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Addressing Engineers and Stakeholders Social and Institutional Power in an Human-Centered Design Capstone Course

Dr. Corey T Schimpf, University at Buffalo, The State University of New York

Corey Schimpf is an Assistant Professor in the Department of Engineering Education at the University at Buffalo, SUNY. His lab focuses on engineering design, advancing research methods, and technology innovations to support learning in complex domains. Major research strands include: (1) analyzing how expertise develops in engineering design across the continuum from novice pre-college students to practicing engineers, (2) advancing engineering design research by integrating new theoretical or analytical frameworks (e.g., from data science or complexity science) and (3) conducting design-based research to develop scaffolding tools for supporting the learning of complex skills like design. He is the Division Chair Elect for the Design in Engineering Education Division for the 2023 ASEE conference.

Dr. Jessica E S Swenson, University at Buffalo, The State University of New York

Jessica Swenson is an Assistant Professor at the University at Buffalo. She was awarded her doctorate and masters from Tufts University in mechanical engineering and STEM education respectively, and completed postdoctoral work at the University of Michigan. Her current research involves examining different types of homework problems in undergraduate engineering science courses, the intersection of affect and engineering identity, and improving the teaching of engineering courses.

Courtney Burris

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Introduction

As trained professionals, engineers have well recognized areas of expertise. Such expertise often translates into expert power in their professional practice. Expert power can be defined as the ability to influence other people, decision-making, and project planning and/or project outcomes based on the perception that someone has specialized knowledge or skills [1]. Moreover, engineers typically work with a wide variety of stakeholders [2] that have differing levels of social or institutional power and often conflicting views, e.g., business leaders, community members, or policy makers. This adds another layer of power dynamics engineers must navigate. In preparing students for professional contexts, there are increasing calls to develop human-centered design skills and perspectives that have the potential to take into consideration designers' social power and the institutional power they face and seek a deeper integration of the views of stakeholders. However, the social and institutional power engineers must navigate has received little explicit attention in engineering education. This work attempts to better integrate theories of power from the social sciences [1], [3]–[5] into a senior capstone course.

Three major pedagogical strategies were used to incorporate the topic of power into the course. First, we draw on the work of British Sociologists Steven Lukes [5] and his three faces of power framework (i.e. power over decision making, turning topics into non-decisions, and setting an ideological agenda). Students read Lukes and had a class discussion. The instructors translated each of these “faces” of power into engineering design scenarios and had students discuss how they would respond to each.

Second, a case study focused on the engineering failures that magnified the tragedy of Hurricane Katrina. Two readings covered: 1) the culmination of many decisions that led to segregation and inequity in New Orleans, and 2) the engineering failures of the levy system which left historically black neighborhoods at risk. Class discussion began by acknowledging the sensitivity of these topics. The discussion focused on the convergence of the articles. This topic relates to power imbalances in both political institutions and engineering decision-making.

Third, we asked students to select a scenario either local to the community the university is in or their hometowns that centered on public health, environmental, or ethical concerns related to infrastructure or industry. Scenarios selected included historical sites, such as the Love Canal, to modern issues, such as a local sport team’s new stadium. Other problems included lead water pipes in their high school. We asked students to identify all potential stakeholders for their problem and select three stakeholders to analyze their power to address the problem. Lastly, the

students provided solution suggestions that addressed stakeholders' concerns and differences in power.

We present each of these pedagogical strategies as cases or examples of how power can be taught in engineering design courses. We explicitly draw on theories of power from social science to inform our creation and teaching of these activities as well as interpretation of students' responses to the activities. Theories give us the ability to recognize, describe, and respond to some phenomena [6] and therefore help us introduce and discuss issues of power in engineering design. Moreover, power is a complex phenomenon with many definitions, subcomponents, and related concepts (e.g., see [3], [7], [8]) so drawing on these theories allows us to better focus and ground our activities for students and help them recognize where, when, and in what ways power may be at play.

