Engineering Education Discourses on Underrepresentation: Why Problematization Matters*

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Despite decades of research on and efforts to increase the low numbers of women in engineering in many parts of the world, underrepresentation persists. This paper analyzes recent engineering education scholarship to determine what reasons are given to explain why underrepresentation is a problem, in other words, how underrepresentation is problematized. Using discourse analysis as the theoretical lens, and drawing on prior research that employed similar methods and theoretical perspectives, this paper examines an international dataset of engineering education journal articles and conference proceedings from 1995–2008. Four categories of problematizations are identified and discussed in order to advance critical reflection that could be beneficial in moving forward discussions about underrepresentation.

Keywords: discourse; gender; problematization; underrepresentation; women in engineering

1. Introduction

In 1952, an article in the *Journal of Engineering Education* stated:

> Since it seems the shortage of engineers may jeopardize our national welfare, the next question is what we can do about it . . . Women have certain inherent characteristics which stand them in good stead. For instance, they are conscientious, they know how to use their hands, they are careful about detail, and quite important, they are not adverse to trying something new. Witness, for example, their proclivity to change the furniture around in the house about every three days to see if they can find a more efficient arrangement [1, pp. 174–75].

In 2006, an article in the *European Journal of Engineering Education* stated:

> Diversity is an important issue in globalization and competitiveness of institutions and corporate entities . . . Women need to love their work and be 'crusaders', meaning they need to have dedication, courage and drive. If those traits are combined with female qualities of intuitiveness, flexibility and people skills this obviously brings great value to the profession. . . . Women are physically different, think differently and can be more emotional. Hence they contribute another dimension to the male workforce [2, pp. 661, 63, 67].

These quotations, published over 50 years apart, reveal both a longstanding interest in recruiting more women into engineering as well as a long history of explanations as to how engineering will benefit from their presence. The quotations are striking both for their similarities as well as for the different traits they ascribe to women. The aim of this paper is to explore the current ways in which women's underrepresentation in engineering is framed in engineering education research and to suggest that the persistence of underrepresentation, despite decades of attention, may be related to those framings and how they are articulated.

There is now a large body of international literature documenting women's underrepresentation in engineering in many, but not all, parts of the world [3–9] and proposing a broad range of explanations for and solutions to it. Moreover, increasing diversity within engineering has been cited as one of the major drivers behind the growing international interest in engineering education research [10]. However, despite the fact that concerns about women's underrepresentation in engineering are shared among a group of engineering educators around the globe—and have been discussed for decades—the extent to which their concerns are shared by the engineering education community as a whole is unknown, and there are indications that recognition of and interest in underrepresentation and gender biases in the field are not widespread and are considered to be outside the real concerns of engineering [4, 11, 13]. Therefore, a critical look at the arguments being put forth to explain why underrepresentation is a problem is warranted.

Within this literature on underrepresentation, some authors have demonstrated how engineering and engineering education are socially constructed enterprises. As such, post-structural feminist and discourse analysis approaches can provide insights about their construction [14, 15]. These approaches hold that engineering is situated in certain historical, social, political, and cultural milieu—which vary over space and time—and that this milieu, which includes beliefs about gender, affects how engineering is conceptualized and discussed. These conceptualizations and discussions of the field in turn affect how underrepresentation is conceptualized and discussed. Building on their approaches, as well as other work discussed below, this paper identifies and analyzes the varieties of justifications given for needing to increase women's participation

in engineering. Understanding the justifications as discursive formations will shed light on their historical construction and allow for critical examination. One benefit of discourse analysis is that it opens up for discussion topics that were previously understood as unquestionable facts not worthy of academic study. So, although it has not yet been common in engineering education research to theorize about how underrepresentation is framed, such theorizing has been established in Science and Technology Studies and the field of business [16–18], and there are several prior examples of similar work from engineering education [19, 20].

The purpose of this paper is to name and unpack stories around the question of why underrepresentation is a problem, thus offering them up for much needed, yet largely absent, discussion and analysis within the engineering education community. It is important to name the narratives we use to discuss the engineering profession, and the assumptions therein, because doing so opens up those narratives for critical analysis and reflection [21–23]. As Pawley explains, "If we as engineering educators fail to name and unpack our own stories, we risk carrying on the way 'it's always been done,' maintaining the discipline upon its historical and arguably exclusive foundation" [21, p. 317]. Prior scholarship has explored similar questions in other contexts and data sources and has discussed changing justifications over time [16–18, 24]. Similar discourse analysis methods have also been used to study historical trends in justifications for international engineering education initiatives [25].

Building upon this prior work, this paper addresses the following questions:

(1) What justifications or motivations do authors give to explain why underrepresentation is a problem?
(2) What critical perspectives on those justifications exist? Or, what does each justification potentially hide?

While I focus on a dataset of research on women and gender, this analysis has implications for broader understandings of diversity as well.

