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Power over and power with: integrating the concept of power into design team and stakeholder interactions

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As professionals in the workplace, engineers often have high levels of power or social influence over other people or groups they work with, including in decision-making, project planning, and other professional activities. The concept of power has received considerable attention in the social sciences and humanities but has received less attention in engineering education. Despite this, power is a crucial topic for engineers to understand as they are constantly navigating power dynamics across many groups of stakeholders. In this space we introduce the concepts of *power over* and *power with* into a two-semester senior engineering design capstone course through a series of activities and project scaffolds. Briefly, *power over* involves an actor being able to constrain the actions of another whereas *power with* involves an actor being able to empower or enable another actor to take new actions. Students were taught a framework that combines the concepts of *power over* and *power with* to reconsider and transform their interactions with stakeholders. We employ a case study to show how these concepts were integrated into the class and use directed content analysis of students' final design reports to analyze the degree to which students were able to apply this framework. The results first highlight how activities over the semesters helped students learn the framework and later apply them. Next, the results of the content analysis indicate that students were able to share *power with* several stakeholders and recognize some instances or risks of *power over*, although some gaps remained with how power was reported or recognized. This work extends and adapts concepts of power from the social sciences and humanities to the field of engineering education, argues for the importance of covering both *power over* and *power with* in classes and provides some evidence of the productive beginnings of engineering students using these concepts. We close with implications for other engineering classes and future research.

KEYWORDS
human-centered design, engineering education, power, empowerment, engineering design

1 Introduction

As professionals with well recognized areas of expertise, engineers often are granted high levels of power or social influence over other people or outside groups they work with, which manifests throughout project decision-making, planning and outcomes, and other aspects of their work. This is sometimes referred to as expert power (French et al., 1959). Power as a topic of inquiry has received considerable attention in the social sciences and humanities (Foucault, 1980; Lukes, 1986; Wartenberg, 1991; Avelino, 2021; Pansardi and Bindi, 2021), but typically receives limited attention or direct use in engineering education. Despite this lack of attention, power is a crucial topic for engineers to understand and weave into their practice. While most engineers will attempt to exercise the power they have judiciously, misunderstandings or minimal awareness can lead to engineers speaking for users or stakeholders and/or ignoring critical stakeholders or user groups. Subsequently, any project outcomes will suffer as a result and designed products or systems may underperform or be wholly inappropriate for some groups.

To begin to address this gap, the present work reports on a two-semester senior capstone design class that integrated the *power over/with* framework into the learning outcomes and student team performance expectations. This course was explicitly grounded in three frameworks: human-centered design for more deeply integrating users and stakeholders through the design process (Zhang and Dong, 2009; Zoltowski et al., 2012), liberative pedagogies for promoting greater equality between teachers and students (Riley, 2003) and citizen engineering for more deeply understanding how engineers work impacts their local community (Douglas et al., 2010). These three frameworks all reflect considerations of power between design teams and stakeholders across the design process; consequently, we were able to integrate concepts of power throughout the curriculum, both as a matter of learning and application to design teams' interactions with clients, users, and stakeholders. Liberative pedagogies also holds implications for instructor and student interactions.

In the social sciences and humanities literature on power, theoretical work has begun to outline interrelated forms or dimensions of power. Of particular interest for engineering education are the concept of *power over* and *power with*. *Power over* is defined as the ability of an actor to constrain the choices or actions of another actor (Pansardi and Bindi, 2021), whereas power with refers to the ability to empower other actors or groups to take actions or choices they may have not been able to otherwise employ (Arendt, 1970; Wartenberg, 1991; Held, 1993). We explicitly draw on these and related theories of power from social science and humanities to inform how we created this class and prepared and scaffolded students to interact with stakeholders. In education research and practice, theories give us the ability to recognize, describe, and respond to some phenomena (Magana, 2022) and therefore these theories helped us introduce and discuss issues of power in engineering. Moreover, power is a multifaceted and widely debated phenomenon with many definitions, subcomponents, and related concepts (e.g., see Olsen and Marger, 1993; Avelino, 2021; Pansardi and Bindi, 2021) so drawing on these theories allows us to better focus and ground our class and activities for students and help them recognize where, when, and in what ways power may be at play.

To assess the impact of the framework on engineering students understanding of *power over* and *power with* and their ability to engage in the productive beginnings or emergent forms (Hammer et al., 2012; Watkins et al., 2014; Goodhew and Robertson, 2017) of using power analysis in their interactions with stakeholders, we analyze their final design reports guided by our research question:

In what ways and to what extent do students employ the concepts of *power with* and *power over* when reporting on their interactions with stakeholders?

In the remainder of this paper, we review past literature on power, with a particular focus on *power over* and *power with*. The review also draws connections to some design approaches, such as human-centered design, and the design justice movement. Next, we describe our senior capstone design class context, and how we drew on three frameworks, human-centered design, liberative pedagogies and citizen engineering to construct the class and embed concepts of power within the class. Following this, we provide a more detailed description of activities and pedagogical supports that had students engage with both *power over* and *power with*, in class and in their project interactions with users, clients and stakeholders. We then share results of a content analysis of student teams' final design reports that uncovers the ways in which employed or recognized instances of *power with* or *power over* in their interactions with stakeholders, users, and clients. Our discussion focuses the importance of addressing both *power over* and *power with*, and summarizes the key insights from the analysis of student's design reports. The paper draws to a close with implications for incorporating concepts of power into other engineering classes and highlights future directions of research on power in engineering education.

2 Literature review

The power that individuals or groups have has been heavily theorized across the social sciences and humanities (French et al., 1959; Lukes, 1974; Foucault, 1980; Lukes, 1986; Castells, 2011; Avelino, 2021). Similar to many other areas in the social sciences and humanities, these theories have resulted in multiple frameworks and theories rather than a single definition. Indeed, attempts to summarize this work has led to compilations of theories of power (Lukes, 1986; Olsen and Marger, 1993) or work that discusses common themes without necessarily producing an integrated definition (Avelino, 2021). Historically within this work researchers have argued over the nature of power and made attempts to arrive at a singular definition (Pansardi and Bindi, 2021) or sometimes synthesized past theories into a more comprehensive theory of power (e.g., see Lukes, 1974; Haugaard, 2012). However, over the last several decades theorists are increasingly recognizing that power may have multiple distinct co-existing forms including both *power over* and *power with* Allen (1998), VeneKlasen and Miller (2007), Avelino (2021), and Pansardi and Bindi (2021). We address research on both of these forms of power below.

2.1 Power over

Most of the early theories of power focused specifically on what is now often called *power over* (Lukes, 1986; Allen, 1998). One of the foundational definitions of *power over* comes from the German sociologist Max Weber, who stated: "'[p]ower' is the probability that one actor within a social relationship will be in a position to carry out his own will despite resistance" (Weber, 1993, p. 37). Several theorists have continued to build on and expand earlier notions of *power over*. For instance, Lukes (1986) synthesizes three faces of power, which draws distinctions between more overt conflict between parties, as seen in Weber's definition and more covert forms of power like removing potentially contentious issues from discussion.