In the remainder of this paper, we first present our theoretical framing synthesized from relevant theories of power in the social sciences. Following this, we review human-centered design and the ways in which power has been addressed in this work as well as how power has been addressed in the broader engineering education research (EER) literature. Next, we review the case study method used for this paper and the classroom context in which these activities happened. Following this we present the three cases, each representing one of the activities related to power. For each case, we cover the learning objectives, a description of the activity, and connections to the theories of power previously covered. The discussion covers our reflections on the strengths and challenges of each case, synthesizes common themes across cases and draws implications for teaching power in engineering, before concluding.

Theoretical Framing - Theories of Power in the Social Sciences

The nature of power that individuals, groups or organizations hold has been heavily theorized across the social sciences [1], [3], [5], [8]–[10]. As with many areas in the social sciences, these theories have resulted in a variety of frameworks and approaches rather than a singular definition or theory. Indeed, attempts to summarize this work has led to compilations of theories of power [7], [8] or work that discusses common themes without necessarily producing an integrated definition [3]. Consequently, this work does not attempt to create a single definition, but rather reviews several relevant theories and concepts of power that help ground the activities we had our engineering students undertake. It should be noted too, that we do not claim to be comprehensive in our treatment of theories of power, as entire books have been written on this subject (e.g., [7], [8]).

First, a foundational definition of power comes from the German sociologist Max Weber, who wrote that: "'[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..." ([11], p. 37). Many theorists have built upon or extended this definition to cover different sources, types, and modes in which power

may operate. While Weber discussed some sources of power, Galbraith's [4] three sources of power may be more applicable to the present work: 1) personality or charisma, 2) wealth or status, and 3) organizational. In other words, people with strong personalities or who are highly charismatic may hold or exert power over others as well as those with notable wealth or status in society (such as a political representative). Organizations too, such as a business or university, can act as a source of power, enabling resources or supporting a position or decision that may be difficult to achieve without that support.

Beyond these sources, French, Raven and Cartwright [1] identified several bases or types of power including reward, coercive, referent, legitimate, and expert. Most pertinent here are the notions of legitimate and expert power. Legitimate power is that which is viewed as appropriate or normatively correct in social institutions. For example, in a traditional workplace setting it is typically viewed as appropriate for a supervisor to assign a subordinate a task. This is considered a legitimate part of the role of a supervisor, even though it compels the subordinate to perform actions they may or may not want to perform. Often legitimate power is used by those in a position of authority, like a boss or governing official and may have legal support. Expert power is power that comes from an individual being perceived as having specialized knowledge or skills. For instance, city officials will view a civil engineer from a construction firm as having expertise in building or infrastructure and thus accept their plans (in regard to technical expertise, not necessarily on financial grounds). An important implication of these sources and types of power is that they are typically not distributed evenly across individuals or groups in society [4], [12].

In an attempt to address more overt and covert displays of power, Lukes [5] created a framework called the three faces of power. Each face or dimension is a different way power may be enacted, starting with the most overt and ending with the most covert. The first dimension, referred to as decision-making, involves at least two parties who have differing views on how a decision should be made. Conflict here is overt and the use of power can be seen clearly (i.e., whose view wins). The second dimension, referred to as non-decision making, involves at least two parties where something that could be treated as a decision point is instead turned into a non-decision, i.e., attempts to debate or discuss it are foreclosed for some other reason. The issue(s) at the center of this dimension are considered out of bounds. This can lead to both overt and covert conflict, depending on whether conflict arises over whether the issue is a non-decision or not. The third dimension, referred to as ideological agenda setting, involves a party setting a broader agenda or plan for what may be debated or not, thereby attempting to influence the interests and goals of the other party or parties. The third dimension is more far reaching than the decision-making situations of the other two dimensions and may operate covertly unless challenged.

Before concluding this theoretical review, we note that how power is enacted may not always be problematic. In the example of expert power involving a civil engineer, many times the influence

of an expert like this will not result in negative or unwanted outcomes. Moreover, power may be used in a positive or supportive sense as is seen with the concept of empowerment where others are enabled to take greater control or direction over something (see, [3], for a summary of this literature). However, there is always a risk that power can be and often is used in ways that negatively affect individuals or groups, sometimes called "power over" others, (see, [3]) especially those with less power in society (e.g., lower SES, minoritized populations, etc). Additionally, these negative forms of power often remain hidden or unnoticed ([13]), furthering the need to explicitly address them.

