Engineering doctoral student retention and persistence from an organizational climate and intersectional perspective: A targeted review of engineering education literature

Dr. Julie Aldridge, The Ohio State University

My background and research interests are in organizational change, innovation, and leadership. My current work focuses on organizational climate to better support the retention of engineering doctoral students from diverse groups to degree completion.

Dr. Nicole M. Else-Quest, University of North Carolina at Chapel Hill

Nicole M. Else-Quest is Associate Professor and Associate Chair of Women's and Gender Studies at the University of North Carolina at Chapel Hill. A first-generation college student, Dr. Else-Quest earned her Ph.D. in developmental psychology at the University of Wisconsin—Madison. She uses a combination of quantitative and qualitative methods to understand psychological gender differences, how they develop and shape participation in STEM, and how we can intervene to expand women's and girl's participation in STEM. She has written extensively on implementing intersectionality within social sciences research and adapting quantitative as well as qualitative methods to do so. Else-Quest is currently PI on two grants from the National Science Foundation, both focused on interventions to improve girls' and women's participation and persistence in STEM education from elementary school through doctoral training. In addition to her scholarly work, she is co-author of the undergraduate textbook, Psychology of Women and Gender: Half the Human Experience+ (Sage, 2022). She is a Fellow of the American Psychological Association and is Associate Editor of the journal Stigma and Health.

Dr. Joseph Roy, American Society for Engineering Education (ASEE)

Joseph Roy has over 15 years of data science and higher education expertise. He currently directs three national annual data collections at the ASEE of colleges of engineering and engineering technology that gather detailed enrollment, degrees awarded, research expenditures, faculty headcounts, faculty salary and retention data for the engineering community. He is PI of a NSF Advanced Technological Education funded grant to build a national data collection for engineering-oriented technician degree and certificate programs at 2-year institutions. Prior to joining the ASEE, he was the senior researcher at the American Association of University Professor and directed their national Faculty Salary Survey. He also developed a technical curriculum to train analysts for a national survey of languages in Ecuador while he was at the University of Illinois as a linguistic data analytics manager and member of their graduate faculty. He has a B.S. in Computer Science & Mathematics, a M.S. in Statistics from the University of Texas at San Antonio and a Ph.D. in Linguistics from the University of Ottawa.

Dr. So Yoon Yoon, University of Cincinnati

So Yoon Yoon, Ph.D., is an assistant professor of the Department of Engineering Education in the College of Engineering and Applied Science (CEAS) at the University of Cincinnati. She received her Ph.D. in Gifted Education, and an M.S.Ed. in Research Methods and Measurement with a specialization in Educational Psychology, both from Purdue University, IN, in the United States. She also holds an M.S. in Astronomy and Astrophysics and a B.S. in Astronomy and Meteorology from Kyungpook National University, South Korea. Her work centers on engineering education research as a psychometrician, program evaluator, and data analyst, with research interests in spatial ability, creativity, engineering-integrated STEM education, and meta-analysis. As a psychometrician, she has revised, developed, and validated more than 10 instruments beneficial for STEM education practice and research. She has authored/co-authored more than 70 peer-reviewed journal articles and conference proceedings and served as a journal reviewer in engineering education, STEM education, and educational psychology. She has also served as a co-PI, an external evaluator, or an advisory board member on several NSF-funded projects.

Engineering Doctoral Student Retention from an Organizational Climate and Intersectional Perspective: A Targeted Literature Review of Engineering Education Literature

The National Science Board has declared that the long-term vitality of the U.S. workforce relies on the full range of science, technology, engineering, and mathematics (STEM) career pathways being available to all Americans. This declaration was premised on the increasing diversity in the U.S. population [1] and the need for multiple perspectives to the complex problems faced by society [2]. Thus, the National Science Foundation, the National Academies of Science, Engineering, and Medicine, the American Institutes of Research, and the Council of Graduate Schools have stated that the increased participation of women and members of racially minoritized and marginalized (RMM, including Black, Hispanic/Latinx, and Indigenous) groups in STEM is imperative to maintain the U.S. standing as a global leader in innovation. Because engineering doctoral graduates account for a large share of the innovation workforce [3], the ongoing lack of diversity in the engineering doctoral workforce remains a problem with far-reaching implications for the U.S. economy.