2. Theoretical perspective

The theoretical basis of this analysis is post-structural discourse analysis in which, "discourses constitute symbolic systems and social orders, and the task of discourse analysis is to examine their historical and political construction and functioning" [26, p. 5]. This approach allows an examination of problematization—or how problems are conceptualized and discussed—and aims to show that those problematizations are not simply the Truth,

but rather are the result of the social and political milieu in which they exist [26]. "Ideas that do not draw on or interact with available discourses will be dismissed as strange or irrelevant" [27, p. 83]. In other words, discourse,

> . . . governs the way a topic can be meaningfully talked about and reasoned about. It also influences how ideas are put into practice and used to regulate the conduct of others. Just as a discourse 'rules in' certain ways of talking about a topic . . . so also, by definition, it 'rules out', limits or restricts other ways of talking, of conducting ourselves in relation to the topic or constructing knowledge about it [28, p. 72].

For example, if it is thought that more women are not attracted to engineering because they simply are not aware of it or because they do not know what work engineers do, then efforts will of course focus on outreach and informing female students of the opportunities engineering careers offer them. However, by thinking about the problem in this way, the field itself is unexamined and unchanged because discourses that locate the causes as masculine biases within engineering itself are not considered.

Therefore, the goals of discourse analysis include examining and deconstructing the problematic assumptions that exist within a discourse [26], and understanding how the framing of a problem makes some facets of it appear normal, fixed, or appropriate and other facets appear inappropriate [29]. To put it another way, it is a fact that there are fewer women engineers than men engineers in some parts of the world; however, the meanings and interpretations we give to that fact can be studied through discourse analysis. And, moreover, if that fact is taken to be a problem, then how we frame the problem matters for the solutions we imagine. This process of identifying a problem as such is called *problematization* [30].

The problematizations of underrepresentation found in the engineering education literature are parts of larger *discursive formations* [28] and *discursive economies* [31]. These terms refer to the fact that discourse is never just one isolated statement, text, or action; rather, it occurs across multiple sites, statements, texts, and actions [28] and derives power (or weakness) from its location within broader discourses in society. Thus, the isolated statements in engineering education articles are indicative of larger discourses and meanings, calling attention to their historical, social and political dimensions.

3. Literature review

3.1 Uses of discourse analysis in engineering education research

Discourse analysis has been successfully employed in engineering education research. In particular, the

importance of discourse to how we think about recruitment and retention is recognized in the work of Pawley [12] and Watson and Froyd [32]. They have demonstrated that the ways in which underrepresentation is commonly described and conceptualized is limited and misguided. Pawley, for example, argues that the pipeline and chilly climate metaphors are problematic because, "they leave uninterrogated both how we define 'engineering' and how we use 'gender' as a category to understand women's underrepresentation in engineering" [12, p. 1]. She proposes that a boundary metaphor would better allow,

> . . . both "gender" and "engineering" [to] become interrogated categories of analysis . . . [helping to] make visible the gendered nature of engineering. Ultimately, the act of recognizing and making explicit the metaphors that we use—often unconsciously—can help us think about how we construct both "problems," and "solutions" [12, pp. 5–6].

Watson and Froyd also critique the pipeline discourse stating that the "mental model oversimplifies complexities of the underlying processes, focuses interventions at points of unwanted leakage, and suggests that leaks need to be plugged instead of systems renewed" [32, p. 19].

In addition to critiquing metaphors, discourse analysis has been utilized in other ways that illuminate gendered facets of engineering, including to analyze ethnographic data [4, 15, 33–37]. For instance, Stonyer identifies three engineering discourses that shape the identities of engineers: scientist, servant, and citizen. She argues that it is important to understand these discourses because,

> Engineering education is . . . not a 'given'. Rather it is a constructed response—'an invention'—of the tensions and contradictions, the different points of view and the fundamental assumptions in each discourse. These discourses exercise 'power' to justify and legitimate particular actions . . . [15, p. 393].

In other words, the contents and practices of engineering education are the result of broader discourses in which engineering exists, and what is possible or considered legitimate within engineering education acquires that status through certain discourses, which could be different and can be changed. This scholarship has successfully demonstrated the ways in which discourse analysis offers insights into engineering education and how we conceptualize and go about solving problems of underrepresentation.

3.2 Prior studies on problematizations of underrepresentation and diversity

Prior studies have critically examined diversity discourses and initiatives in science, engineering, and business, documenting both historic and current trends while demonstrating the need to understand the history and the implications of how we think and talk about diversity and underrepresentation [16–20]. Still others have noted in passing that there have been shifts in the discourse over time [24, 38]. In this section of the literature review these prior studies are discussed, and in the following section, 3.3, their findings are synthesized to draw out common themes that exist across the studies. Critical perspectives on each theme are then presented and used to discuss what each discourse risks hiding—an approach to studying different aspects of engineering that has long been used in the work of Downey [39–41]. Although, many of the studies discussed below focus on US history, parallels can be seen in work focused on Europe and Australia [24, 38]. The point of this review is not to provide a history of any one country, but rather, to show that these issues have been studied and have advanced understandings of underrepresentation and diversity. The dataset is international, representing authors from around the world; detailed histories of the discourse in each country are beyond the scope of this paper.

