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Board 39: Increasing Students' Understanding of Stakeholder Perspectives: A Value-Sensitive Design Case Study

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Increasing Students' Understanding of Stakeholder Perspectives: A Value Sensitive Design Case Study

Abstract

For students to become engineers who habitually seek out opportunities to create extraordinary value, they need to understand the different stakeholders who are impacted by the designs they create. In a typical civil engineering design process, direct stakeholders (e.g. the client) may be involved during the beginning of the process when establishing the criteria of the project, with perhaps some limited community engagement during public outreach. This approach however limits the perspectives contributing to a project. Values Sensitive Design (VSD) is a methodology that asks the engineer to systematically consider values and norms, direct and indirect stakeholders, and the long-lasting impacts early and throughout the design process to craft more equitable solutions and reduce or eliminate unintended consequences. In a senior technical elective course offered in the School of Civil and Environmental Engineering, students explore the direct and indirect stakeholders involved in a coastal engineering design example. During an in-class session, students learn how to brainstorm the values and norms of stakeholders that they identify, and then integrate those values into design criteria such that it benefits a broader swath of the community. The students then applied the VSD concepts to a course project that required them to create design criteria that satisfied stakeholder's needs beyond the original client. The inclusion of this activity in the course curriculum created students who were more invested and aware of the potential impacts of their design.

Introduction and Literature Review

When considering bias in engineering, social bias, like racial and gender bias, typically come to mind. Investigation into these biases are thorough (Eddy & Brownell, 2016; Ohland et al., 2011; Williams et al., 2016) and increasing awareness of them is warranted. But considered less frequently is the role that cognitive biases play in engineering design (Carmichael, 2020; McDermott et al., 2020; Mohanani et al., 2020). Cognitive bias refers to the variations in thinking and decision-making that occurs between individuals when presented with the same information. Just some examples of cognitive bias in engineering include ownership bias: the preference towards one ideas over the ideas of others (Toh et al., 2016; Zheng & Miller, 2019), confirmation bias: the tendency to seek out and interpret information that supports one's existing beliefs (Calikli & Bener, 2015; Hallihan & Shu, 2013; Nelius et al., 2020), and in the case of interdisciplinary teams, disciplinary bias: a preference towards data that is relevant to one's own discipline (Harris et al., 2009; Horn et al., 2022). A common recommendation for mitigating bias in engineering design is the inclusion of varying perspectives as contributors. This often is understood "horizontally," referring to interdisciplinary engineering teams, but can also be done "vertically" with the inclusion of representatives from engineering, policy, management, and other key stakeholder groups.

Stakeholder analysis is not a new concept (Achterkamp & Vos, 2008; Brugha & Varvasovszky, 2000; Kujala et al., 2022; Littau et al., 2010), and is a common practice in policy, project management, and organizational management (Brugha & Varvasovszky, 2000). Even still, the recommended process for stakeholder analysis is not always straightforward, and it is often limited to the beginning of the project, instead of being used dynamically throughout a project (Jepsen & Eskerod, 2009). There is a continuing discussion on the differences between "stakeholder analysis" and "stakeholder engagement," and often the terms are used to describe similar processes (Yang et al., 2011). The purpose of stakeholder analysis also varies depending on the application. The process of identifying and characterizing stakeholders based on contributions, expectations, and power is a useful method for moving a project forward by focusing efforts on the stakeholders who hold the most influence. More involved processes, including surveys, interviews, and focus groups allow for stakeholder feedback into a design. For engineering students though, direct interactions with stakeholders are usually limited to theoretical situations or case studies (Flynn et al., 2016; Martin et al., 2021) or simulated with decision-making criteria (Morshedi et al., 2023). Even when students have opportunities to interact with stakeholders directly as in a dedicated design course, they may not do so effectively. Mohedas et al. (2020) interviewed mechanical engineering students in a capstone design course about their design decisions. From the interviews, the authors analyzed the students' interactions with stakeholders and their perception of the interaction. They found that in order for students to consider a stakeholder interaction as "useful," the students would either predefine clear goals for the interaction, only interact with stakeholders whose expertise closely-aligned to their project, or give control of the decisions to the stakeholder entirely. Information variability and interpretation and application of that information are a key part of engaging stakeholders that is avoided by these strategies.

