Our guiding star: engineering design. But where is it guiding us?

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As our society tackles the grand challenges, diversity in science and engineering is more important than ever. Gender diverse teams lead to better problem solving in science (Nielsen et al., 2017) and increased cultural diversity leads to innovation gains in engineering and design sectors (Neibuhr, 2010). However, much of the gender research in engineering has an implicit liberal feminism theoretical foundation, where the goal is to ensure equal rights, opportunities, and treatment of women (Beddoes, 2011).

Over the last decade, there has been increasing research to understand and address the deeper and fundamental problems about the culture of engineering education and the engineering profession (Riley, Pawley, Tucker, & Catalano, 2009). Researchers have critically questioned how the narratives within engineering education construct and define what is "engineering" (Pawley, 2012). It is evident we need to understand the embedded culture of engineering and how this presents a barrier to diversity. Specifically, this research will take a critical look at engineering design, and discourse used in publications on engineering design. Our objective is to gain insight into underlying dualisms, power, knowledge, and invisible inequalities within the culture of engineering education (Parson, 2016; Lerman, 2009).

This work uses a poststructuralist feminist lens informed by the techno-social dualism framework from Wendy Faulkner (2000). Using discourse analysis, we reviewed the top five cited engineering education journal publications on engineering design. This research will provide new insight into the culture engineering, growing and extending the work that other feminist engineering scholars have accomplished.

Engineering Design Research

Many scholars see engineering design the "central or distinguishing activity of engineering" (Dym, Agogino, Eris, Frey, & Leifer, 2005). Due to this, there has been significant effort in the field of engineering education research to understand how to effectively teach and assess design. Both CEAB (Canadian Engineering Accreditation Board) and ABET include *engineering design* as a required outcome of their programs. Additionally, both organizations include a detailed description of the engineering design process within their curriculum content definitions. The graduate attribute (CEAB) and student outcome (ABET) definitions are provided here. Similarities can be observed across both definitions, and it is notable that they both include a mention of cultural, social, and environmental considerations.

> An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations (Engineers Canada, n.d.).

> An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors (ABET, n.d.).

Engineering design is accomplished through the engineering design process. There is not a clear consensus on the design process, with models having differences in terminology used, order of steps, and pathways through the model (Carberry, Lee, & Ohland, 2010). However, generally it is shown as an iterative process that goes through 5-8 steps consisting of three primary themes: problem formulation, problem solving, and solution implementation (Bailey & Szabo, 2006).

Critics of the design process argue that our most vulnerable populations are often most adversely affected by design decisions, and they are the ones who tend to have the least influence on the process (Costanza-Chock, 2018). The structured nature of the design process leaves little room for creativity in how design problems are approached. Design processes are generally structured by the "matrix of domination: white supremacy, heteropatriarchy, capitalism, and settler colonialism" (Costanza-Chock, 2018, p. 2). Using the design process with universal design principles leads to the erasure of certain groups of people, particularly those with multiple intersectional identities that are disadvantaged in our society and underrepresented in engineering. An inclusive and equitable design process must be flexible and consider whose needs are being met (Riley et al., 2009).

Engineering Culture

Many scholars use discourse analysis to better understand the culture of engineering education. Through classroom observations and interviews, Christman (2017) found engineering education has "teaching methods and deeply entrenched beliefs that transmit inherent messages of a hierarchical discourse community, a community that is not friendly to women" (p. x). Faculty members express narratives of engineering that emphasize the "difficulty and elite character of the profession," often wrapped in implications that women and women's work are not a part of this elite brand of engineering (Pawley, 2009). However, the difficulty and elite culture of engineering is often rationalized by faculty members through a belief that "engineers are critical to society, and such demanding requirements are necessary so only the most capable students can become engineers" (Christman, 2017, p. 253).

Scholars have not only brought to light the masculine, elite, and individualistic narratives of engineering, but also that the culture of engineering is often invisible to those who partake in it and continue to promote it. Most faculty are not able to conceptualize the possibility they are upholding this culture of power, privilege and exclusion (Christman, 2017). Even female students do not "question the profession's central narrative about itself, [rather] the critiques of their marginal status are couched in the dominant ideologies" of engineering culture (Seron, Silbey, Cech, & Rubineau, 2018). Additionally, these perspectives are often challenged because the prominent ideologies of engineering culture, namely depoliticization and meritocracy, make issues of social justice appear irrelevant to engineering practice (Cech, 2013).