The 'mold' for an engineering doctoral student was created by graduate education's earliest beneficiaries: young, White, and single men. Students who fall outside this mold, including women, people of color, older people, people with children, and people with disabilities, are more likely than their traditional graduate student counterparts to report climate-related issues [4]. While some studies of university or campus-level climate for students have included doctoral students in general, few studies disaggregate findings by discipline or by demographic categories beyond gender identity and race/ethnicity. In engineering, Riley, Slaton, and Pawley's [5] observed that the engineering education research community tends to take up issues of diversity focused on "women and [racial and ethnic] minorities while queerness, class, nationality, disability, age, and other forms of difference are for the most part not seen as requiring address".

This literature review was conducted as a preliminary assessment of the available research literature produced by the engineering education community on organizational climate affecting the retention of engineering doctoral students from diverse backgrounds. We seek to understand this specific student group's retention as an organizational climate issue and use an intersectional approach to consider the meaning and relevance of students' belonging, simultaneously, to multiple social categories, such as gender identity, sexual orientation, socioeconomic background, race/ethnicity, and disability status, within the context of engineering doctoral education as a first step to building a climate survey instrument. Searches on February 2, 2023, for existing scoping reviews and systematic reviews on this topic conducted on JBI Evidence Synthesis, the Cochrane Database of Systematic Reviews, and the Campbell Collaboration did not provide results [6].

The objective of this literature review is to explore how the concept of 'climate' is being used in the context of doctoral engineering student retention, to degree completion and gather a body of evidence of climate factors. To do this, we conducted a targeted literature review and used intersectionality [7] [8] as our approach to interpreting the literature, as we aim to understand how climate affects the retention of engineering doctoral students from diverse backgrounds. In this paper, we first briefly present our understanding of organizational climate and intersectionality, then we explain our methodology followed by results, and finally discuss our analysis of the climate literature in engineering.

Organizational Climate

Organizational climate and culture are two distinct constructs used to understand how members "make sense" of their organization. While the terms climate and culture are often used interchangeably, Schneider, Ehrhart, and Macey [9] differentiate the two. Organizational climate

is concisely defined as the meanings people attach to interrelated bundles of experiences they have at work. On the other hand, organizational culture is concisely defined as the basic assumptions about the world and the values that guide life in organizations. Organizational climate research emerged mostly from scholars trained in psychological methods and originated from Lewin, Lippitt, and White [10] who first used the term “social climate” to describe the atmosphere in the group created by leaders of young campers.

Today, organizational climate is understood as *the shared perceptions of and the meaning attached to the policies, practices, and procedures employees experience and the behaviors they observe getting rewarded and that are supported and expected* [9] [11]. Research in this area examines how the social environment is experienced by the people who take part in it. Moreover, it posits that individuals, or subjects, work in a climate but they do not create it. Climate is a perceptual construct rather than an objective characteristic of an organization [12]. Organizational climate, which is an organizational science, should be conceptualized and measured as the domain-specific, shared perceptions regarding key strategic initiatives of the organization [13].

The Oxford Handbook of Organizational Psychology recommends that organizational climate research is best focused on a specific unit [13]. Without a frame of reference, respondents are left to interpret questions and may describe perceptions of any part of their work environment at any level, not necessarily what is being studied. Work levels are complex and respondents exist simultaneously in various subgroups within the larger organization, but employees can distinguish what happens in their subunit from the larger organization as a whole [13]. In a large organization like a university, it is recommended to make the department the unit of analysis because employee performance is assessed at that level [14]. For example, climate for STEM faculty persistence and engineering faculty persistence was examined at the departmental level [15][16][17][18][19]. The department level target also applies to graduate students. Disciplinary, institutional, and professional contexts converge at the department level to shape graduate student experiences [20] [21]. Furthermore, department climate is also identified as a particularly important contributor to graduate student retention and success [4][22][23].

In addition to a focus on a specific level, organizational climate research should be framed on a strategically relevant outcome and/or process (e.g., innovation, safety, motivation, diversity, and so on [24][25]). Ehrhart et al. [26] observed that the focus on strategic outcomes and processes has significantly improved not only the validity of climate research but also the understanding of the contexts in which these climates occur. The processes and/or outcomes focus can indicate specific practices and behaviors that may serve as interventions in organizations to enhance performance in those areas [9][27]. Finally, general measures of organizational climate that lack clearly defined constructs framed by a strategic interest have been categorized as useless, except for a gross description of the range of variation in an organization [11]. Therefore, we examined the engineering education literature for insight into specific climates that could promote the retention and success of engineering doctoral students from diverse underrepresented groups. We present our framework of climates identified by prior research in organizational science in Table 1.