Literature Review

Human-centered design (HCD) can be viewed as an umbrella term for a collection of design approaches, such as user-centered design, participatory design, and empathic design ([14]–[16]), that share several core attributes. These core attributes include placing people at the center of the design process, embracing a more comprehensive view of users or stakeholders, and aiming to involve users throughout the entire design process ([17], [18]).

There appears to be limited work in HCD that focuses specifically on power, i.e., power over, or which formally addresses theories of power from the social sciences. However, work in HCD has addressed conceptually similar areas, such as the Design Justice movement [19], co-design [20], participatory design [21] and others that encourage designers to act less like experts and more like collaborators with users and stakeholders. In these areas, users, stakeholders, and those affected by design outcomes have their voices elevated and often integrated in design decisions, empowering these groups and their impact on what is designed. Other work on empathy in engineering design emphasizes that designers should develop a deep understanding of users and that this understanding should shape designers' processes [22], [23]. In empathizing with users or stakeholders, it is implied that designers should relinquish some of their power or influence (often in the form of expert power). In other words, these areas focus to varying degrees on empowerment, but rarely on power over.

In other areas of EER, outside of HCD, there has been some exploration or application of power to said research [24]–[27]. Some of this work has analyzed power in institutional contexts like industry [24] or universities [25], [26] while other work analyzes how power affects research practice or ideas in EER [27], [28]. For an example of the former, Beddoes, Schimpf & Pawley [26] draw on French philosopher Michel Foucault's theories of power to analyze how policies created to support women in STEM academic positions may not achieve their stated goals. For an example of the latter, Secules et al. [28] collaborative inquiry on positionality statements and their role in EER discuss how power relations are connected to researchers' identities and the identities of research participants, shaping both how we conduct research and report it.

Thus, while power has been analyzed throughout EER, particularly in relation to how it impacts individuals in institutional settings or affects research practice, it has received less explicit attention in engineering design research. HCD regularly addresses the related topic of empowerment, but there remains an opportunity to more deeply integrate theories of power from the social sciences into students' learning experiences. Deeper integration can help design students better recognize when or if power is being asserted (by themselves or by others) in ways that could contradict or undercut the goals and methods of HCD and more broadly negatively impact their design outcomes.

Methods

This study uses a multiple case study approach. Case studies use holistic, often multidimensional analysis to examine a phenomena, event or other entity of interest [29]. Multiple case studies, as an extension of a single case study, additionally allow for comparisons across cases in order to reveal key commonalities and differences in how they operate. A central issue with case studies is defining the boundaries of a case, that is, what is included within the case and what is considered outside of it? This issue is sometimes called “casing” [30]. In the present work we define our cases as each of the pedagogical strategies we implemented as instructors of the course: (1) the discussion of the three faces of power and associated design scenarios, (2) the discussion of the engineering and institutional failures that exacerbated the impact of Hurricane Katrina and (3) the student selected research project on an engineered system that negatively impacted their local community. For each case, we discuss the learning goals of the given activity, how the activity was enacted for the class, and finally draw connections between the activity and the theories of power it emphasized. After presenting the details of each case we share our reflections on each of them as instructors. Our reflections explore what went well with each activity, what challenges it had, and what we might change for future implementations.

Study Context

The three cases reported here all happened in a year-long senior capstone course for a multiple disciplinary engineering degree at a Mid Atlantic University with a large engineering college. This degree allows students to select different technical tracks, from more traditional tracks like Mechanical or Civil, to custom tracks by assembling a set of thematically related technical courses, such as data science. The course was created explicitly to be a human-centered design course from its inception. Moreover, clients were drawn from local community organizations and nonprofits to create a stronger link and basis for regular interaction with users and stakeholders. Two of the authors, who acted as the initial instructors, synthesized three theoretical frameworks, human-centered design [18], liberative pedagogies [31] and Citizen Engineering [32] to inform the content, learning goals, and assessments for the course. More details on how these were synthesized and informed the course can be found in [33]. It is important to note that the class itself also addresses topics of empowerment and how to bring

stakeholders or users more fully into the design process, but for the purposes of the present manuscript, we focus on aspects of the class that relate to "power over" instead of empowerment.