Looking more deeply into *power over*, French et al. (1959) identified several types of power: reward, coercive, referent, legitimate, and expert. Legitimate and expert power are the most relevant to the discussion at hand. Legitimate power is a type of power that is perceived as normatively correct or appropriate in society. For example, at work it is usually viewed as appropriate for a supervisor to assign tasks to a subordinate. Assigning tasks is a legitimate part of the supervisor's role, even if it forces a subordinate to take actions they may not want to undertake. Legitimate power is often tied to positions of authority, like a manager or government official. Legitimate power may have legal support as well. Expert power comes from perceptions that an individual has specialized knowledge or skills. For instance, city officials will view a civil engineer planning a bridge in town as having expertise in infrastructure and thus appraise their plans positively (on technical grounds, but not necessarily financially). Critically, expert, and legitimate power are only held by some groups or individuals and thus create power differentials (French et al., 1959; Mills, 1959).

2.2 Power with

Theories about *power with* are newer, reflecting an ability to empower other actors or for several actors to work collectively toward shared objectives (Allen, 1998; Pansardi and Bindi, 2021). *Power with* owes its origins largely to feminist theories (Wartenberg, 1991; Allen, 1998) as well as the political philosopher Arendt (1970). Arendt never used the term *power over*, but she made a distinction between violence and power. Whereas violence involves rule or command over others, including through "implements" (e.g., weapons), power is" the human ability not just to act, but to act in concert" (Arendt, 1970, p. 44). According to Arendt, this power cannot be reduced to an individual and can be used to empower others.

Turning to feminist researchers, while several focused on *power over* as reflected in men's gendered domination of women in society (Allen, 1998), an additional strand of research sought to uncover the unique type of power held by women (Wartenberg, 1991). These theorists argued that women in traditional gender roles provide support to others and work together toward shared goals (Gilligan, 1982; Held, 1993; Allen, 1998) which is a different form of power than *power over*. Later theorists have extended these arguments to show how *power with* can be practiced more broadly and not just by those in specific traditional gender roles (Wartenberg, 1991). In a related vein, Wartenberg (1991) introduced the concept of transformative power, which complements the work on *power with*, although Wartenberg himself viewed transformative power as not distinct from *power over*. Transformative power is exercised when an agent uses their power to empower a subordinate agent (Wartenberg, 1991). While different definitions of *power with* or related concepts like transformative power put a greater emphasis on either collective/shared action or empowering others (Arendt, 1970; Held, 1993; Allen, 1998), it is perhaps the notion of empowerment where *power with* makes the clearest break from *power over*.

An example of *power with* could involve a team of mechanical and electrical engineers working on product design. After completing research on a problem area, including interviews with potential users or stakeholders, the team has generated a series of conceptual sketches to explore possible solutions. The team could then share their sketches and elicit feedback, new criteria for evaluation or prioritization of criteria from the same users and stakeholders, as a way of sharing *power with* them.

2.3 Power in prior design and engineering education research

There have been a few spaces within engineering education research or EER where power has been discussed, including human-centered design or HCD. HCD refers to a collection of design approaches, such as user-centered design, participatory design, and empathic design (Sanders and Stappers, 2008; Van der Bijl-Brouwer and Dorst, 2017; Mohedas et al., 2020; Sanders et al., 2023), that share several core attributes. These core attributes include taking a more holistic view of stakeholders and users, bringing them more centrally into decisions about design artifacts, and more fully integrating users and stakeholders throughout the design process (Zhang and Dong, 2009; Zoltowski et al., 2012). HCD is a broad umbrella term and following this how *power with* or *power over* is addressed implicitly or explicitly varies across associated HCD approaches. Some, like empathic design, focus primarily on more deeply integrating stakeholders into the design process and compelling designers to develop deeper understandings of their particular needs (Tellez and Gonzalez-Tobon, 2019). In this way, empathic design and other HCD approaches like it primarily reflect efforts for greater *power with* stakeholders or users.

Conversely, some other HCD approaches like participatory design acknowledge conflict between different stakeholders and emphasis power imbalances between groups (Bødker, 1996; Bødker et al., 2022). These commitments in participatory design reflect a greater emphasis on *power over*. However, it is worth noting that many of the methods used in participatory design, similar to empathic design above, rely on greater integration of users or stakeholders into the design process. Therefore, both *power over* and *power with* are reflected in some HCD methods on the other side of the spectrum like participatory design.

Another adjacent area in design research that reflects both *power over* and *power with* is the Design Justice movement (Costanza-Chock, 2020). This network has established 10 principles to guide design such as "We center the voices of those who are directly impacted by the outcomes of the design process" and "We work toward non-exploitative solutions that reconnect us to the earth and to each other" (Design Justice Network, 2018). In the first principle shared, there is a clear emphasis on increasing *power with* those impacted by design outcomes, whereas in the second the focus on non-exploitative solutions highlights the risk of *power over* designers may hold over stakeholders. Moreover, Costanza-Chock's (2020) work on Design Justice refers to the matrix of domination to explain the risks of *power over*. The matrix of domination is drawn from the work of sociologist and black feminist Collins (1990) to denote a system of interlocking social structures that may marginalize or privilege stakeholders in multiple ways (e.g., a black woman may be marginalized through two or more systems). *Power over* is thus deeply embedded into this network. It is important to note however, that both for HCD and the Design Justice movement, these concepts are rarely used directly, but they can be inferred from their methods, commitments, and values.

Turning more directly to engineering education, work on empathy in engineering design, which is a distinct area of work different than the specific approach of empathic design, argues that designers should develop a deep understanding of users which can then inform designers' decisions (Kouprie and Visser, 2009; Hess and Fila, 2017). By empathizing with users or stakeholders, designers are empowering users and stakeholders by incorporating their views into the design process. Some related work in EER has also explored power dynamics between students and instructors. Cieminski and Strong (2017) examine power dynamics during design reviews. They explore two cases, a mechanical engineering (ME) and industrial design (ID) review. Drawing on a discursive theory of power from (Bartlett, 2014), they find more instances of disruption between instructors and students in ME. The authors note these represent the instructor holding greater *power over* enabling them to change the subject, have students return to prior content or other shifts in flow from students' presentations. Conversely, there were fewer instances of instructor driven disruption and greater back and forth discussions between students and instructors in ID. These interactions appear more similar to *power with*. The authors argue that the format of the design review, which differed between ME and ID, likely had a large impact on the type and number of power dynamics. In a related but broader work, Mejia et al. (2023) draw again on Patricia Hill Collins and her theory of domains of power (1990) to explore how engineering undergraduate students experienced power dynamics as part of their educational career. Similar to above, several *power over* dynamics were discussed including between faculty and students and between students themselves, as well as opportunities for empowerment or *power with*.