Table 1. Selected Organizational Climates Relevant to Engineering Doctoral Student Retention

Climate	Definition	References
Diversity climate	Perceptions about the extent to which their organization values diversity as evident in the organization's formal structure, informal values, and social integration of under-represented members	[28][29]
Cultural mosaic beliefs climate: perceived cultural diversity	Perception and accurate recognition of the degree and nature of group diversity including variety in cultural values, beliefs, and practices	[30][31]
Authenticity climate	Perception that the organization encourages and provides a safe environment to express personal identities at work.	[32][33]
Psychological safety climate	Perception of how others in the workplace will respond to risk-taking behaviors such as taking initiative or speaking up about problems in the workplace	[34][35][36][37]
Psychosocial safety climate	Perceived management support and commitment to members' psychological well-being and prevention of psychological distress due to work demands and stress and level of social support from supervisors and peers	[38][39][40][41]
Work-life balance climate	Perceptions about the impact of work on personal life	[42][43][44]
Motivation: Mastery climate	Perception that efforts, sharing, and collaboration are valued, and learning and skill development are emphasized in an organization	[45][46]
Motivation: Performance climate	Perception that competition with, comparison to, and recognition from others are the standards for success.	[47][48]

Intersectionality

Broadening doctoral engineering participation among members of historically excluded groups has the potential to reduce economic inequalities. Yet initiatives to boost participation of underrepresented groups are often limited in scope and only target one group at a time, leaving out members of multiply marginalized groups [49]. For example, when considering the underrepresentation of women in STEM, White women are often the target for intervention, leaving out women of color [50]. Therefore, we adopt an explicitly intersectional approach with this project, in that we consider the meaning and relevance of students' belonging, simultaneously, to multiple social categories such as gender identity, sexual orientation, race/ethnicity, and disability status within the context of engineering doctoral education.

Intersectionality theory is credited to Crenshaw [51][52], who used it to describe the simultaneous consideration of race and gender and noted that analysis of race or gender alone or in isolation fails to capture the experiences of women of color. Yet, the concept of intersectionality originated in Black feminist theory and activism, beginning with works, such as Sojourner Truth's 1851 "Ain't I a Woman" speech and Anna Julia Cooper's *A Voice from the*

South (1892), and continued in the writings of the Combahee River Collective (1982) and others (e.g., [53][54][55]. Today, the reach of intersectionality theory extends beyond the study of Black women [56], offering an approach to understanding the complexities of human experience given inequalities tied to social categories. Thus, an intersectional approach is essential when considering doctoral engineering participation.

While the conceptualization of intersectionality theory varies somewhat across diverse theorists, scholars, and activists, there are essential shared assumptions among them. Synthesizing diverse multidisciplinary scholarship in intersectionality, Else-Quest and Hyde [8] noted that writings share the assumptions that intersectionality 1) attends to the experience and meaning of belonging to multiple social categories (e.g., gender, race/ethnicity, social class) simultaneously; 2) includes an examination of power and inequality; and 3) attends to social categories as properties of the individual as well as to the social context and thus considers those categories and their significance or salience as potentially fluid and dynamic. Thus, as both a critical theory and approach, intersectionality is fundamentally concerned with social inequality, including access to and full participation in doctoral engineering.

Purpose of the Study

This paper presents a literature review [57] that explores how organizational climate has been translated into the domain of doctoral engineering education in the U.S. and applies an intersectional approach. This targeted literature review aims to reframe information published previously by the engineering education community. Our intention is to provoke thought and discussion by presenting these studies in context of organizational science and intersectional theory [58][59]. Further, this review can keep readers updated by summarizing research, and it can challenge ways of thinking about doctoral engineering student diversity and degree completion. We note that unlike a scoping or systematic review, this literature review is not exhaustive and does not employ clearly defined criteria for the selection of articles or explicit methods for extraction and synthesis of data. Therefore, a flowchart illustrating the extraction and exclusion process is not appropriate [6]. This study's intent is to appraise previous studies and assess the current lack of knowledge to provide a rationale for future research on organizational climate in doctoral engineering [57]. Since the purpose of this paper is examine existing climate studies in engineering doctoral student retention with a critical lens, a narrative literature review is an appropriate methodology.

Method

We aimed to locate papers about department level climate and diverse doctoral engineering student retention. We also considered papers addressing diverse doctoral student persistence or attrition. First, we searched for existing scoping reviews and systematic reviews on JBI Evidence Synthesis, the Cochrane Database of Systematic Reviews, and the Campbell, which did not yield any reviews. Next, we noted that there are differences between higher education systems and doctoral studies in the U.S. and the rest of the world (e.g., in terms of cost, application process, qualifications, time to degree completion, etc. [60]). In addition, organizational climate, which is influenced by organizational culture, differs around the world [61]. Therefore, our literature search targeted the *Journal of Engineering Education* (*JEE*) and the conference proceedings of the *American Society of Engineering Education* (*ASEE*). These two sources were selected as they are the primary publication venues for engineering education scholars in the United States. We also searched the *Journal of Organizational Behavior,* which is focused on research and theory on all topics associated with organizational behavior including climate. Finally, we limited our search to papers published between January 1, 2012 and December 31, 2022, as we followed the 10-year rule of thumb in research with exceptions for seminal or foundational works [58][59].