Critically, both HCD and citizen engineering emphasize the importance of more fully collaborating with users and stakeholders and also draw attention to the impact of engineering on various communities. These considerations encouraged us as instructors to incorporate the topic of engineers' power in design as well as the power different stakeholders, users, and communities impacted by designed things may or may not have. This decision was further reinforced by our use of liberative pedagogies in creating the course. While liberative pedagogy primarily focuses on the interactions between instructors and students, as we transferred this framework to an engineering design course, we also had to consider the mediation and interactions between design teams and community members. Therefore, liberative pedagogies added to the importance of addressing issues of engineers and stakeholders, and others power (or lack of power) in the course.

Case Analysis

In this section we describe each of the three cases or pedagogical strategies we used to get students to engage with the notion of power and how it may affect their engineering work and decisions. For each case, we briefly describe the learning goals of the activity. Following this, we outline the activity itself. Finally, we draw connections between the case and which theories or concepts of power it addresses.

Case 1: The Three Faces of Power in Decision-Making

The first case involved a direct reading of the first few chapters of Lukes' [5] book: A Radical View of Power, followed by an in class discussion. Lukes' book dealt with the three faces of power framework, discussed above. The two primary learning goals for this activity were:

1) Students will be able to describe each of the three faces of power in their own words.
2) Students will be able to apply this framework to engineering design situations where power may be operating.

The activity started in the class where the reading was assigned. Lukes is a sociologist and his book relies on some concepts sociologists or sociology students may be familiar with, but engineering students may not. Therefore, to make the reading more approachable, when it was assigned one of the instructors explained several terms or concepts that may have been unclear. For instance, the reading referenced class and class conflict, or the notion that society is grouped into different social classes (such as working class and middle class) and that there may be competition or disagreement between these groups. The following class focused on the reading and its applications to engineering design situations. First, major terms from the reading related to power were discussed such as conflict and decision-making, as the first and second face of

power deal with different forms of decision-making. Students were prompted to define these in their own terms. Following this, we tied the notion of power back to their future work as engineers. In particular, the instructors highlighted that as engineers they will be deemed qualified for certain types of work and decision-making that others may not be. In short, they will have some expert power. Furthermore, this expert power will give them considerable influence over the direction and scope of the design process, interaction with and inclusion of stakeholders, clients and users, and any final artifact that emerges from this process. Next, we provided an overview of each of the three faces of power (see theoretical framework section for more coverage of these). The bulk of the class and discussion then centered around three design scenarios the instructors created to represent situations engineers may find themselves in and which may involve one of the faces of power. See Table 1 for a brief description of each scenario students were presented with.

While the instructors originally intended for each scenario to mostly reflect one of the faces of power discussed by Lukes, students noted the distinction between faces of power was sometimes fuzzy rather than discrete and entertained the presence of multiple faces of power in scenarios. Each scenario involved a think-pair-share, where students discussed in pairs which face(s) of power they thought were active in the situation and then shared with the rest of the class. This led to a broader discussion and debate over each scenario and the ways in which power may or may not be enacted in it.

Table 1 Design Scenarios for Faces of Power Discussion

ID	Description of Scenario	Face of Power
1	You are presenting at a design review to other teams, various stakeholders and users, other experts and faculty. One audience member asks how your product would perform in extreme weather. One of your team members responds that those weather conditions are unlikely to occur where it will be operating.	Decision-making (Face 1)
2	You are meeting with a client. They are asking about a feature to decrease the noise created by the product you are designing. They have mentioned several times, but your team has told them it is out of scope of the project.	Non-decision making (Face 2)
3	Your team is looking to divide and conquer for stakeholders/user interviews and is planning out who to interview. The team lead asks everyone to brainstorm targeted, close-ended questions for their stakeholder interview, so the team can have more time for prototyping.	Agenda Setting (Face 3)

In terms of theories of power, this case directly addresses Lukes' (1974) three faces of power and encourages students to analyze design situations where these dimensions of power may arise. However, as the activity is framed, expert power is also mentioned, and it is in large measure due to engineers' expert power that they may encounter situations where one or more of the faces of power arise. Having some awareness of their expert power is vital throughout the design process, interactions with stakeholders, and ongoing decision-making process. This likewise aligns with calls from the Design Justice movement [19] and human-centered design approaches [17], [21], [34] to more thoroughly integrate a broad range of users and stakeholders into influential roles in the design process.