Lucena studied US National Science Foundation (NSF) policy aimed at increasing STEM participation and found that shifts in national preoccupations over the last five decades shaped changes in NSF STEM (education) policies and initiatives [17]. He shows that, beginning with the 1960s, each decade had a different dominant discourse that defined the *limits of the sayable* in policymaking. In the 1960s, the launch of Sputnik sparked a new concern with producing scientists for the Cold War. This changed in the 1970s when some policymakers began to see scientists and engineers as solutions to domestic energy, environmental, and social inequality problems. It was during this decade that minorities became a "category of statistical significance" and underrepresentation was established as a problem for the NSF to address. Advocates argued that minorities were good for science because their different cultural backgrounds would benefit science by subjecting its values and assumptions to scrutiny. National concerns changed again in the 1980s when technological threats from Japan led to a discourse of economic competitiveness. And in the 1990s those concerns were replaced with a focus on flexibility and global competitiveness as the technological and economic threats first felt from Japan expanded to include other Asian countries as well as the European Union. By identifying rhetorical strategies and models used by the NSF and situating them within the broader historic and cultural context, Lucena aims to help current policy makers and educators locate themselves and understand the history of policymaking.

Slaton's study is similar to Lucena's, but it focuses more specifically on engineering in particular and efforts to recruit and retain African American students at individual universities over the last fifty years [16]. She identified three types of arguments that have been used to advocate initiatives designed to increase the participation of African American students: legal arguments, economic arguments, and social justice arguments. However, in her study she focuses only on the latter two. The popularity of the various types of arguments has risen and fallen over time with broader economic, social, political, and cultural changes in society. Yet, national economic and corporate economic competitiveness arguments have consistently been more common than have social justice arguments. She contends that an examination of the justifications is important because the framing of the problem shapes how we think about inequality. Similar arguments have been made elsewhere [19]. Furthermore, Slaton suggests, social justice rationales may "lead to a more profound understanding of race-based inequalities in STEM fields" [16, p. 9]. For example, her case study of the Texas A&M University system reveals that the limited understandings and discussion of social justice in regard to opportunity structures mean that even Minority Education Programs can unintentionally reinforce unjust social and educational structures as well as narrow conceptions of merit.

Within engineering education specifically no such detailed historical or large-scale research has been done. However, there are several conference papers worth noting. Pfatteicher and Tongue identify and raise important issues about "six potential drivers for diversity":

(1) regulatory requirements,
(2) educational equity,
(3) workforce deficiencies,
(4) workplace demands,
(5) social justice,
(6) professional development [19].

They organized the drivers on a spectrum from external to internal sources of motivation; however, they do not present data on how those drivers have actually been used in engineering education. Hørby et al. briefly discuss three "waves" of underrepresentation concerns in Denmark, all of which evidence labor market concerns, and the effect of each wave on engineering education [20]. They also discuss the most recent trend of linking diversity to innovation. Finally, Nelson and Pawley state that one of the questions they are exploring in their ongoing study of gender in the *Journal of Engineering Education* concerns the goals, rationales, and motivations of gender researchers [42].

In addition to these studies of STEM and STEM education fields, scholars in the field of business have also studied how diversity is conceptualized and discussed [18]. Writing in the mid-1990s, Thomas and Ely asserted that to date diversity initiatives in business organizations had tended to fall into one of two, what they term, "paradigms." The *discrimination and fairness paradigm* is characterized by a focus on equality and fairness to overcome prejudice and unfair advantages. The *access and legitimacy paradigm*, which emerged in the competitive business climate of the 1980s and 1990s, is characterized by an "acceptance and celebration of differences" in order to help business "understand and serve ... customers better and to gain legitimacy with them" [18, p. 83]. In addition to the two paradigms that had prevailed thus far, they argued that a new third paradigm was beginning to emerge. The *learning and effectiveness paradigm* is characterized by integration of diversity into an organization and its work processes, and is a combination of the other two paradigms.

Taken together, these studies establish the following:

(1) Precedence for, and value in, studying the ways in which diversity and underrepresentation are conceptualized and discussed;
(2) That those conceptualizations and discussions are located in specific historical and social contexts that shape their emergence, popularity, and outcomes or effects, and that, therefore;
(3) No problematization should be taken as given, as "common sense," or as beyond analysis, and;
(4) That common themes can be identified across the varying contexts of these studies.

In the next section, I pull out those themes and bring in literature that further elucidates their historic and social situatedness and raises important questions about their use.

3.3 Common problematizations and critiques

Three common discourses can be identified across the studies discussed above. They are summarized in Table 1.