In summary, there has been some attention to *power with* and *power over* in the HCD literature and the Design Justice movement emphasizes both *power over* and *power with* as critical aspects of reconsidering what design should be. The present work and framework of *power with* and *power over* builds on the existing research and theory from the social sciences and humanities and is aligned with the commitments of the Design Justice movement and methods used in HCD that help build shared *power with* stakeholders or users. However, in contrast to many approaches in HCD, our framework has a stronger emphasis on both *power over* and *power with*. Additionally, in contrast with the Design Justice movement we more directly emphasize *power over* and *power with* as concepts that are proximal or relatable to engineering students' everyday lives instead of the matrix of domination which is important but may be difficult to teach and support within the context of a single course.

3 Methods and materials

3.1 Case study on the class

This work uses a case study approach to illustrate how *power over* and *power with* were embedded in a class. Case studies provide a thick and often multifaceted description of a unit of interest (Yin, 2003). A critical decision for creating a case study is defining the boundaries of what counts as the "case" or unit of interest, which is sometimes called "casing" (Ragin, 2009). Here the case of interest is the senior capstone design course itself. Case studies have been used before to describe specific classes, provide a deeper understanding of their structure, content and sequencing, and demonstrate how the class embodied new innovations to support learning (Poole, 2000; Cheaney and Ingebritsen, 2006). They may also include some evaluation of the course. Case studies on classes can support other educators to adapt, extend, and transform ideas from the focal class to their own classes or learning contexts. Our case study has three major components. First, we present activities or assignments that support students to learn about *power with* or *power over*. Second, we present ways students design projects were scaffolded to encourage them to apply these concepts in their project. Finally, we present an evaluation of the ways in which students recognized or applied this framework in their final design reports. Figure 1 provides flowchart of the major elements of the class, their timing, and what we assessed.

3.2 Content analysis of student team final design reports

To assess the impact of the course we analyzed student's final design reports to unveil the ways students did or did not recognize opportunities or risks of *power with* and *power over* in their interactions with stakeholders. Reports contained the following sections: introduction, project timeline and design process, detailed background and stakeholders, needs, metrics and constraints, concept generation, concept evaluation, testing set up and results, and recommendations and conclusion.

Reports were built iteratively during the duration of the senior design course (1 month of semester 1 and the entirety of semester 2). Sections of the final report were first submitted in the form of memos. The teaching team would then provide feedback and the students later submitted revised versions. This structure was designed to (1) keep students on track within their projects (2) demonstrate to the students that revision and iteration are necessary throughout the design process, and (3) so the instructors could further teach the students through feedback, and (4) to create a classroom atmosphere where learning was emphasized over grades. For portions of the final report such as problem definition, students turned in three versions over the course of the semester. Other portions, such as the testing plan and results, were submitted twice. Reports varied in length from 18 to 34 pages.

Our analysis focused on (1) what stakeholders/users/clients were mentioned throughout the report and (2) the nature of interactions or exchange between the design team and stakeholder/user/client as representing instances of *power over* or *power with*. The first part of this analysis used open coding (Strauss and Corbin, 1998) to allow different groups of stakeholders to emerge from the reports. The second part of the analysis used directed content analysis (Hsieh and Shannon, 2005) where codes are derived from a past theory and then texts are analyzed for these codes. This represents a more deductive approach, although it is possible to identify new codes based on the initial theoretically derived set, we focus solely on *power over*/*power with* codes for the purposes of this study. Definitions of *power over* and *power with* were derived from past theoretical work, including several authors who have synthesized the unique definitions of *power over* and *power with* Allen (1998), Avelino (2021), Pansardi and Bindi (2021), and Wartenberg's (1991) additions to *power over* that illustrate that it may not always cause negative outcomes. From these we developed the following definitions:

1 *Power with* happens when inputs to the design process and any design artifacts are shared between the design team and

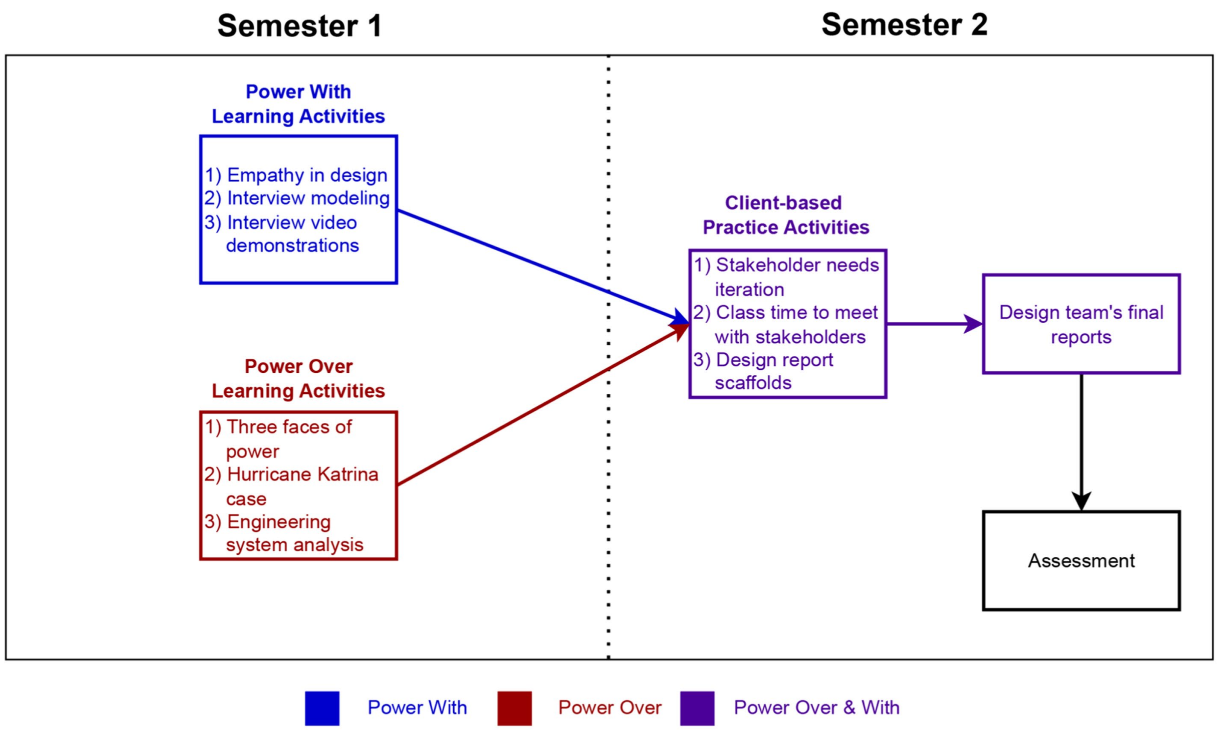

FIGURE 1
Instructional and research design of the case study.

stakeholders. *Power with* interactions reflect a high level of reciprocity between project partners, in other words, the insights, concerns, and views of one or more stakeholder groups substantively inform the teams design processes and/or outcomes.