Case 2: Hurricane Katrina Engineering Failures and Institutional Racism

The second case involved a case study focused on the engineering failures that magnified the tragedy of Hurricane Katrina. 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 [35], and (2) the engineering failures of the levy system which left historically black neighborhoods at increased risk [36]. 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.

These readings emphasize the importance of understanding geographical, social, and historical context and the need for equity considerations in engineering decision-making.

The class began by acknowledging the sensitivity of the topics of natural disaster and institutional racism, as they may be triggering. Then a brief lesson was given by one of the instructors to provide historical context for the racial inequities present in New Orleans which exacerbated the devastation of Hurricane Katrina. Following this, the students summarized the readings as a whole group, then students participated in two discussion groups, which focused on the points of convergence across the articles.

Given the topic, the instructors felt it was critical to include guidelines for respectful discussion, as well as a disclaimer about how this may be a lived experience for some. At the start of class the following guidelines were reviewed with the students.

- Listen deeply and respectfully.
- Accept one another's reality.
- Ask compassionate questions.
- Challenge yourself.
- Expect to experience discomfort.

- Allow others to learn what you already know.
- Respect confidentiality – take the stories but leave the names.
- *Disclaimer: For some this is more than a news story, this is a lived experience so we need to be cognizant of that as we discuss (some students may have also been affected by other hurricanes, wildfires, etc., where the emotional experience may be similar).*

For both group discussions, the students were divided into small groups of approximately 3 students. They were given a discussion topic with a set of discussion questions and 10-15 minutes to talk in their group. Afterwards, the class came back together to have a large group discussion which was facilitated by the instructor.

The first discussion covered prior knowledge of Hurricane Katrina and the students were given the following questions to discuss.

1. What did you know about/how did you experience Katrina? What knowledge is new to you based on this week's readings?
2. How do you believe our knowledge of disaster events is affected by features such as geographic location, demographics, economic status, profession, etc. (e.g., does living in New York make us less informed about hurricanes that happen in Florida or Louisiana?)

The second discussion pertained to the engineering failures and the following questions guided discussion.

1. What engineering failures impacted the outcomes of Hurricane Katrina?
2. How did the engineering failures lead to the exposure of social injustice?
3. How were people from different racial groups (i.e., Whites and Blacks) affected by Hurricane Katrina?
4. What is the importance of studying historical events and how can this lead to improved engineering practices?

In reference to theories of power, this case most directly relates to organizational or institutional sources of power [4] as well as legitimate power [1]. Leading up to the disaster, several organizations from the Army Corp of Engineers, to local and state organizations, to real estate and construction firms, made decisions, implemented policies or took action that ultimately put Black Americans at heightened risk if a hurricane made landfall, as Hurricane Katrina demonstrated. And the damage done was later exacerbated by similar actions from other organizations such as FEMA. As Henkel, Dovidio, & Gaertner [35] note, many of these policies or actions reflected institutional racism, which they define as "intentional or unintentional manipulation or toleration of institutional policies …that unfairly restrict the opportunities of particular groups of people" (p 101). Institutional racism has a direct link to legitimate power, as the acts or policies of organizations like the Army Corps of Engineers and FEMA are assumed to be unproblematic and often unquestioned.

The [36] reading reflects aspects of engineers' expert power and indirectly Lukes [5] faces of power. However, since [36] only speaks of decisions at an aggregate level, it is difficult to pinpoint what faces of power may have been involved, so these theories of power were less central to this activity. Engineers will often find themselves in institutional contexts and dealing with past policies and decisions that may adversely affect those they are trying to help, so understanding how legitimate power operates and how social and cultural contexts evolve over time will be important for addressing critical needs and hopefully minimizing disasters like Hurricane Katrina.

Case 3: Research Report on Engineering System with Negative Impacts

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.