3.3.1 Economic competitiveness

Economic competitiveness—for the nation and individual businesses, which are not wholly separable—has been used to argue the need for more engineers generally, no matter who they are, and for a more diverse population of engineers. As discussed, Lucena and Slaton identified economic competitiveness justifications in their historical studies of STEM (education) discourses. Pfatteicher and Tongue include similar issues in their "workforce deficiencies" driver, and in the field of busi-

Table 1. Common discourses and critiques

Discourse	Description	Critiques
Economic competitiveness	Nations and businesses need more diverse engineers to be economically competitive	• Hides critiques of ties to military and industrial systems • Hides important aspects of engineers' relationships to their work • Places a superficial emphasis on diversity • Underrepresentation a problem only because more engineers are wanted
Benefits to the field	Diversity directly benefits the contents, practices, and perspectives of science and engineering	• Universalizes and essentializes groups of people • Attributes ascribed to women reinforce gender hierarchies • Features of engineering prevent diversity from being expressed in ways that could benefit the field
Social justice and equality	Features of engineering that systematically benefit some groups and disadvantage others are inherently wrong	• Equal treatment not necessarily just • Equality can be narrowly construed to mean only equal numbers of students from various groups or to require "sameness"

ness, Thomas and Ely also identified economic competitiveness justifications in their *access and legitimacy paradigm.* This literature demonstrates that the discourse of economic competitiveness is historically and politically contingent, and should not be treated as a "given," or as beyond question. Economic competitiveness arguments may seem to be "givens," however, because capitalist discourse has long been one to which people can appeal because it is credible, non-confrontational to widely-held economic and political beliefs, and makes sense to many [27]. It has been observed that advocates of international engineering education often couch their rhetoric in terms of economic competitiveness to acquire funding and support, while their true motivations lie elsewhere [41]. It is possible that advocates for diversity do the same. Indeed, in a recent engineering education publication, Julie Martin Trenor and Alice Pawley contemplated whether "we have had to diminish the social justice issue to get attention from funders to study race, class and gender in engineering education? What have we sacrificed (or what people are not participating) if we make that bargain with funders to support out work?" [43, p. 71]. Interviews with engineering educators revealed similar concerns and a higher value placed on social justice [44].

Despite its credibility and status as "common sense" for a large part of the population, advocates framing underrepresentation in terms of economic competitiveness should be aware of what this discourse potentially hides. First, it can hide the fact that engineering's relationships to those systems of economic and military competitiveness and the ways in which economic imperatives shape engineering have been subject to critique [13, 15–16, 39]. For example, the research agendas that shape engineering have been critiqued for being implicated in exploitative economic structures and for narrowing the scope of problems that the profession addresses [13, 15–16]. Second, conceptualizing engineering work solely in terms of competitiveness

means that important facets of our understanding of engineers' relationships to their work are not seen [39]. Third, it hides its own underlying logic; namely, that if nations and corporations were not perceived to need more engineers, then underrepresentation would not be a problem—a proposition that many would not agree with. Fourth, in business environments, economic competitiveness justifications for diversity have been critiqued for placing superficial emphasis on cultural diversity without a deep appreciation for or understanding of what those differences mean for the work itself and for hiding the fact that it often stems from "very immediate and often crisis oriented needs for access and legitimacy in markets" and almost only works in companies *threatened* by a diversifying customer base [18, p. 84]. Therefore, scholars using the economic competitiveness discourse should be aware, in the first place, that it *is* a discourse, and second, that it has been critiqued.

3.3.2 *Benefits to a field's contents and practices*

A second common discourse can be expressed as the notion that the presence of diversity directly benefits the contents and practices of science, engineering, and business. While this theme is not always completely separable from the first theme of economic competitiveness, especially in the case of engineering, it does deserve its own discussion. The notion of diversity as beneficial to contents and practices emerges in Lucena's study in the 1970s with arguments that diverse individuals were actually good for science because their fresh perspective would lead them to question aspects of science that were taken for granted by others. The theme also emerges in Thomas and Ely's *access and legitimacy* and *learning and effectiveness* paradigms with the beliefs that diverse cultural and language skills help businesses understand and serve their customers and diverse perspectives should be learned from and incorporated into an organization's practices. Pfat-

teicher and Tongue's "professional development" driver likewise evidences this theme.

As with economic competitiveness, there have been critiques of the idea that increasing the number of women will *necessarily* change a field [14–16, 18, 45–47]. Generally, these critiques recognize that increased diversity could improve the contents and practices of those fields, but there are reasons that increasing the numbers of women does not automatically do so. First, this discourse hides the ways in which engineering's control by corporate or commercial interests circumscribes the work that engineers actually do [15], and that "It is not necessarily the absence of diverse personnel that has led to the social narrowness of research agendas in engineering. Rather, it may be the narrowness of the social interests" of those in control of programs and funds for research and eligibility [16, p. 214]. As one illustrative example, Slaton describes how the interests of business became dominant and marginalized research to address urban social problems in Chicago during the 1960s and 1970s. It is certainly true that scholars have demonstrated that technologies bear the sociopolitical and cultural stamps of their producers—including gendered dimensions [48–54]. For example, many household and office technologies actually do not benefit women in the ways they are assumed to and also reinforce gendered divisions of labor [50, 53]. And stories abound about women engineers solving problems that remained unseen or unaddressed by male engineers; however, the fact that social, cultural and political dimensions are built into technologies is not only a factor of the demographic categories of the individuals producing them. Rather, there are larger belief systems that shape science and technology and simply having more women will not necessarily change that [14, 45–47]. In fact, it has been argued that women who succeed in engineering, do so precisely because they fit the existing norm, not because they challenge it [47].

