Understanding Ethical Reasoning in Design Through the Lens of Reflexive Principlism

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Introduction

Despite increasing emphasis on understanding and developing ethical competence among engineering students [1], [2], few studies portray *how* engineering undergraduates engage in ethical reasoning, particularly as it unfolds and shifts throughout the course of the design process. Even fewer have examined ethical reasoning when situated within authentic design contexts, particularly those in which students must navigate the messy interconnections between end-user needs, design constraints, team dynamics, technical problems, and ethical dilemmas. To prepare engineers capable of grappling with these ethical complexities, engineering educators need a richer understanding of students' situated, daily ethical decision-making. Drawing on a case study of 13 students in an undergraduate service learning engineering course, this study applies reflexive principlism as an analytical framework to explicate how students negotiate ethical decision-making throughout the course of the design process. In doing so, this project provides a rich description of students' ethical reasoning and its theoretical and practical implications for design. By tracing decision-making processes throughout the lifespan of design projects, it also provides a quasi-longitudinal examination of how design and ethical decision-making shifts throughout the course of the design process. Finally, this study offers an application of an emerging ethical decision-making framework, enabling educators to observe its principles in practice and apply these concepts in engineering ethics pedagogy.

Engineering Design and Ethics as Social Processes

Increasing research highlights the profoundly social nature of design (e.g., [3], [4], [5]) wherein personal values, beliefs, and social practices infuse all aspects of the design process, bearing out in team interactions, design decision-making, and the final design products themselves. As Bucciarelli [3] states, "Design is, in process, a social process and it demands an account that searches for the true significance of technical constraint, values and norms on the form of the artefact in the everyday thought, expressed beliefs, and practice of participants" (p. 185). In this way, ethical decision-making in engineering design is interwoven with these social processes [6], [7]. In collaborative design teams, members must negotiate understandings of 'what is ethical' in a given context, inevitably engaging their own perspectives, experiences, and values as they make design decisions. These processes are the "everyday ethical issues" in engineering design work that carry larger ethical implications for the end user (cited in [8], p. 266).

However, traditional approaches to engineering ethics often focus on the *products* of design and their ethical implications, placing the emphasis on "the outcomes of processes of technology development rather than on the *internal dynamic* of these processes" [9] (p. 224). Furthermore, dominant approaches to teaching ethics either involve analyzing specific cases of large-scale ethical dilemmas in engineering contexts, discussing historic moral theories, or emphasizing the profession's codes of ethics [10]. As these approaches tend to "decontextualize" ethics by describing them in abstract terms or situating them in hypothetical contexts [11], researchers question whether students fully engage the complexity of the daily ethical decision-making

embedded within engineering design and its implications [5]. As a response, scholars have begun calling for approaches to ethics that grapple with the messiness of everyday design decision-making [12], [13], [11]. In order to develop approaches that attend to the situated nature of ethics, it is important to know how these ethical decision-making processes materialize throughout the design process and their implications.

Analytical Framework: Reflexive Principlism

In order to understand these processes and their implications, this study takes an 'everyday ethics' approach to exploring the micro-level ethical decision-making occurring in student design projects. We employ Beever and Brightman's [10] "reflexive principlism" framework as an analytical device to explicate these processes. According to these authors, reflexive principlism is "an approach to ethical decision-making that focuses on internalizing a reflective and iterative process of specification, balancing, and justification of four core ethical principles in the context of specific cases" (p. 275). Beever and Brightman [10] recently developed this framework in order to address the perceived insufficiencies of traditional approaches to ethics pedagogy. More specifically, the authors propose reflexive principlism because: 1) it provides a comprehensive, unified approach to ethical reasoning amid the diverse array of pedagogical techniques, 2) it is "uniquely aligned" with understandings of engineering design, 3) the concept of principlism is applied in similar occupational contexts that carry a similar broad societal impact as engineering, 4) its principles clearly map onto the moral concerns inherent to engineering, and 5) it is flexible and adaptable to changing techno/social needs and contexts.