2 *Power over* happens when inputs into the design process and any design artifacts are largely unilateral, with major decision-making coming primarily from the design team. When information or insights are gathered from others (i.e., stakeholders) they are largely filtered through the lens or goals of the design team and may not represent the original needs of the group. This is similar to Zoltowski et al. (2012) analysis of students' ways of experiencing HCD where stakeholders are seen as a "source of information" and not as reciprocal project partners. Such unilateral influence may also start with stakeholders and impact either the design team or other stakeholders.

For each team, we used these definitions to guide our analysis of how they interacted with each stakeholder they identified. In order for a stakeholder to be part of the analysis, the team needed to mention the stakeholder in at least two sections of their report or the stakeholder had to be discussed heavily within one section. This ensured we were not analyzing stakeholders the team rarely interacted with, as it would be difficult to assess if these represented *power over* or *power with* given limited information. Finally, in instances where the interactions between the design team and stakeholders were unclear in their final reports, we returned to earlier report submissions as an additional source to clarify any ambiguities in their interactions.

3.3 Class context

The class reported on here is a senior capstone course at a Mid Atlantic University with a large engineering college. The engineering degree itself is called Engineering Science and is multidisciplinary that allows students to create their own technical focus, which could be a set of classes from an established discipline of engineering like Electrical Engineering, or student identified or tailored areas, such as data science, where there is no formal degree. The degree is new so a capstone class had to be created for it, which gave the authors, who were also the instructors, substantial creative freedom. The case study covered here is from the first time the class was taught. Student clients were recruited from local nonprofit and community organizations. As mentioned previously, in creating the course, we drew on three frameworks, human-centered design, liberative pedagogies, and citizen engineering. A full discussion of how these frameworks informed the creation of the class was previously published (Schimpf and Swenson, 2022). Here we focus on how these frameworks informed how *power with* and *power over* were incorporated into the class. HCD, as previously discussed, emphasizes the need to more deeply and thoroughly integrate users and stakeholders throughout the design process (Zhang and Dong, 2009). Citizen engineering calls engineers to change their mindset from that of being solely embedded within a company or industry, to also being embedded in the communities and social groups who are affected by engineers' work (Douglas et al., 2010). Liberative pedagogies call on instructors to assess their own power and privilege in the classroom and refocus learning on student development, agency, and greater well-being (Riley, 2003). Synthesizing these frameworks, both HCD and citizen engineering encourage greater collaboration and integration of users, stakeholders, and local communities, which are areas were understanding the risks of *power over* and the opportunities of *power with* are critical. Moreover, liberative pedagogy explicitly addresses *power over* in the classroom between teachers and students. As we designed the course, we also drew implications from liberative pedagogies in how students interacted with each other and external clients, essentially encouraging students to examine their own power and privilege when interacting with classmates, clients, or others outside the classroom.

While these frameworks underscored the importance of incorporating *power over* and *with* into the class, we still had to consider when and how these concepts would be introduced. We took a two-stage strategy. In semester one, we introduced these concepts through readings, discussions, activities, and small projects. Students did not begin working with an external client until the latter half of the first semester, so we used the skill-building focus of the first half of semester one to help students learn the power concepts and allow students to apply them to class examples. In semester two, the focus shifted to supporting students to practice what they had learned in semester one as they worked with an external client, users, and stakeholders.

3.4 Participants

Participants were all enrolled in the same senior design capstone class for the Engineering Science degree. It was a two-semester course, with eight total students, split into either teams of three or two. The class was fully in-person and was taught in the early 2020's after COVID restrictions had been scaled back. Due to the newness of the degree, students would have limited experience working on client-based projects prior to this capstone course.

4 Results

In the results we first present the ways in which *power over* was embedded through learning activities in semester one, and then present the learning activities for *power with*. Following this, we describe the ways we supported or encouraged students to practice these skills in semester two as part of their primary design project with an external client. In discussing semester two, the practice or support activities are grouped together for the *power over/with*, as the support activities we provided students allowed them to employ either of these concepts as they saw appropriate in their project context. Finally, in the last part of the results, we present the findings from the content analysis of students' final design report, detailing incidents of *power with* and *power over* students exhibited with their project stakeholders.

4.1 Course integration of power over and power with

4.1.1 Power over: learning activities

One of the activities we had students undertake to learn about *power over* involved a reading and class discussion of work from British Sociologists Lukes (1974). In his book, Lukes presented a framework called the "three faces of power," where each face of power represented different types of *power over* including overt, confrontational uses of power between two parties, and covert manipulation of points of discussion and hiding potential decisions or choices. In the more covert expressions of *power over*, power is still operating but it is hidden or not directly expressed. The learning goals for this activity were:

1 Students will be able to describe each of these three faces of power and
2 Students will be able to apply this framework to engineering design situations where power may be operating.

Due to the sociological nature of the reading, the instructors provided a glossary of definitions beforehand. In class, we first discussed the reading, the different faces of power and why power was relevant to engineering (e.g., situations where they as future engineers may have expert power). Following the opening discussion, the instructors presented a series of hypothetical design scenarios and students worked in with a partner to discuss how they would respond to each scenario. For example, one of the scenarios prompted students to consider a design meeting where their client had repeatedly brought up a new design criteria, but the team had repeatedly responded the criteria was "out of scope." This was related to Lukes second face of power, non-decision making, where a potential decision is removed from discussion between parties due to some other reason (e.g., lack of time). The bulk of the class discussion was around these scenarios, how *power over* may be enacted or mitigated in them, and how students would respond to each scenario. This activity is discussed in greater detail in Schimpf et al. (2023).

In the second activity, students explored the nuanced complexities of engineering failures that exacerbated the aftermath of Hurricane Katrina, with a specific focus on the compounded influences of institutional racism and deficiencies in the levee system. Two readings were covered: (1) the impact of institutional racism and culmination of many decisions and policies that led to segregation and inequity in New Orleans (Henkel et al., 2006), and (2) the engineering failures of the levy system which left historically black neighborhoods at increased risk (Roth, 2013). The learning goals of this class included:

1 Students will be able to describe institutional racism in their own words and understand how this may interact with their professional engineering decisions.
2 Students will be able to apply ideas from these readings to understand the potential consequences of their decisions and how these consequences may affect racial groups differently.

Notably, the instructional approach underscored the imperative of factoring in geographical, social, and historical contexts in engineering decision-making processes to foster equitable outcomes.