Theoretical Frameworks

This work uses a *poststructuralist feminist* lens, an approach modeled off Laura Parson's (2016) critical analysis of STEM syllabi. Poststructuralism rejects objectivity and the premise of a single reality and provides a foundation for examining dominant realities that have been constructed to serve "patriarchal or essentialist claims" (Hesse-Biber, 2014, p.43). In this framework, analysis of discourse and language is critical to deconstruct invisible inequalities and power structures (Parson, 2016), where "language is regarded as a constitutive of experience and not simply representative of it" (Hesse-Biber, 2014, p. 44). Using this lens to analyze the engineering design texts allows us to explore how language shapes our perception of engineering design. Specifically, along with this framework, we seek to deconstruct the techno-social dualism that is embedded within engineering design discourses.

Techno-Social Hierarchical Dualism

Wendy Faulkner first wrote about the techno-social dualism in 2000, where she describes the gendered aspects of the techno-social dualism in engineering. Within this, technical skills and social skills are often in mutually exclusive silos with limited cross-integration, where technical skills are valued over social competence (Leyva, Massa, & Battley, 2016). Specifically, Faulkner (2000) states that "at the core of engineers' identities and engineering practice lies a sense of the technical which specifically excludes the social […and this] technical prowess is what defines them as engineers and what makes them feel powerful" (p. 763). Explorations of this gendered dualism since Faulkner's article in 2000 offers "insight into different strategies that marginalized populations […] adopt in navigating the heteronormatively masculinized spaces of engineering" (Leyva et al., 2016, p. 6). However, this dichotomy does not reflect the heterogeneity and blend of real engineering practice in industry, thus there is a tension that arises within the division of labour. Women and minoritized individuals will assimilate valued forms of technical masculinity in the workplace in order to build positive professional identities. This techno-social dualism is used as a framework for analyzing engineering design discourses to deconstruct invisible messaging that may unintentionally create spaces that are not inclusive.

Method

This paper uses discourse analysis to review highly cited engineering education literature on *engineering design* and observe themes. The discourse analysis methodology and the dataset selection method are both described here.

Discourse Analysis

Discourse analysis is a qualitative method that allows for systematic analysis of textual documents. *Discourse* refers to "certain ways of using language, acting, interacting, behaving, believing, using tools, sign systems, and so forth, which characterize a particular community" (Allie et al., 2009, p.361). It can be defined simply as "language in use to do something" (Jones, 2012), where the meaning is derived from the social practices in which the discourse is embedded (Gee, 2004). Discourse conveys thought in a way that is "somehow prior and more essential than language" (Lerman, 2009, p.1). Gee says that "words have histories" (2004, p.54), and their meaning in the present is an artifact of the past, an outcome of past cultural situations, meanings, and models. The "storyline" connected to each word creates the unconscious cultural model within groups of people, where "linked networks of cultural models help organize the thinking and social practices of sociocultural groups" (Gee, 2004, p.81).

Discourses used in educational settings provide insight into underlying regulations, power, and knowledge (Lerman, 2009). Specifically, this research aims to analyze the language used to describe engineering design to uncover the underlying implicit cultures of engineering.

Dataset (ie. papers reviewed)

Papers for review were chosen based on number of citations. ScienceDirect, Scopus, Engineering Village, and IEEE Explore were used in the initial search to determine the most appropriate database. In the end, we chose Scopus as the database for the literature search, mainly due to the applicability of the articles and to the ease of sorting results based on number of citations. Initially, we tried different search words in order to settle on the appropriate listings.

- OPTION 1: TITLE-ABSTRACT-KEYWORDS("engineering design")
- OPTION 2: TITLE-ABSTRACT-KEYWORDS("engineering design") AND TITLE-ABSTRACT-KEYWORDS ("engineering education")
- OPTION 3: TITLE("engineering design") AND SOURCE-TITLE ("engineering education")

The top 20 articles from each search were reviewed for most applicability to the study at hand. In the end, the results from Option 3 were chosen for this study as the articles were based in engineering education journals and more focused on the approach for *teaching* engineering design. For this preliminary analysis, the top five articles were reviewed and qualitatively coded in detail. Future work will expand this analysis to add more articles from a wider variety of publications and years, see the *Future Work* section for more details. The five chosen articles are summarized below in Table 1.

Table 1. Summary of reviewed engineering design education articles.