Our intention with this project was to remove the typical focus of design work in generating a solution so students could focus on diving deep into all the non-technical aspects of the problem. One professor, the second author, created a sample project and presented it to the course to help students scope their topics. The assignment began with students proposing a topic and having it approved by the teaching team. The final report then asked students to conduct research for historical context and propose solutions and provide a full list of stakeholders. Students then were required to pick three stakeholders who have different levels of power in making decisions about the problem and discuss their point of view. Lastly, students were asked to propose the best solution they saw fit to address the problem.

The problems students chose can be found in Table 2. Most students chose problems very specific to their home communities and involved many state, regional, and city communities. In many of their 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.

Table 2 Problems Chosen by Students and their Stakeholder Analysis

Problem	Stakeholder 1	Stakeholder 2	Stakeholder 3
East Side of Buffalo Lead Paint	Property Owners	The City of Buffalo	Residents of Neighborhood
Arsenic in Public Housing Tap Water of New York City	Mayor of New York City	Residents of Public Housing Project	NYC Housing Authority
Water Pipe Contamination in NYC Public Schools	Students	Parents	Faculty
NFL Team Stadium	New York State	Seneca Nation	Local Community
Decommissioned Nuclear Power Plant	New York State	The Public	The environment
Love Canal	The Residents	The Government	Hooker Chemical
Solar City/Tesla Factory	Tesla	Local Government	The Community
Flushing Waterfront District	Councilman for Flushing	F&T Group, Young Nian, and United Construction	Flushing Chamber of Commerce and other community representatives

Returning to the theories of power, this activity relates to [4] sources of power, i.e., wealth/status, personality/charisma, and organizational. These sources of power help explain the differences between the stakeholders identified by students. For instance, several students identified state or local government officials as relevant stakeholders in the problem they examined. Government officials will often have both social status and organizational backing (i.e., the branch or institution of government they are part of) as sources of power. In contrast, local communities, students, parents, and others identified by our engineering students will often not have access to these sources of power. Additionally, this activity highlights the importance of legitimate power or power that is given to an authority figure and often assumed to be an unquestionable part of their authority or legally justified [1], [11]. While legitimate power may be used appropriately or without causing undue negative effects on less powerful groups, that is not always the case, and research from students suggested some stakeholders with legitimate power took actions or made decisions that negatively affected other stakeholders. For instance, the student investigating lead paint on the East Side of Buffalo noted property owners have ignored or found ways to evade laws to address lead paint, leaving this area, which is predominantly a community of color, with unsafe living conditions. As engineers move into

their professional careers our students will need to interact with a variety of stakeholders and a better understanding of potential sources of power, its uneven distribution, and the often surreptitious nature of legitimate power will help them more accurately, ethically, and empathically balance their different needs and views.

Discussion

Instructor Reflections

Looking back at the three faces of power activity, there were several promising aspects of how it unfolded. Students engaged deeply with the material, discussing and debating which face of power was represented in each scenario. In their discussion, students pushed back on the implicit discussion boundaries set by us instructors and questioned whether scenarios could represent multiple faces of power, instead of each scenario only representing a single face of power. In so doing, students also challenged how discrete the faces of power are and identified aspects of the design scenarios where it seemed like multiple faces of power overlapped or where distinctions were unclear. For instance, some students questioned whether scenario 2, where a team told a client the noise generated by the device was out of project scope, was only about non-decision making (face 2), i.e., saying it was out of scope or whether there was conflict over decision-making (face 1) about whether or not the topic should be discussed. That is, was scenario 2 only about treating something (noise generation of the device) as non-debatable or was there overt conflict leading to decisions about whether or not to discuss the topic, before even arriving at a decision if noise should be a criterion addressed by the design.

However, some parts of the activity proved more difficult. The reading was challenging given that it was written for a different audience than engineering students and some of the academic jargon remained confusing, even with clarifications from the instructors before the reading. A few students were less engaged with the activity than others and one suggested that instead of challenging or thinking about power dynamics on a team it was better to do as one was told. This response came specifically from scenario 3, where a team lead was setting the design plan in a way that may have excluded or diminished the voices, concerns, and thoughts of several stakeholders.

Going forward with future versions of this class, the team is considering creating a summary or translation of the original work by Lukes [5] that may be more approachable for engineering students and not weighted down by terms assuming the reader is deeply familiar with the sociological literature. A central challenge here is to retain the key meanings and concepts, while simultaneously creating a stronger bridge to applying them directly to engineering contexts.