Acknowledging the sensitivity of the subjects at hand, instructors implemented guidelines to facilitate respectful discussions, accentuating the potential lived experiences of certain students. These guidelines encompass encouraging profound and respectful listening, embracing diverse realities, posing compassionate questions, and challenging individual perspectives. The class received a comprehensive historical overview delineating racial inequities in New Orleans. Students were divided into groups for discussion, enabling students to collectively distill readings and explore converging themes in more intimate settings. The ensuing small-group discussions honed in on distinct facets of Hurricane Katrina. The first discussion revolved around students' prior knowledge and experiences related to the hurricane, while the second scrutinized the engineering failures, probing their implications for social injustice, racial disparities, and the broader ramifications for improved engineering practices. In particular the second line of discussion reflected examples of where engineers as experts and other stakeholders held *power over* others. For more information about this activity, refer to Schimpf et al. (2023).

After the two in class discussion activities, we wanted the student to think about and evaluate the power of various stakeholders in a real-world engineering scenarios. Students were asked to pick an environmental, ethical, or health related scenario that either was part of the greater university community or their home community. Then, they had to develop a list of the stakeholders from the scenario. Students had to choose three different stakeholders and analyze the power they had in making decisions in the scenario. Lastly, considering these power differences, students had to propose the best solution they saw fit to address the problem. The learning goals of this research report project were:

1 Students will be able to richly explore and analyze non-technical facets of a problem or engineering system.
2 Students will be able to analyze the power differential between stakeholders.
3 Students will be able to make recommendations to the problem to address non-technical challenges and observed differences in power for stakeholders.

The non-technical dimensions specifically included examining sustainability, having empathy, considering ethical decisions, and analyzing stakeholders' power. To scaffold this experience, we asked students to choose an environmental, ethical, or health related problem either from the local community of the university or the students' local home communities. For some students, they grew up local to the university area so these communities were the same. Most students chose problems very specific to their home communities and involved many state, regional, and city stakeholders. In most analyses, the state or city governments had the most power while residents, students, native tribes, or the natural environment had the least amount of power.

In most of the students' analysis, stakeholders had *power over* other stakeholders due to wealth/status or elected or organizational hierarchies. It was rare to find a scenario where *power with* was uplifting or aiding a group with less power. Many scenarios found state or local government officials had the most power due to the social and organization position given to them by elections. These scenarios found local communities of residents, students, or the environment had the least amount of power. Those with *power over* many times could decide who to side their *power with*, or use their *power over* to question, neglect, or uphold laws, but unfortunately did not make the choice to share *power with*. Our engineering students were able to see how power is unevenly distributed in these real life scenarios and how this lack of balance can hurt residents or the natural environment.

4.1.2 Power with: learning activities

One of our activities on *power with* involved a reading and discussion of a paper by Kouprie and Visser (2009) that introduces the concept of empathy into design. Empathy is defined as one person (or more) deeply understanding the needs and concerns of users or stakeholders by entering the "world." The article addressed different types of empathy including cognitive empathy, which involves taking other's perspectives and affective empathy, which involves feeling emotions for or with another person. The authors also discuss techniques for building empathy or empathic understanding, such as conducting research interviews or observations with users or stakeholders. The learning goals of this activity were:

1 Student would be able to define empathy, its different forms, and techniques used for building empathy.
2 Students will be able to apply empathic techniques to their own design process.

In class, we first reviewed what empathy was, its different types, and discussed techniques for building empathy with users, stakeholders and clients. At this time, students were working on a shorter design project about a problem on campus. Next, students were asked to come up with plans on how they would use one of the empathic techniques in their own design project. The rest of the discussion focused on sharing how students would apply these techniques to their project.

In another activity, we, the instructors, modeled an interview with a stakeholder during class, with one instructor as the stakeholder and the other asking questions to prepare students to conduct their own interviews. Part of this modeling involved asking a stakeholder to talk about a product they currently use, in this case one instructor's work bag, and to discuss any problems they have with the current device. The interviewer started by asking questions and progressed to more specific preferences with students from the class joining in with their own questions. This provided students an opportunity to practice what they saw in the interview demonstration and to receive feedback from the instructors on their questions.

The final activity involved a series of demonstration videos for interviewing and communicating with others created by one of the instructors. These videos were shown in class and covered topics including different interview techniques, types of questions, and common pitfalls. Students watched the demonstrations and then had a classroom discussion about what they learned for their stakeholder interviews.

4.1.3 Power over and power with: practice and support activities

At the end of the first semester, the student teams' final deliverable was a problem definition report which contained an introduction and problem statement, needs, constraints and metrics and an updated project plan for semester 2. After we reviewed students' problem definition report, we noticed several challenges with them including problem statements that were too solution focused, lack of integration of stakeholders needs or concerns, and underdefined needs and metrics. Consequently, the instructional team discussed what to do and decided to ask all teams to iterate on their problem definition report, with prompts to address these issues and more fully integrate stakeholders views into their report. This occupied the first several weeks of semester 2 and emphasized to students the importance of more fully collaborating with and understanding various stakeholders who may hold different levels of power.

Another support the instructors provided was dedicated class periods to arrange meetings with stakeholders. It took many prompts from the instructors to get teams to go outside of only talking to their client and talk to stakeholders. Having not been engaged in such a real-world design process before teams acted like initial meetings with their clients contained all the information they needed. This included no plans to meet with local community members (current users or future users) thus not considering those with less power. The instructors provided feedback to the students that they needed to seek these people out as well as class time to leave campus and have these meetings. Despite prompting and feedback, students still struggled to consider power within their lists of stakeholders and the instructors continued to prompt this issue at meetings between the design teams and instructors.

Our final mechanism for supporting students to apply *power over/with* into their main design project and process involved prompts embedded into their final design report and prior design report milestones. Some of these prompts encouraged reflection or integration of insights from either *power over* or *power with*, while other prompts targeted only *power with* or *power over*. For instance, in the first and second semester students were required to submit a stakeholder report that called for a summary of their interactions with clients, users, and stakeholders as well as sharing these groups' needs and concerns. Note we use the term stakeholder in the report name but it was intended to be inclusive of the three groups. These prompts were intended to encourage recognition of instances of both *power over* and *power with*. Another design report milestone, their concept evaluation report, where students had to evaluate their design concepts through a decision matrix, also requested students identify how each criteria was derived. Students were asked to share whether the criteria came from a stakeholder need or another source. This prompt more closely reflected *power with* as it encouraged students to include technical and design team derived criteria with those from users, clients, and stakeholders in their evaluations. Lastly, in their final design report students were asked to provide a summary of key stakeholders and their insights, a list of needs or criteria from stakeholders, and an analysis of the power stakeholders had or did not have. The final design report again offers entry points for integrating insights from either *power over* and *power with* into the document.

4.2 Student team's interactions with stakeholders

In this section of the results, we present the analysis of students' final design reports and how they interacted with stakeholders as viewed through *power over* and *power with* framework. We briefly outline the projects each team was working on to provide some context for the analysis. Some of these projects are still ongoing after the class ended, so the name of client's organizations and their locations are anonymized to avoid disrupting their work.