Abbrev.	Full citation	Number of Citations (via Scopus, Jan 2020)
A1	Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of engineering education*, *94*(1), 103-120.	1613
A2	Atman, C. J., Adams, R. S., Cardella, M. E., Turns, J., Mosborg, S., & Saleem, J. (2007). Engineering design processes: A comparison of students and expert practitioners. *Journal of engineering education*, *96*(4), 359-379.	433
A3	Carberry, A. R., Lee, H. S., & Ohland, M. W. (2010). Measuring engineering design self-efficacy. *Journal of Engineering Education*, *99*(1), 71-79.	192
A4	Dally, J. W., & Zhang, G. M. (1993). A freshman engineering design course. *Journal of Engineering Education*, *82*(2), 83-91.	120
A5	Miller, R. L., & Olds, B. M. (1994). A model curriculum for a capstone course in multidisciplinary engineering design. *Journal of Engineering Education*, *83*(4), 311-316.	113

Findings

In line with discourse analysis methods, the findings are presented through quotes and passages from the five papers reviewed. It is important to note some of these quotes are paraphrased in the articles, based off engineering design work done by others. We have not included these citations, as we are analyzing the authors' discourse, which includes their paraphrasing approach.

As this analysis was done through the lens of poststructuralist feminism, the papers were reviewed with a very critical eye. It is important to keep in mind that in addition to the critical themes below, there is valuable information and research presented in each of the papers, which is evidenced by their high number of citations. In the findings we focus on highlighting the critiques observed from our analysis. However, first, we start with the discourses we found where there was more of a clear balance between the techno-social dualism.

1. Recognition in the importance of society in engineering design

Throughout the papers, it is evident the authors are aware of the importance of society in engineering design. A few of the papers defined the steps of the design process and included social elements such as "identify a design need" and "research a design need" (A3, p.74). These would need to be further defined in order to ensure students were properly considering the needs of their users and the impact on society. For example, one paper further defined the outcome to be "Appreciate and consider the non-technical constraints (ethical, political, aesthetic, environmental, economic, cultural, etc.) in their work" (A5, p.2).

Many of the findings which came out of the research also reflected on the importance of furthering this connection to society. For example, one of the authors recommended to "engage design coaches to help manage the contextualization of engineering design theory and practice" (A1, p.114). In another paper, the authors reflected that industry engineers had developed the ability to gather diverse information on the problem with "a higher concentration of issues regarding the user and issues related to the situation context" (A2, p.373). They considered this ability to go beyond the design specifications and consider the user an important skill for us to foster in our engineering students.

The authors were also sometimes able to recognize their own shortfalls, and the shortfalls of engineering design itself. One paper astutely noted that, "the decision-based design framework assumes that designers make critical decisions only *after* design concepts and alternatives" (A1, p.107). Another, noted that we are sometimes constrained by "the often narrow technical confines within which engineering design is currently taught" (A5, p.1).

One paper modeled appropriate design behaviour by doing need gathering themselves. Before developing their own capstone courses, they reached out to over 100 industry members to get their feedback on the important design attributes for graduates of engineering. Through this process they learned "engineering design courses need to do a better job of imparting skills which have not been associated with traditional science-based education" (A5, p.3).

2. Missing the substance – Society only discussed in introduction and conclusion

Although the first theme shows how there is a recognition of the importance of engineering design's integration with society, in our critical review we found it was mostly grand statements being made in the introduction and conclusion, without much real substance in the meat of the paper. This was most prominent in A4's paper. The second paragraph mentions the importance of covering "social issues like the environment" (A4, p.83), and in the conclusion they conclude the students "have shown significant progress in […] developing an appreciation of the engineering involved in creating wealth for society" (A4, p.90). Whereas, during the textual analysis of the remainder of the paper, there were almost no other codes for *society*.

This is again evident in A1, where the second sentence of the paper states "programs should graduate engineers who can design effective solutions to meet social needs" (A1, p.103) implying this is a priority for the paper. However, there are limited further mentions of society, mostly coming during the introduction of future sections. In section II.D they start with "to an increasing degree, design is being recognized and taught as a team process with multiple socio-technological dimensions" (A1, p.107), and in section III.C, they start with "today's engineer must design under – and so understand at a deep level – constraints that include global, cultural, and business contexts." Although they continuously come back to this social element, there is little other discussion of it. A5 states in their second paragraph we "the need to better integrate liberal arts studies into engineering education and, in particular, to provide students with a design experience that encompasses technical, humanistic, and socially relevant aspects" (A5, p.1).

