significant indirect effects across all three disability categories (third column) indicate that part of the reason engineering professionals with physical disabilities, chronic illness, and mental illness are more likely than their peers to consider leaving their job is because they are less likely to encounter respect and inclusion at work.

Overall then, students with physical disabilities and mental illness, and professionals with physical disabilities and chronic and mental illness, encountered persistently more negative treatment by their peers than engineering students and professionals without these forms of disability. Persistence intentions were lower on average among engineering students and professionals with disabilities compared to their peers, and this was partly accounted for by their greater exposure to social exclusion and professional devaluation in their classrooms and workplaces.

4.4 | Intersectional patterns

Experiences of disability are not gender, race, class, or age-neutral (Brown, 2021; Lee, 2014). The broad patterns of relative exclusion and devaluation documented above may be experienced differently depending on gender, race/ethnicity, age, and socioeconomic background. Because disability status is entwined with other axes of disadvantage, I examine potential intersectional patterns by gender, race/ethnicity, class background, and the engineering subfield students are enrolled in using the ASEE-DIS data, and intersectional patterns among engineering professionals across gender, race/ethnicity, age, employment sector, and engineering subfield using the SIS survey data.

4.4.1 | Intersectional patterns among engineering students

To protect confidentiality, the analyses of intersectional patterns that follow aggregate students with physical disabilities and chronic illness into a single category. Because the sample of students with disabilities is small ($n = 145$), I highlight instances where interaction effects reach at least marginal statistical significance ($p < .10$) in these supplemental OLS regression models.

First, there is important variation by socioeconomic background in the experiences of engineering students with mental illness. Students with mental illness from less privileged economic backgrounds were significantly less likely than students with mental illness from wealthier backgrounds to feel accepted by peers (mental illness × class background interaction term: $B = -0.091$, $p = .024$), and more likely to have reported having stayed home from school because they did not feel welcome ($B = 0.086$, $p = .038$).

Second, although there are few systematic differences by gender in experiences of inclusion and respect for students with disabilities, my analysis uncovered important intersectional differences by race/ethnicity. Specifically, Black students with physical disabilities or chronic illness were less likely than white students with such disabilities to say that their peers respect them (Black × physical disability and chronic illness interaction term: $B = -0.615$, $p = .038$), were less likely to say that their work is respected ($B = -0.638$, $p = .033$), and were less likely to say they intend to stay in engineering ($B = -0.803$, $p = .053$).

I also find a few points of variability by engineering subfield. To assess subfield differences across the seven subfields, I aggregated all three disability categories into a single disability status indicator. In supplemental models, I added interaction terms between this disability status indicator and each of the engineering subfield indicators. Net of controls, students with disabilities enrolled in aerospace engineering were marginally more likely than students in other subfields to report that they have stayed home from school because they did not feel welcome (aerospace × disability interaction term: $B = 0.320$, $p = .052$). Students with disabilities in biological engineering were less likely than students with disabilities in other disciplines to report that their classmates treat them with respect (bioengineering × disability interaction term: $B = -0.574$, $p = .003$) and marginally less likely to say that their work is respected ($B = -0.376$, $p = .052$). This pattern is surprising, given that bioengineering typically has greater gender and race diversity than other engineering subfields (NSF 2019). It may be that bioengineering students and faculty are more likely than engineers in other subfields to adhere to a medical model of disability, which perceives disability as a biomedical characteristic of individuals rather than an outcome of social and cultural structures.

4.4.2 | Intersectional patterns among employed engineers

As with the intersectional analysis using the student data, I aggregated respondents with physical disabilities and chronic illness into a single category to assess intersectional patterns among engineering professionals. Here, I ran separate supplemental OLS regression models that included interaction terms between disability status and gender, disability status and racial/ethnic category, and disability status and age. These models included the same controls for education level, professional society, and other demographic measures listed in Table 2.

First, compared to men with physical disabilities or chronic illness, women with physical disabilities or chronic illness were less likely than men to report feeling included socially and less likely to feel respected at work (woman × physical disability or chronic illness interaction term: $B = -0.261$, $p = .002$ for social inclusion; $B = -0.132$, $p = .041$ for respect). Gender nonbinary engineers with mental health difficulties were less likely than men to say that they are seen as equally skilled professionals (gender nonbinary × mental health difficulties interaction term: $B = -0.841$, $p = .022$). Possibly reflecting stereotypes that feminize mental illness, women with mental illness were more likely than men with mental illness to feel like they are included socially among their peers (women × mental illness interaction term: $B = 0.305$, $p = .024$).