We limited our searches to paper titles, tagged topics, and keywords. Search results that included document content such as abstracts returned hundreds and, in some cases, thousands of papers unrelated to our topics of interest. We discovered that any paper with an author who used the term *student* or *doctoral* in their role (e.g., doctoral student, graduate student) was included in search results. Similarly, searches using *PhD* captured author titles even when the search was limited to title or keyword. We consulted a university reference librarian who confirmed this search issue occurs throughout all databases and publications.

For the ASEE database, we searched titles and tagged topics. Variations of the *Doctoral student* + c*limate* combination produced no results. We then ran two separate searches, one for *doctoral student* and the other for combinations of *climate* + *student* and *climate AND student*. The *doctoral student* search returned 38 papers and the *climate* + *student OR climate AND student*' search returned nine papers. We also crosschecked by running the ASEE conference paper search through Scopus and got the same results.

The nine *student* + *climate* ASEE papers covered several climate topics. Off topic papers (i.e., climate change) were excluded. We also excluded the three papers which studied undergraduates. The two remaining papers investigated campus climate for graduate students with doctoral and masters analyzed as a monolith [62] and institutional climate in preparing doctoral students for academic careers [63]. Although neither paper exactly fit our topic of interest, we included both in the review. We screened the 38 *doctoral student* papers located in the ASEE database. This search located a paper about institutional change [64] which is included in our review. The other papers cover topics such as a sense of belonging, motivation, and identity formation. We consider these papers to be informative as the findings shed light on the experiences of engineering doctoral students, some from diverse groups, that may influence their retention to degree completion. These papers were further screened for relevancy, and Table 2 presents the papers that were included for analysis.

Finally, for the ASEE database, we searched for *doctoral* in titles and tagged topics and found 77 papers. This set of papers spanned a wide range of topics not related to our project, such as surveys of earned doctorates, candidacy exams, and establishing new programs. We also found many of the papers located in this search were included in our *doctoral stude*n*t* search; however, this search term did locate three new papers [65][66][67] that we include in our review.

In the *Journal of Engineering Education*, there were four papers with *climate i*n the title: two editorials and two about undergraduate students. There were no results for papers with *climate* as a keyword. Six papers used *doctoral* in the title, and three papers used *doctoral* as a keyword. One of these papers, Zerbe et al. [68]is included in our review.

Separate searches in the *Journal of Organizational Behavior* for *student* as a keyword and in titles produced zero results. A title search using *doctoral* also produced no results. A keyword search for *doctoral* resulted in one paper [69] and, although the study population was STEM, not limited to engineering, we included this paper in the review because it provides an example of doctoral student climate literature peer-reviewed for publication in an organizational science journal.

Results

In total, 21 papers were analyzed in our narrative review. Papers were analyzed for two key pieces. One, we searched each study's results and findings for evidence of climate-related perceptions based on our climates of interest (Table 1). Two, we checked each paper to see if an intersectional approach was applied by searching for the term *intersection* and noted each study's research design. While three of the papers we collected explicitly used some form of the term, *intersectional*, many of the other papers focused on a specific intersectional group, such as Black women doctoral students.

Overall, we found no mention or reference in the engineering education literature to any of the climates identified in organizational science literature that are relevant to member retention (see Table 1). However, we did find indications of seven climates of interest with some studies providing evidence from the perceptions from several intersectional groups. Also, most of the engineering studies that captured climate evidence were not intentionally investigating climate. Table 2 presents the papers we collected and analyzed.