These grandiose introductory sentences left us feeling let down. Our analysis seems to indicate that engineering design papers use “needs of society” as a buzz word to emphasize the importance of engineering design work, without follow through in how the social side is actually integrated into the design. As the next theme will show, the papers tended to lean instead towards more a technical bias in the body of the paper.

3. Technical design valued higher than non-technical considerations

The most common code by far across all papers was the emphasis on the *technical* design process. Although the technical elements of design are important, they were not well balanced and tended to imply that technical design was the dominant and more powerful activity. For example, although A5 had the most progressive statements on society integrated throughout their paper, when it got down to the actual project it was still heavily focused on the technical. After the students’ first semester, they submitted a proposal document which included “the design team’s preliminary engineering analysis and design work, [and] a detailed work statement, proposed budget, and project completion schedule” (A5, p.3). Students will interpret the importance of activities based on those included in the proposal, and there is no requirement to include any societal considerations of their project. This paper also states in their conclusion that students gain an understanding of “the basic philosophy of engineering design” which is implied to be only the technical activities “open-ended problem-solving abilities and engineering analysis” (A5, p. 4). This actual reported student experience feels contradictory to the quote from the previous theme where the authors of A5 were emphasizing the importance of the humanistic and socially relevant aspects of design.

During the design decision process, the papers emphasized the importance of them being “mathematically or scientifically sound” (A1, p.107). Another paper took it further saying:

> A design process in industry, regardless of the product under development, is focussed on developing a quality product that is reliable and profitable. […] A good engineering design not only ensures outstanding performance, but also offers ease in manufacturing piece parts and facilitates the assembly. (A4, p.84)

Both quotes put technical solutions above all else, emphasizing the importance of the technical prowess of engineers to solve problems. This is furthered by the limitation of design knowledge including only “knowledge of design procedures, shortcuts, and so on, as well as knowledge about design objects and their attributes” (A1, p.108). This statement distances design from any real human or societal connections, and implies design is only connected to the physical objects created, without any consideration of how these objects will interact with the world around them.

When breaking design down into a process or set of outcomes, there was almost always a technical bias to this list. For example, A4 had “three fundamental phases” of the product design process: “design, manufacturing, and assembly” (A4, p.83). Within these three phases, they had a list of 22 product design steps, and only *one* of these *may* have implied the need to engage stakeholders – “definitions of design specifications” – although the use of the word *definitions* implies that the engineers would be the ones making the decisions on these specifications (A4, p.84). In another paper, when evaluating the quality of design, the rubric outcomes were broken into “diversity of [playground] activities, aesthetics, protection from injury, uniqueness, and technical feasibility” (A2, p.368). Although this project had intentionally given participants extra pieces of information about societal facts (such as information about the area, labor availability and cost, and neighbourhood opinions), they still did not evaluate the final design based on the ability of the engineers to integrate these considerations. It is evident that the technical design features were valued more than the societal features. Within the technical focus, there is also an implied notion that there is one right solution, that we can apply “proven principles […] to analyze a problem to reach verifiable, ‘truthful’ answers to a solution” (A1, p.104).

4. Social and environmental impact an afterthought, an imposition

When the social and environmental impacts were discussed, they were often an afterthought. After first having a long list of technical considerations, the papers would *then* mention society. For example, A2 has a lengthy paragraph on questions to consider when analyzing design, and it wasn’t until the last question that they included, “Also, when a design in intended for a target population, how do we learn about the quality of the solution in the eyes of that population?” (A2, p.363). The same paper provides three main implications of their findings, one of which is to improve students’ abilities to scope a design problem and gather information required (A2, p.376). Although it is the first implication listed, this implication is not expanded on, and it doesn’t include any citations (whereas the other two do). The authors didn’t feel it was important to clarify how this needs to be done, and just assumed that we need to make it happen, somehow.

Many papers mention social and environmental impact, but the language used imply that it is an imposition to the engineering design process. For example (emphasis added by me):

- “**Further**, designers are **now** required to expand the boundaries of the design to include such factors as environmental and social impacts in their designed systems” (A1, p.105).
- “**In addition**, and for several reasons [without expansion on these reasons], ethics and social impact have **become part of the fare** of both cornerstone and capstone courses.” (A1, p.109)
- “Usually the topics covered in this course include orientation, graphics, a computer programming language, ethics, and **often** social issues like safety and the environment” (A4, p.83).