Turning to the Hurricane Katrina case, the activity was a success as students clearly demonstrated an understanding of how institutional racism and historical racial injustices

compounded to exacerbate the devastation of Hurricane Katrina. This was exhibited both in how students addressed the guiding questions and how they interacted with their peers during the discussion. The students held steadfast to the discussion guidelines, exhibiting respect and consideration for their fellow students, allowing for a deeper conversation. As the class consists of senior engineering students, the expectation was that they would be able to identify the engineering failures, but may struggle with the discussion on racial inequities due to a lack of exposure in previous engineering courses. Surprisingly, the students understood and articulated the impact of institutional discrimination on the events leading up to and response to Hurricane Katrina.

However, not all of the students reviewed the reading material prior to class. Since a large portion of the class had not done the required reading, despite several reminders prior to the class, time needed to be given for students to read/skim the material. The time allotted to review the readings took away from the discussion time. It is not known whether students neglected the reading due to forgetfulness, time management, or a disinterest in the given material.

In future versions, different readings may be chosen to hopefully prevent a large portion of students neglecting the reading. Both class readings [35], [36] were heavily academic, one being a book chapter and the other being a peer-reviewed journal article. Perhaps students would prefer more easily digestible material in the form of a video or multimedia document.

Finally, the research project was a success in getting students to think about local and meaningful issues related to engineering. As every student chose a problem close to their home communities, the instructor felt they got to know each of the students better. Most students were able to analyze and discuss the different power stakeholders had within their problems and could point to why the problem wasn't resolved. The student who examined water pipes in their city public schools even went above the project requirements and interviewed each of his chosen stakeholders about the problem.

One aspect of the project where students fell short is the broad stakeholder categories some students considered. For example, a few students considered "The Community," "The Public," or "The State," which are large groups of people that could have been broken into smaller, more explicit categories of stakeholders with different needs and levels of power. For example, a state has a number of departments, such as Environmental Conservation or Water Quality, which could have long standing policies different from those of the current Governor. We think some more early feedback or teaching to students could eliminate some of these shortcomings.

In some cases, the depth of student research seemed minimal, with some students more focused on the story of the site than their analysis. Yet, it is difficult to require a certain amount of research and effort without multiple rounds of feedback.

Comparison Across Cases

Looking across the cases and the instructor's reflections on positives, negatives, and potential changes several themes begin to emerge. First, in general students were engaged deeply with the activities and even pushed the boundaries of what was expected of them. For example, in the faces of power activity students challenged where and how faces of power applied to design scenarios and in the research project one of the students conducted additional stakeholder interviews. Students' deep engagement is particularly promising as the topic of power between social groups or their own power as experts in engineering is rarely covered in their typical engineering classes. While creating these activities for our capstone course we knew there was a risk that students might consider these as tangential or irrelevant to the design process.

Second, integrating theories of power into these activities offered students several new ways to think about how they approach design problems. For the faces of power case, students were encouraged to critically reflect on their own perceived expert power and how that affected their actions and decisions throughout the design process. For the Hurricane Katrina case, students had to contend with policies and actions of several institutions and organizations that led to differential risks and outcomes for minoritized groups and exacerbated engineering failures. In short this activity highlights the importance of understanding the social and historical context in which engineering design happens. Finally, for the research project, students were able to apply the beginning of a common type of social science analysis by investigating (1) who was impacted by, affiliated with, or had a stake in an engineering system, (2) what power or influence each of these individuals, groups or organizations had and (3) how their interactions affected the system and its ongoing operations. Therefore, integrating theories of power into activities in an engineering design capstone can have multiple benefits for developing as a professional designer. Moreover, beyond the initial activities and associated theories of power explored here, there may be other activities or ways to integrate associated theories that offer additional perspectives or skills for students.

Third, while there were several common positive themes, there were also some challenges. In the two cases that were reading and discussion driven, students found the readings were difficult or in the other case, some students did not complete the reading before class. This likely put limits on how much some students could interact with the content and participate in class discussion. Additionally, with the research project, although students were able to identify stakeholders, many of these were very general, such as community or state. The lack of specificity identifying stakeholders meant analyzing their power was less accurate and illuminating. Instead, when students identified general stakeholders, they had to rely on broader generalizations. Thus, while students were able to engage with the material, there were some limits on how deep students could probe a topic.