Another issue is that this discourse hides the concerns that have been raised over ascribing attributes to underrepresented groups. One concern is that this discourse universalizes and essentializes groups of people, or takes social stereotypes as natural and ideal attributes that apply to all women [14, 16, 22, 52]. A related concern is that the attributes ascribed to women reinforce women's subordination to men because the idealized masculine and feminine traits are valued differently [52]. Udén explains that, "the tendency to overestimate the range of 'different' values and practices among women is easily explained, as it creates an account of reality that at the same time confirms ideology compatible to ruling gender orders and strengthens the case of women in the struggle for gender equal-

ity" [14, p. 463]. Scholarship on gender roles has explored how the links between genders and certain traits came to be and has highlighted problems that association with feminine traits can cause for women [55]. As the epigraph at the beginning of this article demonstrates, attributing certain desirable traits to women is not a new strategy in engineering education—although, evidently these "female qualities" have changed since the 1950s. We need to consider current discourses with the same critical reflection that we may view statements from the 1950s, and consider that, as Jolly argues, essentialism that portrays women as "more socially and environmentally sensitive with greater communication and teamwork skills than men" may be related to the failure of many standard interventions [22, p. 1].

3.3.3 Social justice and equality

A third common discourse that emerges from the literature frames underrepresentation as an issue of social justice, equality, morality, or fairness. While these terms can have different meanings for different people, generally this theme can be summarized as the notion that any structural or cultural features of engineering that favor the success of some groups while hindering the success of other groups need to be corrected because intentional and unintentional biases are inherently wrong. It is also important to note that equality and justice should not be conflated because equal treatment is not necessarily just treatment. However, for the purposes of this paper, those terms are included in the same section. As discussed, Lucena shows how concerns with social inequality shaped the discourse of the 1970s NSF policies. Slaton also identified social justice as one of three justifications used to recruit and retain African American engineers. Thomas and Ely's discrimination and fairness paradigm likewise expresses the idea that minority exclusion is an issue of fairness and social justice, and Pfatteicher and Tongue discuss "educational equity" and "social justice" as potential drivers of diversity.

There are not as many critiques of the social justice discourse as there are of the other two themes, and critiques of equality or equity tend to focus on certain, limited, interpretations of those terms. One critique comes from Thomas and Ely who say that the *discrimination and fairness paradigm* operates under the assumption that all individuals are the same and that differences do not count [18]. However, this issue, the insistence on sameness as a requisite for equality, has been resolved in the minds of many other scholars who have concluded that equality does not require sameness [56]. Thus, the way that paradigm has operated in the past is not necessarily how it must operate: there is nothing

inherent in arguing for fairness, or social justice, that necessitates the emphasis on sameness to the detriment of validating differences. Regarding equity specifically, Pfatteicher and Tongue argue that if equity is conceptualized only as greater numbers of people from different social categories, then the status quo is maintained, a "diversity of learning styles" is not incorporated, and "interactions between privileged and target groups" remain the same [19, p. 3]. However, equity can have much broader meanings, including extending to those issues they identify. Additionally, there have been instances of engineering educators arguing that there are better ways to think of diversity than in terms of morality and fairness [32, 57, 58], but they do not articulate any specific critiques; they merely imply that there are better problematizations.

It is significant that the discourse of social justice has lost traction as economic competitiveness arguments have become dominant. Lucena found that economic competitiveness replaced social justice arguments in NSF discourse in the 1980s, and Slaton similarly found that as economic discourses increased, the popularity and resonance of social justice discourse declined. Similar shifts in focus from equity to competitive advantage and productivity have occurred in Europe [38]. And Australian scholars have also noted the discourse of underrepresentation shifting away from social justice and equity after the 1980s [24].

4. Methods and sources

The dataset for this content analysis [59] consists of engineering education journal articles and conference papers from the years 1995–2008. Other facets of these sources have been analyzed in prior work [60–61]. For 2005–2008, empirical articles and editorials from the following journals and conference proceedings were included: *Australasian Journal of Engineering Education (AJEE), European Society for Engineering Education Annual Conference (SEFI),* and ASEE *Global Colloquia.* The *Australasian Association for Engineering Education Annual Conference (AAEE)* was included for 2006–2008. For 1995–2008 all articles in the following journals were included: *European Journal of Engineering Education* (EJEE), *International Journal of Engineering Education (IJEE), and Journal of Engineering Education (JEE).*

All *IJEE, EJEE,* and *JEE* papers and editorials, as well as papers that contained empirical data from *AJEE, AAEE, SEFI,* and the *Global Colloquia,* that had women or gender as their primary focus were read and instances of a problematization were noted. From this list of problematizations, four general themes emerged that were based upon similarities among statements, allowing the dataset to be coded into the categories that emerged from the data, which are described below. For each category, I provide several examples of the statements included therein. The statements are from North America, Europe, Australasia, Turkey, and India.