According to reflexive principlism, ethical reasoning centers on understanding and applying four core ethical principles to specific cases. This concept of 'principlism' emerged within medical ethics, primarily in response to human rights abuse cases that occurred in the 20th century, such as the Tuskegee syphilis study [10]. Within principlist approaches, universal notions of morality form the basis for four core ethical principles: 1) beneficence, providing benefits to society; 2) nonmaleficence, actively avoiding causing harm; 3) autonomy, respecting the agency of individuals in decision-making; and 4) justice, distributing risks, benefits, and costs equally among all individuals [10]. The authors describe how these principles can be conceptualized according to two axes that form an "ethical reasoning space." Beneficence and nonmaleficence form two ends of the "benefit to harm axis," which represents the ratio of value addition to risk. Autonomy and justice operate as two polarities on the "stakeholder impact axis," which measures one's emphasis on the individual or collective good.

In reflexive principlism, the individual "specifies" the larger, abstract principles by placing them in particular contexts and scenarios. For example, one might ask, "What does autonomy look like in this particular situation?" Next, one engages in 'balancing' or evaluating the tensions between ethical principles within that context. However, the authors note that the goal is not equilibrium per se, but a recognition of the competing forces within various scenarios, and an examination of the implications of prioritizing particular principles. In this way, balancing principles within particular contexts bears similarity to negotiating the constraints within particular design processes. Finally, individuals must then "justify" their ethical decisions based upon these evaluative processes. This process necessitates an internal *reflection* on one's immediate context and larger moral principles. Beever and Brightman [10] stress the importance of cultivating this

practice among engineering students so that it becomes a habituated, *reflexive*, nearly subconscious process. Thus, Beever and Brightman [10] summarize, this approach to ethical reasoning should become an "internalized intuitive application of basic moral principles—specified and balanced according to the case at hand by reflection against codes and intuitions—to solve ethical problems" (p. 282).

As more researchers recognize the need for understanding and teaching ethical decision-making as an everyday, situated process, engineering educators need to know how these processes materialize throughout the design process and their implications. We use reflexive principlism as an analytical framework to examine and describe the ethical decision-making processes of undergraduate engineering students. Although Beever and Brightman [10] put forth this framework as a prescriptive, pedagogical tool designed to cultivate ethical reasoning skills among students, we use it as a descriptive device, aptly suited to explicating the ethical reasoning processes of undergraduate engineers as they describe and reflect on their design decision-making in interview contexts. By using the processes of specification, balance, and justification as an analytical lens, we examine how undergraduate engineers negotiate the relationships between design work, their specific design contexts, and ethical decision-making. Doing so also sheds light on how the ethical decision-making guides design decisions and, ultimately, design outcomes.

Furthermore, different stages of the design process invite different ethical considerations and potential dilemmas. Thus, in addition to providing rich description and analysis of ethical decision-making, we track how ethical reasoning shifts and develops over the course of the design process. Therefore, we ask the following research questions:

RQ1: How do student designers describe ethical decision-making during design?
RQ2: How do student designers specify, balance, and justify ethical decision-making in design?
RQ3: How do descriptions of ethical decision-making stay the same, shift throughout the design process?

Methods

In this study, we utilize a qualitative case study approach in order to generate thick description about students' design decision-making and their retrospective sense-making of their ethical reasoning. Interviews are especially useful in this context as they prompt students to engage in reflection on their ethical decision-making, creating space for them to articulate the various thoughts and dynamics that played into their past design decisions. Furthermore, in a semi-structured interview, the interviewer asks probing follow up questions designed to make participants think deeply about their answers. This reflexive discussion enabled our team to draw out rich, nuanced descriptions of students' ethical decision-making as it emerged throughout the course of the design process.