Table 2. 21 Studies with Research Evidence of Climates for Engineering Doctoral Students

Was the term 'climate' used?	Climate definition given by authors	Which climates are evidenced?	Climate Evidence in Study Results or Findings	Study Population (as described by the authors)	Was 'inter-section' used?	Method	Ref
"Campus climate"	the current common patterns of important dimensions of organizational life or its members' perception of and attitudes towards those dimensions	motivation: mastery climate & performance climate	Hearing my advisor tell me I did a job well; collaborate closely with other graduate students; part of a group of graduate students who provide each other with academic support and/or encouragement.	engineering graduate students disaggregated by citizenship and race/ethnicity for US domestic students	no	survey	[62]
"Institutional climate"	4 dimensions: historical, structural, perceptual, behavioral	motivation: mastery climate;	bouncing ideas off each other; support from faculty & peers; discussing problems; asking questions;	engineering alumni and current grad students	no	mixed: interviews & survey	[63]
department climate	none provided	psychological safety climate	voicing opinions to advisors	faculty & grad students, disaggregated by race/ethnicity	no	survey	[64]
no		authenticity climate; cultural mosaic belief climate; diversity climate; mastery climate	authentic self, problems based on cultural identity, social inclusion, support, confidence,	international engineering doctoral students	no		[71]
no		authenticity climate	expressing the 'public you' vs 'private you'	Black women doctoral engineering students	yes	interviews	[72]
no		motivation: mastery climate	feedback loops to enhance communication skills and improve mentoring relationships.	doctoral engineering students, advisors, postgraduates	no	survey	[73]
no		motivation: mastery climate	seeking help, clarifying expectations, creating a supportive environment	doctoral engineering students	no	survey	[74]
no		diversity climate; cultural mosaic belief climate; motivation: performance climate	racial isolation, language isolation, stereotyped-based interactions, questioning of ability, not viewing international peers as diverse	Black engineering doctoral students, international Asian students	no	interviews	[76]
no		motivation: mastery climate and performance climate; cultural mosaic belief climate;	demonstrating academic competency through comparison to peers, asking questions, positive feedback from advisors, support from peers, interest from faculty in cultural background, support from faculty regarding personal issues	international doctoral engineering students	no	interviews	[75]

Was the term 'climate' used?	Climate definition given by authors	Which climates are evidenced?	Climate Evidence in Study Results or Findings	Study Population (as described by the authors)	Was 'inter-section' used?	Method	Ref
no		motivation: mastery climate; psychological safety climate	faculty sharing ideas; comfort in asking questions; opportunities for growth; encouragement & help in reaching goals	engineering doctoral students; faculty; postdoc	no	mixed	[77]
no		psychological safety climate; diversity climate	voicing feelings to advisor; relationships with other graduate students; social isolation	URM engineering doctoral students	no	survey	[78]
no		authenticity climate; diversity climate	code-switching; tokenism; sense of invisibility	Black women doctoral engineering students	no	interviews	[79]
no		motivation: mastery climate & performance climate	making decision with advisor; advisor sharing ideas; not being able to ask for help;	International and domestic doc engr. students	no	interviews	[80]
no		motivation: mastery climate & performance climate; psychosocial safety climate	academic gatekeeping; expressing and pursuing own research interest; peers questioning competence; isolation; "othering", microaggressions; lack of support within dept.; invisibility; hypervisibility; burnout, mental health, and well-being;	middle-class, cis-gender, able-bodied, U.S. born Asian-American man, member of LGBTQ+ community; woman and a person of color	no	autoethnography	[81]
no		motivation: mastery climate & performance climate		engineering doctoral students	no	mixed	[82]
autonomy and relationship climate	Work/lab environment climate as it relates to working with others, including the level of supervision	psychosocial safety climate; motivation: mastery & performance climate	Pressure and stress of environment; Mission and task focus; mental well-being; Becoming a resource for others	engineering doctoral students disaggregated by gender, LGBTQ race/ethnicity, (but not all results provided disaggregated)	no	interviews	[68]
no		motivation: mastery climate & performance climate; psychosocial safety climate; authenticity climate; diversity climate	intrinsic motivation; process of learning to communicate with her advisor; experiencing fatigue; mental well-being; create spaces where URM students can express their identities freely such as with other URM students	URM doctoral engineering students	yes	interviews	[67]

Was the term 'climate' used?	Climate definition given by authors	Which climates are evidenced?	Climate Evidence in Study Results or Findings	Study Population (as described by the authors)	Was 'inter-section' used?	Method	Ref
no		psychological safety climate	courage to speak up; show them what's happening; have to be the best to be considered good; "You don't look like a computer science student."; "What I'm most aware of every day is that I'm Black, I'm a woman, and I'm short."; You're bringing a lot of stuff that doesn't have anything to do with things and trying to make people understand why they do matter; hyper-visibility.	Black women doctoral engineering students	no	case study	[79]
no		authenticity climate	sense of twoness in one's self-concept that arises from seeing oneself through the eyes of both the predominantly White profession and one's own racial community.	URM doctoral STEM students	no	interviews	[69]
no		psychological safety climate; diversity climate; motivation: mastery climate & performance climate; psychosocial safety climate	biggest career challenge would be to “mak[e] sure that I can make my voice heard without being the angry Black lady or the sassy one that has an attitude.”; “I've got to prove myself; mental health; isolation, rejection, and invisibility, “Most minorities come from a very community-based and a familial background [so] that cutthroat and no-real-care-for-other-people-if-it-doesn't-directly-benefit-you [mentality is]. I think that's one of the reasons that they don't go into academia.”	engineering doctoral students, international and domestic identified by gender, race/ethnicity and nationality	yes	interviews	[83]