Several limitations of this study should be noted. First, only English language publications were included although there is much engineering education research in non-English language outlets as well as in regional outlets around the world. Second, some important English-language outlets, such as Frontiers in Education, were not included because of the need for a manageable size dataset, the already large number of papers from the US, and the aim of incorporating more international sources. Third, the themes identified necessarily involved simplifying what are complex concepts in order to create clear and manageable categories. Such simplification is an inherent part of social research [62]. For instance, as discussed above, equality, justice, morality, and fairness are all treated as one theme. In part, this simplification is also justified by the data because the meanings of those terms are not usually delineated in the publications.

5. Findings

In this section, I identify four categories of problematizations found in the dataset. Briefly, they are: economic competitiveness, professional service and representativeness, women's attributes, and social justice. As readers will see, the first three are highly intertwined, yet distinct enough to allow differentiation and separate discussion. Although I have separated them in this paper, it was often the case that several problematizations were found within one paper. These statements appear almost exclusively in the introductions of the papers. The categories identified in this dataset largely align with those themes identified in the literature review. One difference is that instead of one general theme regarding the benefits to STEM fields, two distinct but related categories emerged from the dataset, those of professional service and representativeness, and women's attributes. Both of these categories express the belief that women benefit the profession, but in the interest of a more thorough and nuanced description, I divided them into separate categories. These findings are summarized in Table 2 along with key terms that were found in the data for each category. It is also worth noting that no significant geographic differences were found in the use of any one problematization; each category contains statements from several different regions. When it is not otherwise clear from the sentence which country a

Table 2. Problematizations in the dataset: key terms and alignment with literature review

Problematization/Discourse	Relevant literature review theme	Key terms from data
Economic competitiveness	Economic competitiveness	Economic/economy Competitive(ness) Market Gross national product Industry/industrial
Professional service and representativeness	Benefits to the field	Customers Populations People-centered Clientele Users Good engineering design Solutions Socio-technical challenges
Women's attributes	Benefits to the field	Flavor Intuitiveness/intuition Flexibility People skills Communication skills Creativity Beauty
Social justice and equality	Social justice and equality	Social justice Social need Equal opportunity Moral(ly) Unjust Segregation Women's quality of life

statement is from, I include the country of origin (based on institutional affiliation) in parentheses.

5.1 Economic competitiveness

One category of problematizations concerns economic competitiveness and expresses notions similar to those described in the literature review. For instance, Trenor et al. write that, "For the U.S. to remain competitive in today's global economy, it is essential to attract and retain more women—from all backgrounds—in the field of engineering" [63, p. 450]. Likewise, Ihsen writes that discussions of women in engineering are important for "economic success and social stability in Germany. Today the country has to cope with more complex requirements because of changing global markets" [6, p. 488]. Paloheimo et al. assert that women's underrepresentation in technical fields in Finland is a problem because of the potential for "decelerated Gross National Product" [64, p. 1]. Dengiz and Smith (Turkey and US) cite concerns over the "world economy" more generally needing engineers: "The reliance of the world economy on advanced technology is increasing and will be highly dependent on the quantity and quality of a well-educated and skilled engineering workforce. Hence, all available talent should be cultivated carefully" [65, p. 1]. Zimmerman and Vanegas (US) state that, "Engaging women and underrepresented groups in SET will build additional capacity in these fields

that are critical to advancing economic, environmental and societal goals" [66, p. 243]. Lastly, Watson and Froyd (US) cite former President of the US National Academy of Engineering, William A. Wulf's contention that the lack of diversity is "simply unacceptable and will become increasingly unacceptable to industries that need diversity among their engineers in order to compete in a global market" [32, p. 19].

5.2 Professional service and representativeness

Another problematization, which is distinct yet related to economic competitiveness and often seen in the same articles, is that as a profession engineering needs to be more representative of the clients and customers it serves so as to better understand and meet their needs, or to produce better solutions and designs. Because clients and customers are diverse, and increasingly so with globalization, then, the engineering workforce should reflect this diversity. The arguments in this category are most similar to the second theme identified in the literature review: diverse people benefit engineering because they bring new perspectives and experiences to the contents and practices of the profession.

For example, Ihsen (Germany) states that,

Today the mostly *homogeneous* male engineering teams are no longer able to deal with the more and more diverse customer wishes. Thus, within the issue of diversity, the issue *of women in engineering* is achieving more and more economic and political relevance. But

there are not enough female engineers who are used to translate the wishes of the more or less unknown female customers into new or more appropriate products [6, p. 487].