Participants and Context

Participants for this study are students enrolled in EPICS, a multi-disciplinary service-learning design program at Purdue University. In EPICS, students of multiple majors are taught a model of human-centered design, in which they develop projects to meet the needs of specific community members, and are instructed to engage these partners at each stage of the design

process. For example, a team of engineering and entrepreneurship students may partner with a community member with a disability in order to design assistive technology for him/her. Other teams may design products for larger social groups, and partner with a specific individual or community who represents that group in order to determine product needs and specifications (e.g., designing for those who are visually impaired by partnering with a classroom at school for the visually impaired). We discuss findings from students in project teams in four design classes across three semesters. Each class included separate design projects with approximately 15 design projects represented across the three time points. These design projects, during the time of the study, were in distinct phases of the design process, changing during the three time points of data collection.

Procedures

As part of a larger NSF-funded study, we conducted semi-structured, one-on-one interviews with students of four sections of EPICS classes across three semesters, resulting in 103 total interviews. Interviews focused on team member relationships, design decisions, and importantly, ethical decisions that were either made or considered during design projects [5]. These interviews were transcribed and anonymized to protect the participants' confidentiality. In order to capture the unfolding nature of ethical reasoning and decision making, we sampled from our interview dataset to capture a range of participants who participated for multiple semesters in one project, seeking to understand more in-depth specific participants' ethical reasoning and its potential shifts over time. This resulted in 10 participants and 26 interviews. We then supplemented this dataset with a few more participants engaged in projects at different stages of design, so that collectively the dataset represented all phases of the human-centered design process. This resulted in a total of 13 participants and 30 interviews.

These interviews were analyzed using a constant comparative method [14] in which the research team generated an initial set of codes through an open coding process of several sample interviews, and then, through the constant comparative process, refined the list of codes, developing an established codebook. The research team used this codebook to analyze the remaining interviews. Codes included categories such as identification of ethics, design, team process, etc. For the case study, we further partitioned this dataset by extracting codes related to descriptions of ethical reasoning and/or decision making. For further analysis, we took a reflexive principlism lens focusing on the core ethical principles of beneficence, nonmaleficence, autonomy, and justice. Following this framework, we analyzed students' descriptions of ethical decision-making, seeking to identify where these principles appeared to materialize, how students appeared to specify (contextualize) them, balance (negotiate) them, and justify (provide rationale for) their decisions. Throughout this process, we referenced the original transcripts in order to understand the broader social and design contexts in which their decision-making emerged.

Findings

In the following sections, we outline how student design teams engaged in ethical decision-making throughout the design process, specifically explicating how students appeared to specify, balance, and justify ethical principles in their sense-making of these processes. In doing so, we

use EPICS's model of human-centered design. In this model (Figure 1), the phases of design are as follows: problem identification, specification development, conceptual design, detailed design, and delivery. We structure the findings around these phases in order to a) draw linkages between points in the design process and those ethical principles and concerns that emerge as most salient, and b) demonstrate students' shifts in ethical sense-making over time.