Was the term 'climate' used?	Climate definition given by authors	Which climates are evidenced?	Climate Evidence in Study Results or Findings	Study Population (as described by the authors)	Was 'inter-section' used?	Method	Ref
no		motivation: mastery climate & performance climate; diversity climate; cultural mosaic belief climate; psychological safety climate	Lack of belonging among other demographic groups due to multiple experiences including not being believed when they provide information on engineering topics; students from different backgrounds not being respected or treated the same; not being comfortable discussing engineering or personal topics; peers trying to exert authority.	engineering doctoral students by race/ethnicity x gender (no white men), sexual orientation, nationality, disability status	no	survey	[66]

Here we expand on the descriptions of the organizational climates related to member retention from organizational science research [see Table 1]. We then show how results and findings from the papers in this review indicate different organizational climates. The majority of these papers were not presenting climate research, and we identified climates that were not noted by the studies' authors. First, our framework includes **diversity climate** and not inclusion climate. Organizational climate researchers have found *inclusion climate* to nest inside diversity climate [28]. *Diversity climate* is defined as perceptions about the extent to which the organization values diversity as evident in the organization's formal structure, informal values, and social integration of under-represented members [28][29]. As Perry and Li [28] explained, diversity climate "is the subjective interpretation of organizational practices and programs, not the existence of these practices and programs nor the actual proportion of minority members". Furthermore, diversity climate is the property of an organization and focuses on the work environment as a whole rather than an individual's own experiences, attitudes, or beliefs [12] [28] [29]. Dwertmann et al. [29] suggested that diversity climate includes a negative and a positive aspect. A positive diversity climate impacts organizational members indirectly through reduced discrimination, exclusion, isolation, and interpersonal aggression. As researchers have explicitly stated that individual attitudes toward diversity, personal experiences, and the presence or absence of specific practices do not reflect diversity climate [28], evidence of this climate was limited to emergent themes from qualitative studies [67][75][83]. Thus, we also excluded papers based on autoethnography or findings relying on unique statements reflecting the experience of a lone participant.

Cultural mosaic beliefs climate: perceived cultural diversity [30][31] is a recent addition to the climate literature. We included it in our framework due to the high proportion of international students in engineering doctoral programs. *Perceived cultural diversity climate* is defined as how well organizational members accurately recognize the degree and nature of group diversity, or subjectively perceived diversity, and accept and encourage the free expression of cultural values, beliefs, and practices. Without such recognition, it is unlikely that an organization will foster an accepting climate for cultural diversity. This recognition is not a given in multicultural groups, and "even superficially homogeneous groups may vary in core cultural values due to differences in country of origin, linguistic background, religious traditions, and other distinctions" [30]. The authors explained this construct is different from diversity climate, which is typically limited to intrinsic benefits about diversity. In addition, research suggests that RMM group members' perceptions of cultural mosaic beliefs climate can differ depending on the demography of the group.

Lee et al.[71][75] and Ridgeway et al. [76] provide insight into perceived cultural diversity climate through the perceptions of international engineering doctoral students and Black engineering doctoral students, respectively. For example, Lee et al. [71][75] found that differences in international students' cultural backgrounds and/or languages have emerged as influencers of students' perceived acceptance, isolation, and discrimination. These authors also found that international students reported lower interactions with faculty and peers compared to other groups (e.g., RMM as well as White students). In juxtaposition, Ridgeway et al. [76] found the Black doctoral engineering students in their study did not perceive international Asian students as also minoritized in engineering. The respondents in this study reported feeling isolated due to interactions with international Asian students, whom they viewed as overrepresented. Furthermore, the Black engineering doctoral students perceived the international Asian students as experiencing less racial isolation. We consider these findings as indications of a weak or lacking cultural mosaic beliefs climate for perceived cultural diversity.