Similarly, Gill et al., (Australia) write that, "While the engineering profession continues to be comprised of a narrow range of people—far narrower than the populations it serves—its potential to develop innovative and people-centred solutions is going to be limited" [4, p. 391–92]. Chubin et al., (US) state, "Engineering has a 'diversity' problem. Like all professions, it must narrow the gap between practitioners on the one hand, and their clientele on the other" [57, p. 73]. And, as Daudt and Salgado (Netherlands) explain, "For bridging the gap between technology and users of technology, [creating a woman friendly culture] is not only desirable but also necessary" [67, p. 465]. Additionally, Foor et al. (US) expressed a similar sentiment when they cited William A. Wulf, former President of the US National Academy of Engineering, stating that the capability of the engineering profession to produce "elegant solutions" is dependent on the individual diversity making up the "gene pool" of engineers [68, p. 103]. Watson and Froyd (US) also cite Wulf, arguing that diverse perspectives and life experiences "bear directly on good engineering design" because they allow engineers to "effectively address current, complex socio-technical challenges" [32, p. 19].

5.3 Women's attributes

A third category of problematizations, again related but distinguishable from the first two, centers around the desirable skills, traits, or abilities that women bring to engineering. It was distinguished from professional service and representativeness by the identification of specific skills or traits that were often related more to the internal relationships and practices of engineering, as opposed to external relationships with clients and customers or engineering products. This category is most similar to the second theme identified in the literature review: diversity benefits the contents and practices of engineering.

Some in this category are vague statements such as, "Women bring a much needed and different flavor to engineering and we cannot afford to lose them" [69, p. 9] (Australia). Others are more specific and explicitly identify the traits and skills they believe women bring. For example, "Female qualities of intuitiveness, flexibility and people skills . . . [bring] great value to the profession" [2, p. 3] (UK). And, "Women provide invaluable input to engineering teams where their intuition and communication abilities can make a change to the positive in the design and manufacture and supervision of

engineering products and tasks" [70, p. 389] (Ireland). Also:

> . . . *female* engineering students in Germany . . .remain interested in aspects of creativity and beauty in engineering activities more strongly than their male peers. Against this background, female students may continue to support change processes in engineering education towards involving more creativity and beauty into engineering education . . . [emphasis in original][6, p. 491].

Thus, female students are perceived to bring a range of different traits to engineering.

5.4 Social justice and equality

The final category of problematization concerns social justice and equality. As readers will see, the social justice problematizations are always accompanied by another justification, usually economic. Given the overlap of these quotations with other discourses, the relevant terms for this category have been italicized. This category of justifications is the only one that does not appear to stand on its own. For example, Walden and Foor (US) comment on, "the current climate of declining STEM enrollments and the *social* and economic need to diversify participation in STEM . . ." [36, p. 202]. Similarly, Felder et al. (US) state that, "For a variety of practical and *moral* reasons, steps must be taken to attract and retain more women in engineering curricula" [71, p. 151]. And Beraud (France) says that, ". . . the number of women involved in Engineering in Europe is increasing very slowly—too slowly! . . . From the point of view of *social justice* and efficiency such a situation appears unacceptable" [73, p. 435]. Trautner and colleagues (US) state that, "It is *unjust* and against equal opportunity laws when women are not equally recruited and retained in engineering" and that it is "*morally* and economically sensible to have women engineering faculty" [74, pp. 46, 50]. Paloheimo et al. (Finland) explain that underrepresentation "produces problems in terms of *labour market segregation* . . . and potential decelerated Gross National Product" [64, p. 1]. Labor market segregation could be interpreted as a social justice concern. Lastly, an article from India states, "Participation of women in the engineering profession is important from the viewpoint of national development. It is also an important factor in improving the *quality of life of women themselves*" [75, p. 631].

6. Discussion

Four categories of problematizations were found in the dataset: economic competitiveness, professional service and representativeness, women's attributes, and social justice. As discussed in the literature

review, economic competitiveness has been a common and compelling framing of the problem of underrepresentation and lack of diversity in both STEM fields and business more broadly, so it is not surprising to find that this discourse is popular in engineering education research as well. However, the popularity of such arguments does not mean that they can be thought of as purely facts not deserving of critical reflection. Given the connections between how underrepresentation is framed and actual changes that can and have occurred in engineering education [16, 20, 22], and given that economic competitiveness arguments have been used since the 1980s yet underrepresentation persists and many in the profession are not concerned about it [4, 11], it would seem that examinations of and reflections upon the accomplishments and critiques of this discourse are warranted. In fact, challenges to this discourse may actually be making their way into engineering education research, as seen in Ihsen's assertion that although discussions of underrepresentation have thus far been fueled by economic needs, it is imperative to move beyond that conceptualization of the problem [6].