Expanding engineering students understanding of the value and purpose of stakeholders is increasing in engineering curriculums (Afroogh et al., 2021; Mueller et al., 2020; Oehlberg et al., 2012). These human-centered and empathic design interventions support our growing understanding of the importance of engineering justice (Castaneda et al., 2021; Grimes & Grimes, 2014; Leydens & Lucena, 2017). In this paper we outline an intervention based on Value Sensitive Design (VSD) (Friedman & Hendry, 2019). VSD is a set of theories and methods used to incorporate human values throughout a technical design process. To do so, the engineer must consider direct and indirect stakeholders, their own values and the values of those stakeholders, the norms and societal context, and the long-lasting impacts of the design (Friedman & Hendry, 2012; Harbers & Neerincx, 2014; Yoo, 2021).

Methods

"Coastal Engineering" is a technical elective course available for upperclassmen undergraduate and graduate students. Enrollment in the course is typically between thirty and forty students, with graduate students representing a third of the students. Topics covered in the course include wave mechanics, coastal structures, wave forces, shoreline change, sediment transport, large scale hydrodynamics, and nearshore hydrodynamics. The course includes a term project where students work in teams of three, mixed graduate and undergraduate students, to address a shoreline protection design problem. The project consists of developing an erosion control design plan using beach nourishment and/or the construction of coastal structures. As part of the design process, the students were asked to use a VSD approach to identify stakeholders and address their concerns and interests that may be impacted by the project. The stakeholder analysis was a required part of the assignment as well as a portion of an extra credit competition in which the student teams competed on the cost effectiveness of the design as well as on how many stakeholders beyond the client the team identified and how well the team addressed those stakeholders' concerns and interests with their design. In preparation for this element of the project, the instructors used an in-class activity designed in the structure of the values hierarchy tool from values sensitive design (van de Poel, 2013).

Stakeholder Values and the Tybee Island Project

The topic of discussion was a hypothetical renewable energy project on Tybee Island, Georgia. Tybee Island is an island on the coast of Georgia near Savannah that has a power grid connection via power lines across the marsh to the mainland. Because this system is extremely susceptible to power outages, the proposed project was to develop ocean renewable energy resources for the island. Participation in the activity involved accessing and posting to at Google Jamboard. Students' initial thoughts regarding stakeholders is typically limited to the client, so to expand students' understanding, two definitions were introduced:

> *"People or entities who are or will be affected, directly or indirectly, by the project."* Adapted from Friedman and Hendry (2019)
>
> *"Stakeholders are broadly conceived: people, groups, neighborhoods, communities, organizations, institutions, societies, past and future generations, non-human species, historic buildings, sacred lands…"* Adapted from Reed (2008)

The class was asked to brainstorm in small groups possible stakeholders for the Tybee Island project and to add them to a Google Jamboard. They were asked to consider both direct and indirect stakeholders.

Once the Jamboard was populated with stakeholders, students discussed what was meant by "value" and how it can be identified.

> "Value can be economic. It can also be social, societal, personal - and likely is a blend of some or all of these elements. Engineers with an eye toward value creation understand stakeholder needs, learn from failure, and habitually work to provide benefits while understanding the consequences of their actions." (Melton & Kline, n.d.)
>
> "Human value is defined as 'What is important to people in their lives, with a focus on ethics and morality.'" (Friedman & Hendry, 2019)

The instructors selected four of the stakeholders identified by the class as examples. On a new Jamboard, students listed possible values specific to those selected stakeholders.

The next step was to discuss how societal norms are the way values are implemented or expressed in a particular society. They can vary based on many factors such as the culture of the particular group. For example: members of a community might value personal security. This is expressed through personal actions like consistently locking doors, or communal actions like the expectation that their community maintains a reliable power supply under all conditions. A third

Jamboard was created that included two selected values from each of the stakeholders. Students then identified various ways those values were implemented or expressed in that stakeholder group.

Next, the instructors held a discussion about identifying and highlighting the potential impacts of the project on the various stakeholders. This was facilitated by using the values and societal norms associated with each stakeholder. Building off of the previous example, the expectation of reliable power to ensure personal security means that the project will be a benefit to the community by providing a local power source. Again, another Jamboard for the four stakeholders was created. The students were then to add benefits and harms using color-coded notes for each of the stakeholders.