The intersectional analyses also revealed greater stigmatization of people of color with mental illness, compared to white engineers with mental illness. Specifically, Latinx engineers with mental illness were marginally more likely than white engineers with mental illness to feel that they fit in among their colleagues (Latinx × mental illness interaction term: $B = -0.403$, $p = .084$). Additionally, Black engineers with mental illness were less likely than white engineers with mental illness to report that their colleagues see them as equally skilled professionals (Black × mental illness interaction term: $B = -0.673$, $p = .038$).

Importantly, however, these intersectional patterns are not consistently additive. In particular, Black engineers with physical disabilities or chronic illness were marginally more likely than white engineers with physical disabilities or chronic illness—and more likely than Black engineers *without* physical disabilities or chronic illness—to report that they are seen as equally skilled professionals (Black × physical disability or chronic illness interaction term: $B = 0.379$, $p = .080$). Additionally, Native American and Pacific Islander (NAAPI) engineers with physical disabilities or chronic illness were marginally more likely than white engineers with disabilities or chronic illness, and NAAPI engineers without physical disabilities or chronic illness, to feel included among their peers (NAAPI × physical disability or chronic illness interaction term: $B = -0.558$, $p = .076$). Although this highlights the need for further research with more nuanced data, this may suggest forms of "intersectional freedoms" (Ridgeway & Kricheli-Katz, 2013) for people of color with disabilities in engineering, whereby disability status may counteract pervasive negative racial stereotypes of people of color as uncooperative or aggressive (Cech et al., 2018; Holly, 2020; Lord et al., 2009).

Additionally, intersectional analyses by age illustrate that older engineers with mental illness were more likely than younger engineers to report that they fit in socially with colleagues (age × mental illness interaction term: $B = 0.013$, $p = .010$). This could be related to longer career lengths which allow older engineers to establish more connections at work, or the result of the attrition of engineers with mental illness who encountered exclusion by colleagues in the past.

Further, I found sector differences in the experiences of engineers with physical disabilities and chronic illness. Specifically, engineers employed in the university sector were less likely than those employed in industry to report that their peers treat them as though they were equally skilled professionals.

Finally, I examined variation in experiences of disability acrossthe engineering subfields. As with the student data, these models aggregate the three disability forms into a single disability status indicator. Industrial engineers with disabilities were less likely than other engineers with disabilities to say that their work is respected (industrial engineering × disability interaction term: $B = -0.398$, $p = .022$), and civil engineers with disabilities were significantly more likely to intend to leave their engineering job than engineers with disabilities in other subfields (civil engineering × disability interaction term: $B = 0.294$, $p = .023$). Bioengineers with disabilities were slightly more likely to report that they fit in (bioengineering × disability interaction term: $B = 2.96$, $p = .005$) and that their work is respected ($B = 2.89$, $p = .001$), compared to other engineers with disabilities in other subfields. Other than these points of variation, the experiences of inclusion and respect and patterns of persistence intentions among engineers with disabilities were consistent across the engineering subfield.

5 | DISCUSSION

The purpose of this article was to investigate possible patterns of interpersonal inequality faced by engineers with disabilities in higher education and the labor force. Emerging research on engineers with disabilities suggests the potential for interpersonal biases such as social isolation and stigmatization. Yet there has been little systematic assessment of the experiences of people with disabilities in engineering across academic institutions and employment contexts. Like other marginalized and minoritized statuses, disability is a presumed divergence from the idealized embodiment of the "engineer" as a white, heterosexual, able-bodied, middle-class, US-born cisgender man (Cech, 2022). This research thus contributes to broader theoretical and empirical conversations in engineering education, STS, and social sciences about the extent and types of sociodemographic inequities that the profession of engineering tolerates and perpetuates.

The results above indicate that both engineering students and engineering professionals with disabilities experience engineering contexts that marginalize them socially and devalue their professional expertise more often than the experiences of their peers. Partially related to this negative treatment, engineers with disabilities consider leaving their engineering programs or engineering jobs more often than other students or professionals without these forms of disability. These outcomes are particularly notable given that ableism in K–12 and higher education may mean that students with disabilities have to be even more dedicated and hardworking to complete their training in the face of these disadvantages than students privileged by these environments (Slaton et al., 2019).