Figure 1: EPICS Human-Centered Design Process
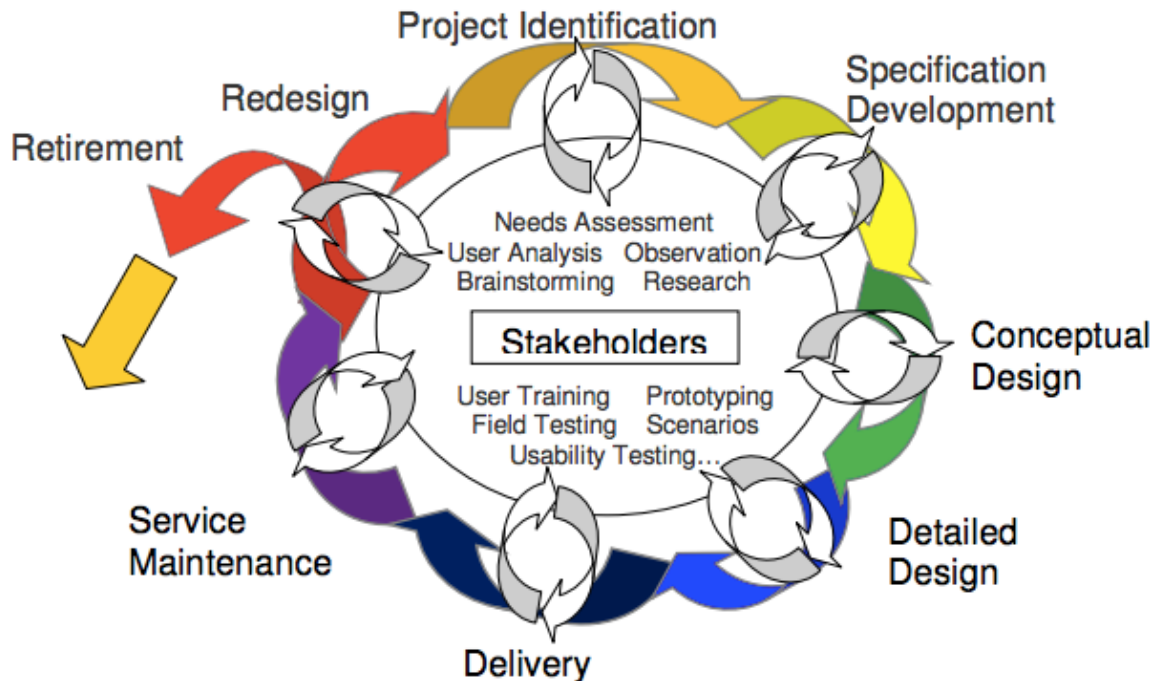
Project Identification/ Specification Development

In this model of human centered design, the first stage is project identification, in which students "identify a specific, compelling need to be addressed" [15]. In the second stage, "specification development," they seek to "understand 'what' is needed by understanding the context, stakeholders, requirements of the project, and why current solutions don't meet [the] need, and to develop measurable criteria in which design concepts can be evaluated." Throughout the interviews, students often discursively blur these two phases together, discussing the 'compelling need' in conjunction with the 'what is needed.' In this section, we discuss how students engaged in ethical decision-making processes in the beginning stages of the design process.

As students engaged in the front-end decision-making for their projects, they prioritized the ethical principle of beneficence, balancing it against concerns of user autonomy and justice. In this case, students appeared to 'specify' these larger moral principles when discussing the *nature and goals* of projects they could pursue in order to feasibly deliver a helpful product (beneficence) while also following the desires of their users (autonomy) and ensuring the device is accessible to all community members (justice).

In these early stages, the students developed their understanding of user needs and project goals according to the explicit or perceived interests of their community partners. At this stage, students engage in tasks such as identifying stakeholders, defining their requirements and objectives, and determining time constraints. As students negotiated these front end elements of their design projects, teams interacting more directly with specific users and project partners demonstrated an emphasis on providing benefits while also respecting user autonomy. For instance, as students on the first team began their project to design a calculator interface for students who are blind and visually impaired, they developed their project goals alongside the interests and objectives of the classroom teacher, Miss Pebblecreek. According to Bruce,

> R: Well we want to make something that works for them. We're not designing for everyone in the world; we're designing for them right now, so we're building everything based on what she wants and what her students want.
> I: Can you be a little bit more specific as far as what they want, kinda that interaction?
> R: What they want? She wants a way to easily be able to communicate with the students in two-way communication, and we can't produce two-way communication this semester, so we're going to do one-way for her for right now.

In this interaction, Bruce justifies their decision to privilege providing benefits over meeting the *exact* need of Miss Pebblecreek because of the time constraints of the semester system. By recognizing that they are not designing for "everyone in the world" but just for the classroom, he acknowledges the necessity of user autonomy in defining their team's goals. However, by recognizing that their team cannot "produce two-way communication this semester," he balances this desire to respect autonomy with the desire to deliver a product within a realistic time frame. Thus, Bruce justifies the decision to prioritize beneficence by emphasizing the need to provide something of value that semester versus nothing at all.