Design team 1 was working with an open-source technology company to develop a prototype tool to teach high school students the fundamentals of quantum computing. The design space included the possibility of physical interactives and/or digital interactives. Design team 2 was working with an environmental organization and municipality to develop a remediation plan for a decommissioned power plant site that is deeply contaminated with waste products from the plant. The final Design team 3 was working with a different environmental organization to design a solution for a public park that had experienced significant erosion along its riverbank. The final list of stakeholders and a count of instances of *power over* or *power with* from each team's report is displayed in Table 1.

Looking briefly at Table 1, design teams identified or engaged in many instances of *power with* and some *power over*. Note, when analyzing design reports, for sections like evaluation criteria or problem needs these were counted as one instance instead of individually by each need or criteria to avoid overcounting. However, if both *power over* and *power with* were present in needs or criteria, each was counted separately as one instance. Most of the instances in Table 1 start with design team and extend to their interaction with a stakeholder. Power over recognition, on the other hand, happened when teams recognized one stakeholder as having power over another stakeholder. Or alternatively, in the case of Design Team 3 they recognized when a stakeholder had *power over* themselves. While Table 1 provides a useful high-level overview, not all *power over* or *power with* had equal impact on the design projects. It also mattered if these instances appeared across multiple design stages. Therefore, below, we describe in more detail the key instances of power at play between design teams and stakeholders and how these shaped their projects.

4.2.1 Design team 1

Starting with Design Team 1, teachers were mentioned in the needs and criteria for evaluating concepts, sections. While this is promising, the needs and criteria mentioned from the team were largely unchanged from the original needs identified before the team spoke to any stakeholders. The needs mostly reflected classroom management issues such as "Time required for setup and reset," and "Ease of cleaning up after the experiment." Given that they were identified before any stakeholder interactions, this suggests minimal shared *power with*, and instead seems to represent *power over* by defining the issues for these stakeholders. The situation was different for students however, who were also mentioned in the team's needs and criteria. While some of the identified needs and criteria were identified by the team before interacting with any members of this group, unlike the teachers, they conducted user testing with students with an early prototype of their design. Students reported several parts of the web app to teach quantum computing were unclear and highlighted several interface inconsistencies. Based on this feedback the team revised their prototype, providing more support for the activities in the web app and addressing interface issues, showing a greater *power with* this stakeholder group and allowing their feedback to inform the final design. It is important to note, however, that the user testing happened primarily with an associated population, college students, as the team struggled to reach high school students directly. Given that student needs and constraints were mostly assumed by the team, but conversely that students were more deeply considered in concept evaluation and through user-testing, there appears to be a mixture of *power with* and *power over* in these interactions. In terms of their client, their input was referenced heavily in their framing of the problem and solution directions they pursued. For instance, in their background section, they note how they worked with their client collaboratively to scope the problem "After discussions with the client we decided that the two best options would be quantum entanglement and quantum computing." Some of the criteria they used for judging concepts likewise came from the client, suggesting they shared *power with* the client.

TABLE 1 Design team's stakeholders and instances of power with/over in the reports.

Design Team 1			
Stakeholder	Power Over Asserted	Power With Shared	Power Over Recogn.
High school teacher	2	1	1
High school student	3	3	0
Physicists and Researcher (client)	0	2	1
Design team 2			
Environmental org project lead (client)	0	3	0
Aquatic life	0	4	0
Natural environment	0	3	0
Design team 3			
Town residents	2	2	0
Town volunteers	0	4	0
Power plant owners	0	0	2
Local experts	0	2	0
Environmental org project lead (client	0	6	0

Interestingly, the team also identified a few potential *power over* risks they perceived in their project, primarily the client and teachers *power over* students. For instance, they explained "…[T]eachers, who have considerable influence over what educational tools are used in the classroom, may have different ideas about what the game should look like or how it should function." Here they are contrasting the views and preferences of the teachers compared to students. While the team identified these *power over* risks, they are not mentioned again outside of their stakeholder analysis, so it remains unclear if they saw these risks arise or how, if at all, the potential of these risks informed their design decisions.

4.2.2 Design team 2

Turning to Design Team 2, they in some ways exhibited the most diverse set of stakeholders as it included non-human entities like the natural environment (e.g., the shoreline and riverway) and aquatic life. While "stakeholders" like these cannot easily be interviewed or interact directly with an engineering team, researchers in environmental politics have argued that *power with* may be expressed through efforts like stewardship or advocacy on behalf of the natural environment or wildlife therein while *power over* may be expressed through exploitation or similar actions (e.g., see Partzsch, 2017). In this context, it was largely the client who acted as an advocate both for the natural environment and local aquatic life. Looking specifically at the team's interactions with each of these stakeholders, their client had considerable input on the framing of their problem, as well as the needs the team recorded and criteria used to judge design concepts, suggesting these interactions reflected *power with*. For instance, while discussing the needs the team identify, they document thoughts from the client "the clients [*sic*] would like the design to contain the least amount of contaminants as possible so the team can keep the shoreline as eco-friendly [and] be made out of natural materials that are able to support the local aquatic vegetation".

The natural environment was highlighted in several of the needs and criteria the team used, including minimizing damage to the shoreline, using natural materials in the breakwater solution to protect the shoreline and minimizing contaminants that may be released into the river (e.g., through damage or erosion of the breakwater). Aquatic life was also highlighted in the needs and criteria. For example, capability for designs to support life, such as giving possible shelter for fish or spaces for plants to grow, was a criterion in their decision matrix each design concept. This criterion was frequently mentioned in their final evaluation decision on a concept, such as for ECOncrete a more ecosystem friendly concrete, where they concluded "This product can more than double the amount of biodiversity compared to traditional concrete." All concepts were evaluated positively or negatively against this criterion. Thus, although the natural environment and aquatic life cannot "speak for themselves," through the client these stakeholders also held a measure of *power with* the team.

4.2.3 Design team 3

Finally, looking at Design Team 3, two of their stakeholder groups are closely related: town residents and town volunteers. Town volunteers had several needs and criteria for evaluating concepts incorporated into Design Team's 3 report, including the duration of the project, the environmental impact of any solution, and rehabilitation preferences such as waterfront access. Moreover, the team conducted user testing or reviews of their concepts with town volunteers, allowing for additional feedback to the team. In short, town volunteers shared *power with* the team. While town volunteers' views may represent the larger town in many ways, the team did not directly speak with other town residents, although they wrote about them in their report. As the students explain "While not all the stakeholders were available for communication, the groups who we spoke to were primarily the town residents volunteering at the [Environmental organization]". It is possible some residents may have different goals for the former power plant site (e.g., commercial, instead of public development) but this remains unknown since the team did not interact with the broader group of residents. This may be an instance of *power over*, although perhaps inadvertently due to time or logistics.