In another paper, from one section of the paper to another there was a mistake in consistency of the language they used, and one of the aspects of designing systems was changed from “recognizing the systems context” to “thinking about system dynamics” (A1, p.105-106). Although likely just an accidental error, it is interesting to observe how the authors moved from focusing on the *context* to using more technical language like *dynamics*, as if it was an afterthought and they didn't actually consider the contextual factors, so they renamed the section.

Another afterthought came from the authors' choices in demographics collection. In A2, they explicitly asked industry participants if they recently visited a playground. However, they decided it was unimportant to collect this information from students because they assumed the students "were closer to an age where they themselves would have used a playground, or could also have taken children to a playground as a babysitter." (A2, p.375). This decision feels like the authors felt it was a hassle to consider the social backgrounds and experiences of the students. It is a huge assumption about privilege made by the authors, assuming all students would have had access to playgrounds and babysitting jobs during their youth.

5. Lack of collaborative language, design is something we do to others

The verbiage used throughout the papers implies engineering design is something we *do to* others, not in collaboration *with* others. Here is a summary of some of the verbs and other words used (emphasis added by me):

- "…design effective solutions to **meet** social needs" (A1, p.103)
- Definition of engineering design is to "**achieve** clients' objectives or users' needs while satisfying a specified set of constraints" (A1, p.104).
- "… **for** whose benefit the designed artifact is being developed" (A1, p. 104)
- "…[design] questioner attempts to converge on and **reveal** 'facts' " (A1, p.105)
- " … 'good design' dictates that technology can and should **serve** all members of the potential user population, including those traditionally underrepresented with technology" (A1, p.108).
- Information included "**issues** regarding the user and **issues** related to the situation context" (A2, p.374).
- "…to **meet** an identified need" (A3, p.71)

Although some of these are all too common to us, we can be complacent in using language that implies engineers have all the solutions and we provide these to others, rather than clarifying the necessity of working collaboratively with others to come to these solutions together.

One of the papers specifically dives into the idea of design thinking as divergent-convergent questioning where "questioning is clearly an integral part of design" (A1, p.104). This statement is furthered by saying that "knowledge resides in the questions that can be asked and the answers that can be provided" (A1, p.104). This perspective is problematic, as it puts the engineer in the active, dominant role and others/society in the passive role. The engineer is the one that controls the conversation to get the information they need, rather than framing it as the engineer being the passive listener and the others/society being an active participant in the design process.

6. “Social” a synonym for teamwork, without considering “social” in terms of societal impact

Teamwork is an important attribute for successful engineering design work, we am not debating this. However, during this analysis we realized that often the dual meaning of “social” means that the societal impact is lost even further as it is buried under a discussion about teamwork.

For example, A1 starts off a section with the need for multiple “socio-technological dimensions” including ABET criterion 3(h) “addresses global and social impacts” (A1, p.107). We assumed this section would address how engineering educators need to foster this attribute in our students through the design process. However, the remainder of the sections just focuses on “design as a social process” and the teamwork required to succeed in design, without any societal mention.

Another spin on teamwork that leads to implicit misunderstandings is how teamwork is used as a checkbox for students learning how to gather multiple perspectives. This was a frequent discourse used across many of the papers:

- “early states of design are ‘inherently argumentative,’ requiring the designer to continually raise questions […] and argue with others over the advantages and disadvantages of alternative responses” (A1, p.107).
- “This review process [with other team members] highlights the important issue that the product design should be approached from multiple perspectives” (A4, p.88)
- “The structure of the course eliminates the narrowness of a single perspective” (A4, p.90)
- “…multidisciplinary design teams tend to produce better engineering designs, presumably because of the broader range of expertise available to the team” (A5, p.4).

Although all the quotes above lead us to believe that students are obtaining a wide variety of perspectives, in each situation they are working on teams with their peers, and in the latter one, with peers from other engineering disciplines. We do not deny the importance of teamwork and working together with other engineers from different backgrounds, but caution the blanket statement that this provides our students with *multiple* perspectives.