In the early stages, the second team also prioritized beneficence, but balanced this principle with justice instead of respect for autonomy. The team set out to design a device that aids those who are visually impaired in reading. They were inspired to do so not only because this device did not exist on the market, but because similar technologies were thousands of dollars, making them highly inaccessible to members of the blind community. Thus, in this case, the team's desire to deliver a working product (beneficence) was constrained—or balanced—by their desire to make the product financially accessible to those in a disenfranchised community (justice). As Danny describes in his interview:

> This particular project, it's not just about designing something and designing a pretty good prototype. It's about designing something that, whether we sell it through a nonprofit or not, we can manufacture it on a large scale and we can give it to the rest of the world. So from the very beginning, our scope was, we need to build something that we can get to everyone. So if we can build it by hand for $5,000, that's not at all good enough.

As Danny provides further elaboration, he explicitly acknowledges how making a device accessible inevitably results in trade-offs:

> So if it's bare bones and it does what we want and we take out a hundred really cool features just so we can get it to as many people as possible, and increase that ridiculous 30 percent literacy rate in the blind community, that's our goal.

In these descriptions, Danny provides justification for balancing their desire to provide a helpful device (beneficence) with a concern for distributive justice.

In the first stages of the design process, both teams negotiate issues of beneficence, balancing them against concerns for justice or autonomy. The differences in attending to user autonomy versus justice reflect the team's closeness with the users they are designing for. As in Beever & Brightman's [10] ethical reasoning space, the teams represent divergent ends of the stakeholder impact axes—teams working closely with the specific end users grapple with how autonomy balances their desire to provide benefits. Teams designing products for larger communities balance beneficence with justice, prioritizing the role of collective good over individual agency. Thus, in these beginning stages of the design process, students appear to wrestle with ethical issues inherent in determining whether to design for one or design for many.

Conceptual Design

In the conceptual design phase of the human-centered design process, students seek to "expand the design space to include as many solutions as possible, evaluate different approaches and select the 'best' one to move forward" [15]. At this point, teams have moved from conducting research on the stakeholders, the context, and the materials, and begun brainstorming design ideas and seeking feedback from users. For teams working closely with individual users, the emphasis on user autonomy intensified during this particular design stage. Rather than merely setting project goals that aligned with the needs of the user, in the conceptual design phase, many team members often had to willfully forgo their own design ideas in order to incorporate user feedback and seek to design a product that truly met their needs.

For example, in this phase, the one team's original plans to provide benefits to their user were challenged by the users' feedback, putting their interest in beneficence in tension with user autonomy. This team set out to develop assistive technology for a toddler with a disability named Ryan. The team conducted research and brainstormed ideas, identifying several potential devices they thought could assist Ryan in feeding himself. However, after meeting with Ryan parents, Tina shares how their team's conceptual design ideas changed:

> R: Um, I think initially, like the first week or two, we brainstormed all of these ideas, we had like a whole board with tons of different ideas, and I think once we met with the parents, that was when we finally decided on like, "Okay, we want to go with the device that you put the spoon on and spin it," because that's kind of what the parents were envisioning a little bit. We thought it would work really well, and it's pretty easy for the user to use. And so that was one of the big decisions, because that kind of took our whole semester, then, to make devices that were similar to that video that the parents had showed us.
> I: And that was mostly based on the parents' kind of preference?
> R: Yeah. Um, part of it was like [pause] yeah, part of it was the parents telling us like, "He doesn't like things to be attached to him," which ruled out a lot of our ideas.

By choosing to follow the parents' wishes, the team's desire to add value (beneficence) by creating a feasible design, shifted once they learned about the desires of the user and his parents (autonomy). By admitting that their design ideas did not match up with "what the parents were envisioning," Tina and the team were forced to reflect on their decision-making, ultimately choosing to follow the parents' wishes, even though doing so "took the whole semester."