Another stakeholder is the power plant owners themselves. Unlike other groups, the team was unable to communicate with them. As they explain in their report "Unfortunately, they were not open to discussing the property… [t]he closest we could get to understanding their point of view was from their 3,700 page, publicly available work plan." In this way, the power plant owners exhibited *power over* the team, denying important information and insight that may have shaped their design decisions and directions and forcing the team to rely on unwieldy written reports alone for technical analysis of the site. The environmental organization (client) enjoyed a similar scope of *power with* the team as the town volunteers. Additionally, the organization employs a justice-oriented environmental framework to guide their work, which the student team also incorporated into their criteria and analysis of design alternatives. The students described how this framework informed their concept generation "The concepts generated take into consideration the needs of the [framework]. As the [environmental organization] base their campaigns on the [framework], we need to make sure our concepts align with this framework, which include reducing resource consumption, restoring biodiversity and traditional ways of life…" Finally, the two local experts, a retired engineer and geologist, provided the team with research background on the site and the challenges associated with contaminated work sites. Additionally, these experts shared other potential solutions with the team and gave the team feedback on concepts they had already generated. For instance, when the team asked these experts about how they should prioritize evaluation criteria, the experts shared "Effectiveness of the remediation and cost need to be justified, we are still at the phase where we do not really know what we could do financially, or how far we need to go". In short, the team also shared *power with* the local experts.

5 Discussion

The discussion focuses on two major points. The first argues why it is critical to cover both of the concepts of *power over* and *power with* in a class. The second major discussion point addresses the results from the content analysis of students' final design reports and what the results tell us for teaching engineering students about the concept of power.

5.1 A comprehensive view of power over and power with

After we taught the class and reflected on its outcomes, the need to teach a comprehensive view of power, inclusive of *power with* and *power over*, became apparent to us. This is due in large measure to the dynamic roles these forms of power play throughout engineering work. While oftentimes it may appear that *power over* has negative impacts on engineering work and *power with* has positive impacts on the same work, their influence is not always this transparent. Previously we argued that in *power over* may be neutral or positive, such as when engineering expertise is applied to ensure infrastructure or consumer products are safe and usable. A more pronounced case of this can be seen in the Challenger tragedy, where engineering expertise was ignored and several lives were subsequently lost (Elliot et al., 1993).

Power with likewise may be mixed in its impact. For example, in a review of service learning and community projects (SLCE) in engineering, Delaine et al. (2023) discovered several instances of power imbalances between student teams and community partners. When employed in engineering design, SLCE typically embodies a close collaboration between project partners although sometimes the goals of learning or service (i.e., addressing community needs) may receive different levels of attention (Swan et al., 2014; Natarajarathinam et al., 2021). On this point, several of the instances identified by Delaine et al. (2023) involved teachers or students only providing limited voice or shared ownership to community partners, or instances where teachers minimized the input of community partners based on the assumption that students would have more positive community impact later in their professional career. While SLCE presents opportunities for employing *power with*, as seen in these examples, many instances fall far short of empowering project partners. Thus, *power over* and *power with* do not lend themselves to being strictly positive or negative in their impacts. Both need to be understood and engineers need to reflect on the context and circumstances when they arise.

Moreover, in practice, when interacting with many stakeholders, users and others involved in or affected by the things being designed, both of these concepts may be operating. For example, one group may have *power over* engineers (e.g., a government authority) and another may be a local community group with which power is shared. Power relationships may also be dynamic across time. For instance, design research has found users or stakeholders are primarily involved early in the design process (Loweth et al., 2021), leaving their *power with* to fade as the design advances. Additionally, as engineers approach the end of their project it is often turned over to manufacturing or sales and engineers will find their *power over* the artifact and process reduced. Therefore, an understanding of both of these concepts is vital to navigating the ebb and flow of power dynamics throughout an engineering work cycle and later stages of technology realization.

5.2 Students use of power over and power with in their projects

Finally, the content analysis of students' interactions with various stakeholders revealed that all teams shared *power with* at least one stakeholder or stakeholder group, and in several cases teams shared *power with* multiple stakeholders. Sharing *power with* was the most common category of power reported or exhibited in teams' reports, with Team 1 reporting 6, Team 2 reporting 10 and Team 3 reporting 14. This reporting happened despite initial resistance to interacting with stakeholders. In turn had a profound effect on their design projects and shaped the directions they headed and what was or was not scoped as relevant for the project. For all the teams, their client had a strong impact on the project and shared an often-notable measure of *power with* the team. This is perhaps unsurprising given the centrality of a client to a project and students inclination to gravitate toward client feedback. Nevertheless, it is not guaranteed that *power with* will happen in these instances and student team's reciprocal interactions with their clients may help form a foundation for sharing *power with* other stakeholders. Although less commonly noted than *power with*, there were instances where the teams recognized *power over* or the risk of it operating in their design project. Team 1 and Team 3 both shared two instances of this in their reports. Although the least common category of power reported or exhibited, these still represent important moments of team self-reflection on power dynamics. In the case of design team 1, they recognized the risk that either their client or high school teachers may have different goals or preferences for the quantum computing educational tool than students, the primary user. Moreover, the team noted that differences in goals or preferences could lead to suboptimal design for students if the client or teachers had conflicting goals that were better integrated due to their *power over* the project. For design team 3, they experienced *power over* directly when one of their stakeholders, the owners of the power plant site, refused to share information, forcing the team to rely on public records for their research.

There were some instances where students exercised *power over* stakeholders, with Team 1 exhibiting 5 instances of *power over* their stakeholders and Team 3 exhibiting two instances. This happened with design team 1's interactions with teachers and design team's 3 limited interactions with town residents. It is also possible there were additional examples of *power over* that should have been recognized by the teams. Nevertheless, all teams showed productive beginnings of engaging with the concepts of *power over/with*. We believe the class structure of first learning about *power over/with* framework and applying them in classroom examples, followed by looser scaffolding that encouraged them to apply these concepts in their client-based design helped students successfully leverage these concepts in a fruitful way. In particular, the instructional team's request for student's to more fully consider stakeholders and iterate on their problem statement, needs, and metrics at the beginning of semester 2 and prompts built into their design report milestones helped solidify students' understanding and use of these power concepts.

Setting aside whether design teams addressed *power with* or *power over* in their interactions with stakeholders, the results also reveal the breadth of viewpoints or perspectives explored by each team. Past research on design has indicated the importance of interacting with a diverse set of stakeholders for any given problem (Mohedas et al., 2020; Loweth et al., 2021). As we described in the methods section, the only stakeholders included in the analysis were those mentioned at least twice in student team design reports. While other stakeholders were mentioned, they were only discussed briefly, therefore it would appear their impact on the design teams was minimal. Looking at the stakeholders that were discussed more thoroughly in team reports, for each team their client was one of the major stakeholders. For Design Team 1 and 2, there were two other stakeholders identified, whereas for Design Team 3 there were four stakeholders identified aside from their client. Overall, the number of key stakeholders reported on seems somewhat low given the human-centered design approach taken in the class. This is especially true for Design Team 1 and 2. For Design Team 2, there were some project specific factors that limited their inclusion of more stakeholders. Given the sensitivity of the project (which was in early stages) the client requested the team not contact many stakeholders, which arose as a conversation between the team, the instructors, and the client in the middle of semester 2. Nonetheless, we the instructors regularly highlighted the importance of stakeholder inclusion, provided class days to meet with stakeholders, and incorporated report sections where teams had to share stakeholder feedback. Despite this the number of stakeholders teams remained low. This raises questions for future work on how to best support not only quality, in depth interactions with stakeholders (e.g., addressing the power framework) but also an appropriate breadth of stakeholders to reflect the multiple perspectives that exist on a given problem.