The final step of the process is to use all this information to formulate what design considerations and requirements engineers should utilize for addressing the stakeholders' benefits and harms. Following the example, the identification of the desire for energy security implies that engineers may want to ensure the design can provide sufficient local power for vital services in the case of prolonged grid power outages. The students then added design considerations to a final Jamboard for each of the stakeholders that could address some of the potential harms and benefits.

Results

The instructors worked through this activity step-by-step, explaining the relevant definitions and giving the students time to think to themselves and with their group before adding their ideas to the Jamboard. One full class session, approximately one hour, was devoted to this activity and surrounding discussions. After a Jamboard was populated, the class discussed the responses and then moved on to the next step. Figure 1 shows the general flow of the Jamboards.

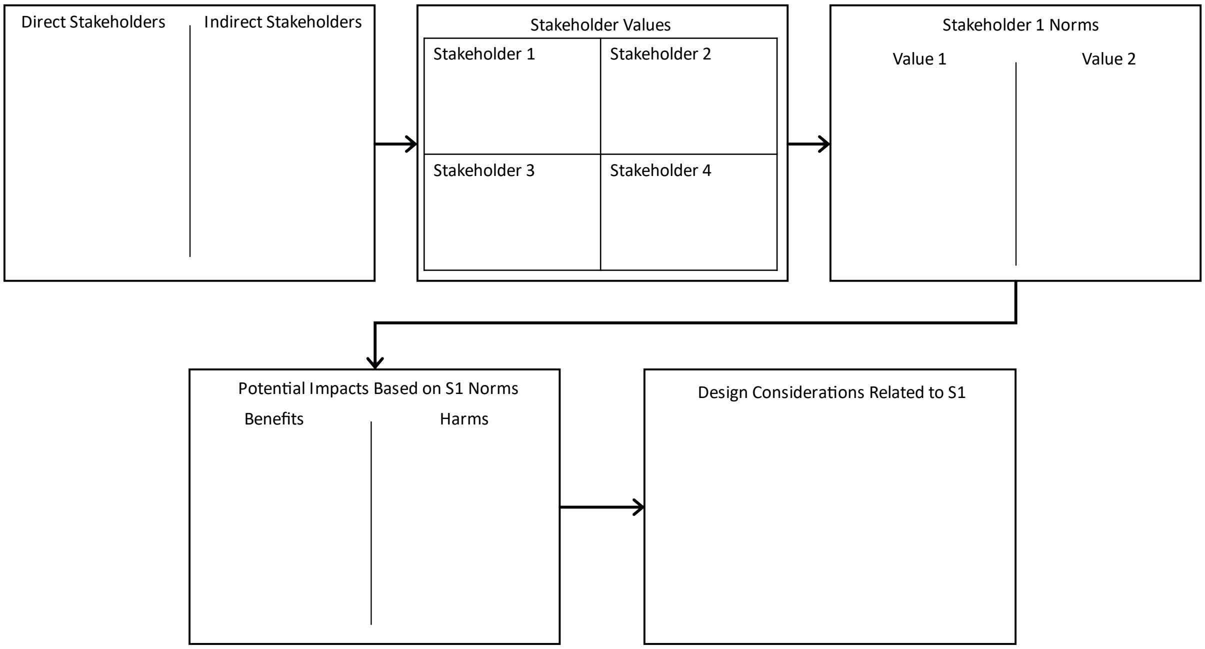

Figure 1: Outline of Jamboard flow. Note: Stakeholder 1 is used as an example, but the process was completed for stakeholders 1, 2, 3, and 4 in parallel.

Starting with identifying stakeholders, students considered direct stakeholders, i.e. those who interact with the design, and indirect stakeholders, i.e. those who do not interact with the design but are still impacted by it. Since this was a short in-class activity, students were not able to conduct extensive research on the stakeholders of the Tybee Island Project, but instead relied on their creativity to imagine potential stakeholders and situations. For direct stakeholders, students identified predominately individuals: investors, tourists, boat owners, and property owners, for example. They also considered organizations, like power companies and construction companies, and elements of nature, like the marine ecosystems. Nature and wildlife are more frequently considered as an indirect stakeholder. Students included fish, algae, and saltwater marshes in this category. Other indirect stakeholders included Georgia taxpayers and Google Maps.