The above point relates to a key decision we instructors made on what readings and activities to include in the class. Those familiar with theories of power in the social sciences will know that the French philosopher Michel Foucault raised several critiques to some of the theories of power reviewed here, arguing that power is: exercised, not owned, dynamic and evolving, not structurally static, and discursively generated [10], [37], [38]. While the instructors acknowledge the importance of these critiques, the context and goals in which power was being introduced also matters. To introduce engineering students to the concept of power and encourage them to engage with it during their design process, we have opted for some theories that are more approachable for those with less training in social theory, such as our students. We also think these theories may be more feasible for our students to apply to design and engineering contexts they are familiar with.

Implications

Several implications can be drawn from the case analysis, instructor reflections, and discussion. First, given the relative success of integrating power into the capstone course presented here, there may be opportunities to more fully integrate power into capstone classes in general as well as transferability to other engineering classes that feature large project-based learning experiences related to practice or professional development. Second, while we have focused on “power over" in this manuscript as an understudied aspect of power, this concept is intertwined with many other integral concepts in EER. For example, the topic of institutional racism and legitimate power covered in the Hurricane Katrina case relates to broader topics of equity and privilege (e.g., see [19]) for individuals and groups affected by engineering projects and outcomes. Likewise, both the faces of power and the research project stakeholder analysis relate to HCD themes of greater integration of users and stakeholders in the design process [17], [18]. While there has been coverage of empowerment within HCD [21], [34], as noted there is limited coverage of “power over” [3] and this work helps paint a fuller picture of how both aspects of power operate in HCD. The focus on the differences between the power groups have and being aware of one's own power (e.g., expert power) also relates to developing empathy for users [22], [23], not just being concerned for or with others but also being thoughtful about how one's actions or decisions might impact users and stakeholders. In brief, power over may be understudied, but nonetheless is interconnected with many other critical concepts and warrants greater investigation. Third and finally, while not explicitly part of the aforementioned activities, this work raises questions about how power affects interactions with teammates, peers, and across the class more generally.

Conclusion

As engineering students leave the classroom and join professional positions, they will find themselves both with greater power over engineering projects and forced to navigate the power

of several, sometimes conflicting, stakeholders. However, there is presently 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 (e.g., [1], [3]–[5]) and integrated these theories or their insights into three activities in a senior capstone course for a multidisciplinary engineering degree. More specifically, we focused on "power over" (see, [3]) or forms of power that negatively affect or disenfranchises some group or groups as this aspect of power remains understudied in human-centered design and other design research, compared to work on empowerment or increasing the power or voice of users or stakeholders [21], [34].

Through a multiple case study analysis we present three different pedagogical activities as cases of how to integrate power into a capstone course. One case involved applying the three faces of power theory to engineering design scenarios students discussed and debated. A second case explored the engineering failures and institutional racism that exacerbated the devastation of Hurricane Katerina and the role institutional and legitimate power played in these. The third case tasked students with investigating an engineering system in their local community that had negatively impacted the community as well as the power and influence of several stakeholders who were involved or affected by the system.

After presenting the cases, their learning goals and how each case related to previously covered theories of power, each instructor shared their reflections. Comparing and contrasting across the cases and instructor reflections, we saw students generally engaged in the activities and each revealed different opportunities for learning about power, such as understanding one's own expert power and how it influences decision-making or how the larger contextual, social and historical factors one is working in are inevitably intermixed with the design process, outcomes, and potential impact on society. However, comparisons also revealed several difficulties, like adapting materials from the social sciences to an engineering classroom, disengagement or limits on how deeply students could engage with the content.

Finally, although we focused on "power over" in the present work, we note that this concept has many implications and connections to other concepts. Given the success of these activities on power, there may be opportunities to integrate similar activities into other engineering design or project-based work. Power is related to notions of equity and privilege, empowerment and empathy within human-centered design, and peer and teammate interactions. Such an intertwined concept warrants greater research to understand how it impacts and interacts with these other key areas of study.

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