6 Implications

Several implications can be drawn from the case analysis of the class, evaluation of the design team's final reports, and instructor reflections. One major implication is for other engineering classes. In light of the relative success of incorporating power into the senior capstone design course presented here, there may be opportunities to more fully integrate power into other capstone classes as well as transferability to other engineering classes that feature large project-based learning experiences. We draw out a few considerations for instructors and researchers interested in integrating power into their classes. First, there may be some need to scope the number of activities related to power depending on how large or encompassing the project(s) for which students are learning about or applying *power with/over*. Larger or whole class encompassing projects like capstone design projects allow for a considerable number of activities, but a shorter half or quarter semester project might require a more targeted selection of activities. Second, the results of our analysis suggest that learning and supporting practice activities are mutually beneficial. This finding echoes insights from Bloom (1956), which categorizes different levels of learning goals. By using both learning and support activities students are enabled to move from understanding, to application, and creation. However, one challenge that arises with including both types of activities is that it will require more class time. Third, developing understanding and skills with recognizing and responding to power *over/with* takes time, so multiple opportunities to practice these across multiple classes and across academic years could prove useful. Viewed from this angle, not all classes may be able to have semester-long projects with power embedded throughout, but exposure across many classes, even if in smaller projects or through case studies that highlight power dynamics, will help students develop these skills.

Another implication from this work speaks to the larger research body. While not explicitly part of the aforementioned activities, this work raises questions about how power affects interactions with teammates and peers within a class. Teamwork has a tremendous effect on a team's outcomes, and past research has identified some ways in which power may be in play. For example, Tonso's (2006, 2007) ethnographic work studied the roles and activities team members were assigned depending on their gender, unveiling that women were often left with less prestigious or more rote work tasks. This suggests power dynamics, such as *power over* may be at play. How *power over/with* operate within design teams or classroom is an untapped area for future research.

7 Limitations

Theorists of power including Foucault (1980), Lukes (1974), and many others have incisively demonstrated the ubiquity of how power operates through society, from social structures, to relationships within and across groups, to individuals housed within these larger systems. Power is always at work, whether we recognize it or not. This also leads to a limitation of the present work. The goal of this class was to draw students' attention to power dynamics when interacting with stakeholders and to help students recognize and better navigate these dynamics in ways that are more responsive to stakeholders. However, even with this focus, we have to acknowledge that other power dynamics will remain at play. These could be between classmates, teachers and students, others outside the class, or many others. Therefore, when we talk about learning or student outcomes as it relates to power, this is primarily in the context of design teams interactions with stakeholders. Other power dynamics likely play some role in impact students, teams and interactions between the instructors and students. We attempted to take these into consideration while running the class as well. Moreover, while we the instructors used liberative pedagogies (Riley, 2003) to reflect on our *power over* students and consider ways to share more *power with* them, we must also acknowledge that some instructor-student power dynamics may have evaded these efforts. In short, power is at play in more ways than our focus here.

8 Conclusion

As engineering students leave the classroom and join professional positions, they will find themselves both with greater *power over* engineering projects and stakeholders for that project, forcing them to navigate the power of several, sometimes conflicting, stakeholders. These instances will also present students with opportunities to practice *power with* or empowerment with others, as well. However, currently there is little formal training for students to understand issues of power in their professional work. To address this, we proposed drawing on theories of power from the social sciences and humanities (e.g., Avelino, 2021; Pansardi and Bindi, 2021) and incorporate these theories or their insights activities throughout a two-semester senior engineering design capstone course. Specifically, we focused on the concepts of *power over* and *power with* (Allen, 1998; Pansardi and Bindi, 2021).

After reviewing the history of these concepts we gave a brief overview of the class and how it was shaped by three frameworks, Liberative Pedagogies (Riley, 2003), Human-Centered Design (Zhang and Dong, 2009) and Citizen Engineering (Douglas et al., 2010) and how these frameworks in turn shaped how we integrated *power over/with* into the class through a series of activities and assignments. In the results we presented both the structure of the class and an evaluation of how students applied these concepts to their client-based senior design project. The first semester of the class focused on learning the power concepts and included activities like discussions, demonstrations, and application to classroom activities. *Power over* and *power with* were addressed in separate activities for this semester. At the end of semester 1 and throughout semester 2 students were focused on their client-based design project. The activities here focused more on scaffolding and prompting students to apply the power concepts to their project. The prompts did not distinguish between *power over/with* to allow students to organically recognize and leverage the concepts as relevant to their project. The final part of the results employed a directed content analysis (Hsieh and Shannon, 2005) of students' final design reports to identify the stakeholders teams engaged with and whether those interactions reflected a recognition or application of the power concepts. In short, students often shared *power with* their client and sometimes other stakeholders, whereas recognition of *power over* was present but less common.

This work contributes insights and best practices for using the concept of power to the ongoing efforts in engineering education to explore the intersection of engineering and areas from the social sciences and humanities (Hynes and Swenson, 2013; Fila et al., 2014; Bucciarelli and Drew, 2015; Kleine et al., 2023). The results also highlight the importance of covering both *power over* and *power with* inside engineering projects as these two concepts are closely linked and interactions with other groups may evolve or shift over time, necessitating a clear understanding of both concepts. Finally, the analysis of teams' final reports demonstrated it is possible to teach these concepts within an engineering class and support students to engage in the productive beginnings of using them in their engineering work.

Looking beyond this case there are opportunities to integrate these concepts into other engineering classes and students may benefit from multiple opportunities to learn, apply and practice the *power over* and *power with* framework. A stronger understanding of *power with/over* will better equip a new generation of engineers for dealing with the power dynamics when interacting with a variety of stakeholders throughout society and increasing pressures for more codesign and greater equality in design (e.g., see Costanza-Chock, 2020) at a time where there is also increasing science skepticism. Work remains for future researchers to propose and analyze how power may be further supported throughout the engineering curriculum, across different types of classes at different academic levels, how power dynamics unfold between students or teams and external groups, and in particular within teams or peers in the classroom.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by University at Buffalo Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because documents were part of classwork and did not involve any additional research collection procedures. Documents were not analyzed until the class was over and grades were submitted, so risk to participants was deemed as minimal and warranted a waiver. Written informed consent was not obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article because data was collected as part of regular classroom activities.

Author contributions

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