Four stakeholders from those identified by the students were used as examples throughout the rest of the boards: property owners, tourists, boaters, and wildlife. When students considered the values of each of these stakeholders, they found that some values overlapped, while others were specific to a particular stakeholder. Property owners and tourists value aesthetic and beauty of the island, tourists and boaters value safety, boaters and wildlife both care about the abundance of fish, and all four care about quality of life. Unique values identified included property owners: taxes, tourists: fun, boaters: navigable waterways, and wildlife: habitats for reproduction. Discussion surrounding values also included highlighting potentially conflicting values, like habitat preservation for wildlife and additional marinas for boaters, or privacy for property owners and accessibility for boaters and tourists.

The instructors selected a couple values for each stakeholder to focus on when considering norms. For property owners, students brainstormed how the values of reliability and cost were expressed in their communities. For tourists, fun and safety; boaters, accessibility and safety; and for wildlife, only quality of life. Examples of norms identified by students during this step are shown in Table 1.

Table 1: Examples of norms the students identified during the activity.

Stakeholder	**Value**	**Norm**
Property Owners	Reliability	Expect consistent power, even during storms
	Cost	Expect expenses to remain the same
Tourists	Fun	Regular visits to beaches that are clean
	Safety	Expectation of lifeguarding or other public safety infrastructure
Boaters	Accessibility	Maintained waterways and marinas
	Safety	Participation in safety equipment checks
Wildlife	Quality of Life	Access to stable ecosystems

In the next step involved connecting those values and norms to the impacts of the design and determining whether the stakeholder would consider it beneficial or harmful. The following are examples of benefits and harms that students identified by building off the values and norms they had previously established. Property owners may like a design that serves as a continuous power source but would also dislike it if that design increased taxes and decreased property value. Tourists who value fun may appreciate a new renewable energy site to tour but be disappointed if it limited jet skiing and parasailing. Boaters concerned with safety and accessibility may consider the design harmful because it adds another hazard when driving, but they may also consider it beneficial in that it could dampen wave energy nearshore. Finally, the design could potentially benefit wildlife with access to stable ecosystems by decreasing boating traffic and thereby limiting disturbances to the ecosystem, but the design could also cause harm by disrupting circulation patterns.

At the end of the activity, students recommended design considerations that were influenced by stakeholder values, norms, and impacts. Figure 2 shows the resulting Jamboard. Design considerations included minimization of view obstruction, environmental impacts of materials, noise limitations in construction, and avoiding interference with high boating seasons.