Intersectional analyses illustrated that students from working-class backgrounds, and students of color with physical disabilities and chronic illness, were particularly likely to encounter social exclusion in engineering classrooms. In the workforce, women engineers with physical disabilities were particularly isolated and devalued in the workforce compared to other women and men with physical disabilities. Gender nonbinary engineers with mental health difficulties were less likely than men with mental health difficulties to report feeling respected by colleagues. Engineers of color were especially likely to experience exclusion by colleagues when experiencing mental health difficulties, compared to white engineers with mental illness. Yet, underscoring the importance of not presuming additive consequences for people with disabilities disadvantaged along multiple axes of difference, Black and Native American and Pacific Islander engineers in the workforce with physical disabilities or chronic illness were more likely than white and Asian engineers with physical disabilities or chronic illness to feel respected and included socially among colleagues.

These patterns deserve careful attention in future research with multimethod samples that allow for a more nuanced investigation of intersectional patterns and the contextual determinants of these outcomes. Of particular importance is research that seeks to uncover the institutional, organizational, and cultural mechanisms of ableism that help perpetuate these patterns.

5.1 | Limitations

The datasets used for these analyses are beneficial in that they tap the experiences of engineering students and professionals across many engineering education and employment settings and allow for direct, systematic comparisons of the experiences of students and professionals with disabilities to their peers. The two datasets in tandem tell an important story about the consistency of these issues across engineering education and the engineering workforce because they contain similar yet context-sensitive questions about inclusion, respect, and persistence intentions.

Despite these benefits, there are several limitations of note. First, the surveys used in this research do not include measures of other dimensions of disability status such as neurodiversity or learning disabilities. Recent scholarship in engineering education has highlighted the importance of these dimensions for understanding experiences and disadvantages in engineering. A crucial next step for future research would be to assess whether similar patterns of interpersonal disadvantage documented here are encountered by, for example, engineers with autism.

Second, these data draw on confidential self-reports of physical disabilities, chronic illness, and mental health difficulties, rather than (often highly inaccurate) institutional counts (Freedman et al., 2020; Maroto & Pettinicchio, 2014). Yet, these surveys do not include direct self-identification measures of "disabled" identity. Recent scholars such as Blaser and Ladner (2020) discuss the difficulties and benefits of various ways of measuring disability status and note that each approach has tradeoffs. The measurement method used here likely includes a larger group of respondents in the disability designation than might be encompassed with a direct self-identification measure. This may be particularly the case for "vision difficulties," which may have provided an overestimation of the proportion of engineering students and professionals with vision-related disabilities. To the extent that this introduces greater variability in the operationalization of disability, it may mean that the results here are underestimations of the strength of the relationship between disability status and the likelihood of encountering interpersonal bias. Additionally, while it is difficult to assess individuals' personal experiences of interactional environments via surveys without the use of self-report measures (Wolf et al., 2016), these self-reports are not paired with researcher observations of interactional environments. Relatedly, these cross-sectional datasets cannot trace patterns over time. I suspect there are iterative relationships between, for example, experiences of social isolation and mental illness, especially among students (Dolmage, 2017). The surveys also did not ask directly about respondents' needs for and access to adjustments to work or learning environments. Related, the analyses here assess the impact of one form of disability at a time. Future research is needed to understand engineers' experiences of multiple forms of disability simultaneously, particularly with qualitative methods that allow for richer accounts of lived experiences.

Third, while the ASEE-DIS data include students from an array of engineering programs in the United States and the SIS includes representative samples of engineering professionals from 21 professional societies, neither are representative of engineering students or professional populations. And, although the sample sizes of student and employed engineers in these datasets allow for analyses of intersectional patterns across disability status by gender, race/ethnicity, class background, and subfield, due to systematic minoritization and exclusion of certain demographic groups, even these datasets do not allow for fully disaggregated assessments of intersectional experiences. To achieve both would require that data collected at the national level through entities like the National Science Foundation's National Survey of College Graduates include both detailed measures of disability and nuanced measures of interpersonal treatment.