We found indications of **authenticity climate** in Artis [65], Artiles et al. [67], Lee et al. [71], and Spencer and Artis [72] as these papers mentioned artifacts of climate perceptions such as "a sense of twoness," "public you vs. private you," authentic self, and codeswitching. By definition, *authenticity climate* entails the perception that the organization encourages and provides a safe environment to express personal identities, or, in other words, people feel free to be themselves [32][33]. The results and findings from the papers we located in the engineering education literature indicated that participants were switching or hiding who they were or not presenting their true selves. These clues suggest the participants were not encouraged or provided with a safe environment for expressing their identities by their department. In these cases, a negative authenticity climate existed in the participants' perceptions. Interestingly, these papers provided evidence of authenticity climate from several different intersectional groups including Black women and international students.

Psychological safety climate is defined as the perception of how others in the workplace (i.e., the department) will respond to interpersonal risk-taking behaviors such as taking initiative or speaking up about problems or issues in the workplace, [34][35][36]. When a psychological safety climate is in place, people in the organization feel a sense of openness and contribute more ideas because divergent perspectives are encouraged, and they are free from fear of negative consequences [37]. We found indications of this climate in [64][65][66][77][78] and [83] whose respondents described issues such as voicing their opinions, comfort in asking questions, and the courage to speak up. Artis and LeSure [65], in particular, provided insight from the perceptions of Black women doctoral students who explained that "you're bringing a lot of stuff that doesn't have anything to do with things and trying to make people understand why they do matter" and identified a "challenge would be to make sure that I can make my voice heard without being the angry Black lady or the sassy one that has an attitude".

Psychosocial safety climate describes perceptions of managerial support and commitment to psychological well-being and work stress prevention [38][40]. The climate encompasses four areas: emotional exhaustion from psychological strain, workload demands, job control (i.e., having some influence over your work), and social support from supervisors and peers [39]. Psychosocial safety climate has been shown to moderate the impacts of work stressors on psychological health as well as the effects of job demands on fatigue, depression, and work engagement [38][41]. Furthermore, a good psychosocial safety climate is associated with less bullying and burnout [40]. We found evidence to support this climate in several papers that mentioned mental health and wellbeing, peers questioning competence, and burnout [81], fatigue and mental well-being [67] and pressure and stress [68].

Finally, our analysis uncovered the most evidence for the motivation climates: mastery and performance. In a **mastery motivation climate,** perceptions are of focus on self-improvement, competency increase, learning, and skill development. This climate is characterized by an emphasis on learning, task mastery, self-growth, peer equality, and

cooperation. In a **performance motivation climate,** perceptions are of focus on demonstrated superiority, favorable social comparisons, and competition to outperform colleagues. In sport and education domains, evidence is consistent that a mastery climate promotes intrinsic interest, increased effort, positive attitudes, trying hard, and persisting when faced with difficulty. On the other hand, a performance climate is characterized by maladaptive outcomes such as performance anxiety, worry, stress, cheating, seeking easy tasks, and giving up when faced with difficulty. Finally, motivation climate has been found to predict employee outcomes including job engagement, burnout, turnover intention, work performance, incivility, innovation, and knowledge hiding [46][47][48].

In the engineering education literature, we found indications of motivation climates in more than half of the collected papers. Some examples include collaborating closely with other graduate students, being part of a group of graduate students who provide each other with support and encouragement [62], bouncing ideas off each other and discussing problems [63], demonstrating academic competency through comparison with peers [75], academic gatekeeping and relationship with faculty [81], peers trying to exert authority [66], and becoming a resource for others [68]. We also note the statement from one respondent, “Most minorities come from a very community-based and a familial background [so] that cutthroat and no-real-care-for-other-people-if-it-doesn't-directly-benefit-you [mentality is]. I think that's one of the reasons that they don't go into academia” [83]. This finding suggests a mastery climate could have significant implications for the retention of RMM students engineering doctoral students and their decision to enter the academic workforce.

While definitions may vary, we understand **work-life balance climate** to refer to perceptions about the impact of work on personal life [43][44]. Research on work-life balance in higher education continues to reveal gender disparities and a lack of policy usage (i.e., paid time off), yet existing research tends to focus on faculty and not doctoral students [84]. Our analysis did not uncover any results or findings that could be directly associated with work-life balance climate for doctoral engineering students.

Discussion

Our review demonstrates that 1) when there are studies of climate, constructs were not defined, ill-defined, or derived from literature outside of organizational science, 2) participant climate perceptions were often captured in studies of phenomena other than climate and 3) while engineering study results and findings often indicated the presence of organizational climate(s), engineering education researchers did not identify or acknowledge climate. We also note that studies purportedly of climate used survey instruments that are not validated either for the climate constructs they claim to measure or for assessment across multiple intersectional groups of students. Therefore, it is difficult to draw reliable conclusions from these studies or translate their results meaningfully to inform policy or practice.