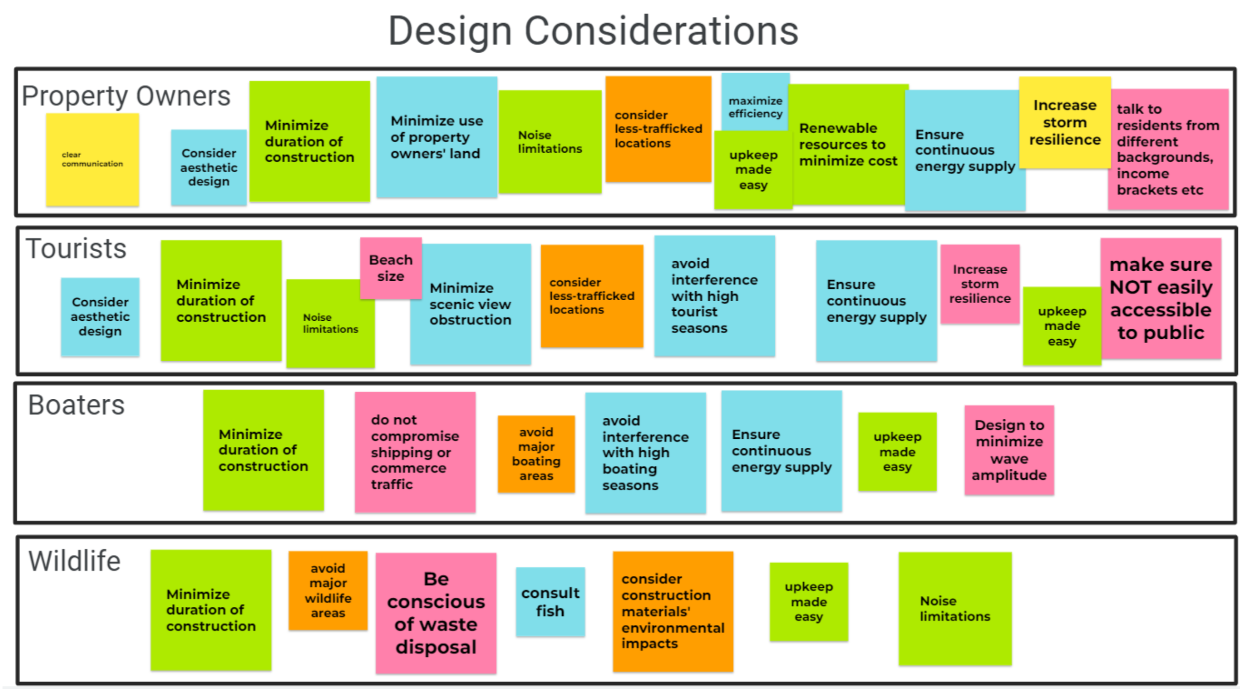

Figure 2: Final design considerations Jamboard

Discussion

The purpose of this stakeholder activity was to introduce the VSD approach and to give the students a scaffolded method for exploring potential design decisions that are motivated by the stakeholders. Rather than starting directly with brainstorming alternative design considerations, executing this form of stakeholder analysis enabled the students to be more creative and identify design considerations that could be more naturally linked back to the stakeholder. Beyond creating a network that connects stakeholders to design decisions, this activity highlighted instances where the values of stakeholders may be at odds with each other. One of the purposes of value sensitive design is to become aware of these value tensions early in the design process to mitigate unintended consequences.

Armed with this approach to analyzing stakeholder values, the students' course projects, aimed at controlling beach erosion, showed a deeper understanding of potential stakeholders with more connections to the group's design decisions. The following lists some of the diverse design decisions from the course projects that were made to accommodate the concerns and interests of stakeholders:

- Use beach nourishment rather than construct structures to preserve views for residents and tourists
- Avoid construction during nesting seasons of local endangered species, with time buffers on either side of the official nesting seasons in case actual nesting happens sooner or later than usual
- Include paths and ramps in the design of coastal structures so the beach remains accessible to wheelchair users

- Prioritize cost minimization above all else to reduce the financial burden on taxpayers
- Minimize the areas of the beach that are modified to avoid disturbing wildlife habitat as much as possible
- Plan construction timelines such that no activity takes place on Sunday mornings, when a local church conducts a weekly religious service on the beach

Training engineering students to regularly recognize and incorporate stakeholder values in design is especially relevant considering ABET outcome 3.4:

> "an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts." (Engineering Accreditation Commission, 2021)

By discussing societal norms prior to potential design impacts, the students are more aware of how the proposed design either supports or disrupts the expectations of the stakeholders. For example, in the class discussion, by recognizing the common activities of tourists and boaters around the island, the students naturally pointed out how the proposed design may limit those activities, thus having a negative impact on those stakeholders while benefitting local wildlife. Extending this concept further, the design could support sustainability of the local ecosystems but, potentially, at the expense of the local economy due to decreased tourist and boater activity. Just a fraction of the tangled network of interactions between values, norms, and impacts was explored in this activity.

This is just one of many methods used in values sensitive design. While typically used in research, some methods have been adapted to be effective classroom activities (Amekudzi-Kennedy et al., 2022; Zerbe et al., 2022). For this activity, using Google Jamboards was an effective way for students to share their ideas with the rest of the class. They were not limited to their own creativity and were often inspired by what others had posted.

The objective for the implementation of VSD in this course was to introduce the concepts and to help students recognize the importance of incorporating stakeholder values in the design process. Because the course project was relatively short and aimed at producing a conceptual erosion control plan rather than a complete design, the preliminary stakeholder analysis using VSD was deemed sufficient. Future implementations of this course can also demonstrate other stakeholder compliance measures such as NEPA documents.

Conclusion

This paper serves as a case study on a value sensitive design in-class activity focused on incorporating stakeholder values into a hypothetical ocean energy design project. Students collectively identified stakeholders, values, societal norms, and potential design impacts which all ultimately influence proposed design considerations. From this activity, students became more aware of the breadth of values that can contribute to a design, and how those values can sometimes appear to be in opposition. Through facilitated class discussion, the students realized the importance of considering stakeholder values early in a design process so they can effectively navigate those tensions and create an equitable design. The value sensitive design concepts learned during the activity were then successfully applied to a course project, with students' project submissions taking into consideration the ways in which their engineering decisions affect others. Through both the in-class activity and course project, students learned the importance for incorporating considerations of stakeholders into the design process and one particular methodology for accomplishing stakeholder analysis.

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