Despite these limitations, this work makes important progress in analyzing interpersonal biases faced by populations of engineers whose experiences are too rarely incorporated into conversations about inequality and disadvantage in the profession. Future research should investigate these patterns of interpersonal treatment intersectionally with special attention to differences along multiple dimensions of disability. These are vital considerations if we are to better understand the scope and range of experiences of engineers with disabilities.

6 | CONCLUSION

> "If disability is seen as a personal tragedy, disabled people are treated as victims of circumstances. If disability is defined as a social oppression, disabled people can be seen as the collective victims of an uncaring, discriminatory society" (Oliver, 1990, p. 94).

In making sense of these findings, it is imperative that we do not interpret them, as Oliver notes, as the outcome of "personal tragedies." The social and material disadvantages that engineers with disabilities may experience within classrooms and workplaces are the product of socially constructed structural and cultural environments that deem certain physical, psychological, and intellectual characteristics as "normal" and take such characteristics as the point of reference when arranging curricula, classrooms, workplaces, labs, and communication infrastructures. Ableism is a characteristic of engineering education programs and the engineering profession the same way engineering is embedded with sexism, racism, and heteronormativity (Cech et al., 2019; Freehill, 2012; Slaton, 2013). As with other axes of sociodemographic inequality, the solution is not to meet those disadvantaged by the culture and structure of engineering with expectations for adaptation or change, but rather to address the biased structures and cultures themselves.

What can engineering programs and engineering workplaces do to address these inequities? First, at a bare minimum, legally-provided adjustments should be easy to access and de-stigmatized, and both students and faculty, and both employers and employees, should be regularly reminded of how and where they can be accessed. In engineering education specifically, reflexivity-driven training of students, staff, and faculty about ableism, particularly the privileges that people without disabilities benefit from—may help the educators and peers of students with disabilities better recognize the pressing need for altering learning infrastructures (Freedman et al., 2020; Lee, 2014; McCall et al., 2020). Universities must also allocate more resources to disability services offices than they currently do. Dolmage (2017) notes that the average annual budget for disability services offices is a miserly $257,289 per year—about one-sixth the average salary of a US college football coach. Engineering colleges and programs should consider investing in their own in-house disability services, staffed by disability specialists with particular expertise to help engineering students, staff, and faculty with disabilities navigate the specific environments (e.g., labs) of engineering courses and research settings.

wInstitutionally-sanctioned adjustments are no panacea, however. Prior research in academia and industry has found that disability services are often compliance-driven and do not necessarily prioritize advancing the success of students and employees with disabilities (Sang et al., 2022).[11] To help combat this, considerations of disability should be included in institutions' and organizations' existing diversity, inclusion, and justice paradigms. In turn, federal and institutional funders of research on broadening participation in STEM should more expansively incorporate considerations of disability status and inequality into funding opportunities.

Furthermore, colleges and employers should provide structured opportunities (e.g., employee resource groups, student groups) for students and employees with disabilities to build community and allyship and to anchor collective fronts for articulating grievances and demanding change. Further, engineering education should take seriously principles of user-centered design, considering the full range of user needs not just those deemed "typical" or "average," and professional engineering practice should see these user-centered design principles as taken-for-granted touchpoints rather than as "extra" considerations (Pearson Weatherton et al., 2017). In these efforts, it is vital that engineers with disabilities are not *designed for*, but fundamentally *designers with* (Napper et al., 2002).

More broadly, serious effort must be directed toward addressing ableism in the culture of engineering in classrooms and workplaces. Notions of "ideal" engineering students and professionals promoted in these institutions should be carefully assessed for ableist bias. If we are to fully understand the contours and mechanisms of inequality in engineering, it is vital that scholars take seriously the manifestations of ableism alongside hegemonic masculinity, sexism, racism, heteronormativity, and class bias (Slaton, 2013; Slaton et al., 2019). Ableism in engineering is rooted in engineering's very cultural definitions of competence and merit (Blair-Loy & Cech, 2022; Slaton, 2013); regardless of the changes made to physical environments and organizational practices, engineers with disabilities may not feel fully respected and included until these ableist cultural structures are dismantled and re-engineered.

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[11]For example, for engineers who manage chronic physical or emotional pain, meeting norms of excess work hours may be infeasible or impossible (Sang et al., 2022).

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