7. Other common themes

There were a few other common themes that emerged from the coding process worth mentioning. Firstly, is the idea of *abstract / concrete dichotomy*, which is one that Faulkner (2000) discusses. This is highlighted in discussion around questioning in the design thinking process: “… convergent questions operate in the knowledge domain, whereas divergent questions operate in the concept domain […] concepts need not have truth, whereas knowledge does. Design thinking is thus seen as a series of continuous transformations from the concept domain to the knowledge domain.” (A1, p.105). This discussion is parallel to Faulkner’s (2000) discussion, where the divergent / conceptual domain is more abstract, and the convergent / knowledge domain is concrete. Similar to Faulkner’s findings, the paper goes on to say that we de-value the abstract thinking, and we should have “more emphasis on experimentation [ie. divergent domain] as a design activity.”

There was also mentions of how engineers tend to just *re-use old designs* and this is acceptable practice, where "design experts may have a rich repertoire of precedents that could be adapted to new situations, [as such] experts may simply develop good first alternatives" (A2, p.362). Additionally, in A4 where the project requires students to build a new playground, for their site visit they only view an existing playground so they can "…modify the existing designs of swing set and incorporate their own concepts" (A4, p.85). Implicit in this process is the idea that designs can always be re-used, as the technical components are sufficient and we don't need to consider the social context of the new environment in our design.

Lastly, there was some discussion around *systems thinking* and how "one of the challenges of systems design is that, as the number of variables and interactions grows, the system stretches beyond the designers' capability to grasp all the details simultaneously" (A1, p.106). However, all engineering design has large number of variables with interactions when we consider the social impacts of engineering work. It was not until the consequences of engineering design impacted elements without our own systems that we need to expand our ability to do systems engineering. The paper goes on to say that "engineering and mathematics education was a significant benefit for the simpler tasks studied, but was far from significant in its beneficial effects on the more difficult tasks" (A1, p.106). This sentence is the key – if we can deconstruct the dualistic thinking and *integrate* society and the environment to be part of our engineering system, then we already have the necessary engineering and math skills to solve any problem.

Discussion and Conclusions

The findings above highlight the implicit culture within engineering, specifically in how *engineering design* is discussed in engineering education literature. Summarizing the themes, there are two main findings that were brought to light through this discourse analysis.

Firstly, we like to talk about social impact of engineering as a buzz word, however we take little action to actually value and work on fostering these skills with our students. This was evident across themes 2, 3, and 4. Technical design was valued higher than social consideration in design, with technical typically taking up most of the papers' substance, whereas social was most frequently emphasized only in the introduction and conclusion. Social was also framed in way that made it appear to be an afterthought or an imposition to the "real" design activities. Our language here implies to our students that the social impact doesn't matter – as long as the solution is technically sound, it is a good solution. This also came through in *7. Other common themes* where we tend to encourage engineers to simply re-use old designs. How can a student know if a design is viable in a new context if they are only told to look at the technical aspects of an existing design?

Secondly, integration of society implications gets lots under the umbrella of teamwork. This was observed across themes 5 & 6. We were surprised in our analysis to realize how often we say that students gain *multiple perspectives* from group work. Although this is true as we have a great diversity of students where they can learn from each other, it is also important students understand these perspectives are still all coming from a similar vantage point – from that of an engineer. The language we use to talk about engineering design further emphasizes this, where it is something we *provide in service* of society, that we *reveal* the *issues* of our society, and then we work *for* the public to give them our solutions. The hierarchical undertone in these words is palpable. And this type of discourse is what leads us to conflicts such as those with indigenous populations. Our engineers have been trained to believe that gathering a variety of perspectives means talking to our team members, with maybe one meeting with external stakeholders. Our language implies we don't truly need their input because we know what is best for them, and our approach is the best approach.

In order to change the engineering culture, we need to change the language we are using and the implicit information we are conveying through our language. The findings of this work highlight important areas for improvement in how we talk about engineering design in order to educate students with a holistic world perspective that *integrates* societal, cultural and environmental considerations.

Future Work

The analysis of these five papers was the first step in this research. The next phase will include adding additional papers using different search terms to expand the variety of literature analyzed. For example, we will review engineering education publications with engineering design (same as within this study), however including only results from the last five years to have more a more recent perspective. Additionally, it will be important to analyze non-engineering education publications with engineering design and conference publications with engineering design. By broadening the scope to include these different publications venues, the goal is to understand if engineering design is conceptualized differently, or if the same dualisms are observed regardless of the publication source.

References

A1 → see (Dym et al., 2005)

A2 → see (Atman et al., 2007)

A3 → see (Carberry, Lee & Ohland, 2010)

A4 → see (Dally & Zhang, 1993)

A5 → see (Miller & Olds, 1994)

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