Likewise, the literature has pointed out potential problems with statements in the professional service and representativeness category. Namely, we cannot assume that simply adding women to the profession will necessarily result in change and that if changes are to occur, attention will need to be paid to identifying facets of the culture that serve to maintain the status quo or inhibit the stated benefits of diversity from being realized. The statements in the women's attributes category also deserve further reflection. Unreflectively ascribing certain traits to women and other groups has been thoroughly critiqued [14, 16, 22, 52, 55]. Awareness of those critiques could help prevent the unintentional reinforcement of gender stereotypes that contribute to the problem and thus undermine efforts to correct it. It is also worth noting that these arguments are related to so-called "soft skills," or social dimensions, which engineers themselves often consider to lie outside the technical heart of real engineering work [16, 22, 76–77]. Female students often have negative experiences in collaborative work despite the assumptions that it is something they enjoy [78]. Therefore, if engineering educators believe that such traits and skills are desirable, they have a stake in asserting that these skills and traits are both important for all students and capable of being cultivated in all students. They should not rely on enrolling new populations, whether or not they embody those traits, as a mechanism for changing the profession. As Jolly explains, "if the profession could find ways to value what it actually does over a stereotyped narrow vision of itself, it may well bring about changes that would ultimately attract a more diverse workforce" [22, p. 5].

Perhaps it is not surprising that social justice arguments are not found on their own, given the findings in previous literature that discourses of social justice or fairness have lost favor to economic competitiveness arguments [16–17] and prior literature documenting beliefs in engineering's neutrality (lack of biases) that limit the reach of social justice concerns in engineering [11, 13, 79]. While this may worry those who do consider underrepresentation a social justice issue, the importance granted or not granted to social justice problematizations should also concern those who would like to see both more and broader social justice and ethics issues in engineering curricula, beyond the specific situation of women's underrepresentation. To the extent that arguments for social justice, ethics, and fairness are not acceptable or persuasive problematizations of underrepresentation, how can we expect those same discourses to hold sway within engineering education curricula itself? Indeed, it has recently been argued that social justice outcomes should be placed above or equal to economic ones and that if engineers became more sensitive to fairness and democracy it will positively affect their work [16]. Thus, the boundaries of discourses of underrepresentation have implications for boundaries of engineering and engineering education more broadly. Finally, the social justice category is the only category that frames underrepresentation as a problem for women themselves—because they are subject to unjust, unfair, unethical, or immoral barriers that prevent them from entering engineering in equal numbers. In the other discourses, underrepresentation is a problem for entities such as nations, businesses, or women as consumers. The conceptualization of whom underrepresentation is a problem for matters because the conceptualization of a problem shapes what questions are asked, what actions are possible, and who really benefits from those actions [16, 19, 22, 45, 80].

Given that the issue of underrepresentation—and diversity more broadly—is a complex problem with many different stakeholders, the range of arguments is likely needed because different problematizations will appeal to different people. Using a variety of arguments could be a sound strategy to appeal to as broad an audience as possible. At the same time, reflexivity and critical analysis of those arguments could help ensure that the discourses engaged do not perpetuate the very problem they are intended to correct. Reflexivity means identifying, questioning, and reflecting upon one's assumptions, preconceptions, and behaviors, and it is necessary for changing and challenging established ways of acting and thinking [23, 81]. Because a feature of discourse is

the way in which it makes certain problematizations (perhaps most notably economic ones) appear as normal and unproblematic—thus compelling scholars to frame their arguments in certain ways—reflexivity about those framings can be difficult. In this regard, engineering education scholars could benefit from work in other fields that has already grappled with these discourses and identified their potential pitfalls.

We now have the benefit of looking back over the many decades in which underrepresentation has been discussed. We can see how the popularity of certain discourses is a product of history, not any Truth inherent within them. Moreover, we can examine what, if any, change a given discourse has actually helped accomplish. In what ways or in what settings has it been successful? If it seems that a specific discourse has not led to desired changes, then it would make sense to reflect upon how it could be more extensively or better articulated to others and/or to question its continued use. This is not to suggest that everyone need agree upon a problematization, or that there is one correct or true problematization. However, to avoid perpetuating a discourse that undermines one's long-term goals for change, awareness of the critiques and implications of our discourse is needed. It is worth recalling here that, "New discourses may alter existing cognitive commitment and thus influence the values and beliefs of actors . . .discourse constrains action but also . . .opens ways to recreate society . . .specific solidified discursive commitments can be dissolved and social change can be brought about" [29, p. 263–64].

7. Conclusion

Four categories of problematizations of underrepresentation were found in the engineering education literature from 1995–2008: economic competitiveness, professional service and representativeness, women's attributes, and social justice and equality. Often, more than one problematization was used in the same article. These categories emerged through interpretation of the data and this analysis does not claim to be *the* definitive categorization scheme; rather, it is intended to begin a conversation around these issues in engineering education. Prior literature demonstrates that these discourses have histories and that scholars have highlighted limitations of each. Thus, wider awareness, and further discussion of, the limitations of each discourse and what each risks hiding could be an important part of both understanding and addressing underrepresentation and other gender biases in the field.

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