Nonetheless, our review found that seven climates associated with member retention are indicated in the literature on doctoral engineering programs. Overall, climate perceptions were most often revealed by participants in studies of phenomena other than climate. The climates most often evidenced were motivation climates; least evidenced were cultural mosaic beliefs climate and authenticity climate. No single project provided a comprehensive examination of climate in these programs by assessing diversity climate, authenticity climate, cultural mosaic belief climate, psychological and psychosocial safety climates, and mastery and performance motivation climates, which leaves questions about how these climates coexist, cooperate, or complement one another. In addition, no project examined work-life balance climate, though it is clearly relevant.

Findings from engineering education research unintentionally captured the presence of multiple outcomes and processes climates that can influence doctoral students’ retention and degree completion. Some climates, such as authenticity climate, may be particularly salient to

the experiences of doctoral students from minoritized or marginalized groups. However, few studies have examined such groups at the doctoral level. While we found several studies that focused on Black women doctoral students, many other groups, such as LGBTQ+ students, students with disabilities, and students who are older than the typical graduate student, are rarely included or entirely absent. This supports Riley, Slaton and Pawley's [5] nearly decade-old observation that the engineering education community tends to overlook differences outside of gender and race/ethnicity. Therefore, insight into climate perceptions of students from diverse minoritized or marginalized groups is limited. For example, we found that multiple studies evidenced mastery motivation climate which suggests all doctoral engineering students may perceive this climate. In contrast, we found no papers with descriptions of work-life balance climate, perhaps because most of the studies included only participants from the traditional mold for graduate students—that is, younger, single, and child-free—who may have limited awareness of policies or practices regarding work-life balance. Studies that focus on students who are older, partnered, and/or having caregiving responsibilities would potentially find work-life balance climate to be more salient or of greater importance.

The long-term vitality of the U.S. innovation workforce relies on the full range of STEM careers being available to all Americans. Engineering accounts for a large share of the innovation workforce, and the ongoing lack of diversity among engineering doctorates remains a problem with far-reaching implications for the U.S. economy. Increasing the participation of women and RMM groups in doctoral engineering is imperative, but limited progress has been made in broadening participation. Engineering doctoral degree completion is traditionally seen as an issue of student persistence or attrition. However, engineering doctoral programs are a type of organization, and the continuation of students in these programs through Ph.D. completion can be viewed as an issue of organizational member retention. Therefore, we suggest reframing the problem of engineering doctoral student degree completion as an organizational science question. From this perspective, organizational science can guide research directed at understanding the climate(s) affecting the retention of students from diverse and intersectional populations. Understanding the range of relevant climates, and the associated psychological and academic processes and outcomes, is relevant to local decision-makers including department chairs and deans.

Considering engineering doctoral student retention as an organizational science issue would also shift the responsibility from the faculty advisor-advisee relationship, which is often considered pivotal from a student-persistence perspective, to higher education leadership. We note that faculty are department (i.e., organization) members and, therefore, work in a climate that they do not create or control. Organizational leadership is positioned to drive organizational change. Therefore, organizational climate is a task for higher education leadership on multiple levels. For example, at the local level, understanding whether a mastery- or performance-based motivation climate exists within a department or program can help leaders, such as chairs and deans, build supportive, dynamic, and appropriately challenging programs that retain diverse students to degree completion. At the national level, understanding which climates present obstacles to engineering doctoral student retention and degree completion can guide funding priorities that expand the advanced engineering workforce and build a thriving, diverse talent pool for the United States.

Recommendations

In conclusion, our analysis of prior studies leads us to a set of recommendations for the future studies of climate among engineering doctoral students:

Recommendation 1. Examine department-level climate in context of organizational science with the goal of making research findings actionable via a policy or pedagogical mechanism or planned process.

Recommendation 2. Adopt an intersectional approach that considers the combination of social identities or locations that students bring with them to inform the assessment and analysis of doctoral engineering program climate.

Recommendation 3. Assess multiple constructs of climate within one climate survey instrument.

Recommendation 1 has to do with translating important academic findings into actionable results to improve climate broadly for engineering doctoral students. This population faces several challenges in completing doctoral programs that require the knowledge developed from climate surveys to center making it actionable in the initial design phase and not just an afterthought. Recommendation 2 is vital to fill gaps in our understanding of the complex climate across a greater diversity of engineering doctoral students than has been previously studied. Finally, in order to execute Recommendations 1 and 2, Recommendation 3 is needed to draw multiple lines of evidence that could interplay differently across intersectional groups to create the climate engineering doctoral students are experiencing.

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