While in the conceptual design phase, another team encountered feedback from their user that pushed them to consider how his needs differed from their original plan. This team set out to

design a brace for a man with a condition that limits his mobility. Adele discusses how their first prototype, designed when brainstorming different solutions for his brace, did not meet the user needs:

> R: Just [pause] taking *myself* out of the situation and thinking about what would be best for the person we're serving. So like for our EPICS project, like yeah, honestly, my first thought was to go with that athletic sock, but then seeing Pat using it, well, that's clearly not working for him. We need to listen to him, listen to his needs, and stop thinking about the first thing that came to our mind and stop trying to improve that, and go with what would be best for him.

She acknowledges how the team must forgo desires to improve their own ideas and continue to brainstorm solutions grounded in the user's experience and interests. This statement also demonstrates her justification for balancing the principles of beneficence and user autonomy. Although the team desired to build a device that provides benefits the user, they need to "go with what would be best for him."

Thus, in this design phase, project partners' direct interaction with students' initial design concepts affected the teams' ethical decision-making, forcing the students to reflect on their conflicting design ideas, and shifting the needle for many teams from prioritizing beneficence toward greater balancing of autonomy.

However, for teams that interacted less with project partners during this phase, the interviews demonstrated less evidence of reflexive discussions of how user autonomy impacted the team's conceptual design. In many ways, students began discussing concerns more related to detailed design—issues of safety, choosing high-quality materials, etc. Several teams received instructions from their project partner during the first two phases, and moved onto a detailed design stage where they sought to produce a product that met those specifications. As Jacob shares:

> R: Basically, I think Paul and Preston gave out the specifications [pause] I guess it was two years ago, jeez.
> I: So they gave out like, "We want these things"?
> R: "We want this, this, and this, and we want it to be able to demonstrate that stuff," and we went from there.

As a result, students in this team engaged in less reflexive discussion about user autonomy as they largely sought to 'follow marching orders' and dive into the more technical design aspects. However, when these teams interacted with their partners in unplanned ways, they were forced to grapple with the project partners' feedback on their design ideas. Jacob admits that their original prototype was not brought to their project partners for approval, as many other teams did during conceptual design, but that once the partners' saw it, they provided feedback. At this point, these teams engaged in decision-making in a similar fashion as those working closely with specific partners, choosing to put their plans in tension (beneficence) with user needs (autonomy). For instance, Jacob mentions:

> Like, I remember there was one time we were at the pole barn, we were getting ready to put the painting demonstration unit together and we happened to run into Paul, and Paul gave us some suggestions on like how to make it smaller, a little bit more stable, and so we rolled with that. As far as the other unnamed, sorta-they're-there stakeholders [pause] well, we tried to put forward the best end product we could, but I'm not sure [pause] like, if we had more input, we probably would've used that as well, you know?

In this interaction, Jacob draws attention to the linkage between interacting with project partners and grappling with user autonomy. Jacob hints at a justice-oriented decision-making process in which he describes their project partners as the "unnamed, sorta-they're-there stakeholders," but rather than 'justify' his prioritization of justice in the decision-making, he speaks more about the absence of user feedback. These interactions reveal ethical decision-making processes that were more passive—or absent—for teams that interacted less with their users during the conceptual design phase.

Detailed Design

In this phase of the design process, students seek to "design a working prototype which meets functional specifications" [15]. They have settled on one design and likely began iterations in order to complete the prototype. For many teams, the ethical decision-making present in conceptual design continued into detailed design, particularly as students interacting closely with community partners continued to grapple with issues of user autonomy as they developed further, more detailed iterations of their design. Despite this continued trend, most teams began to engage more ethical issues related to nonmaleficence during this design stage. As students ordered new or different materials or worked on the small, specific details of their prototypes, many began encountering decisions related to many 'technical' aspects of their prototypes. As a result, they began navigating issues of safety and avoiding harm (nonmaleficence) in their design work.

For example, Bruce on the first team discussed the specific electrical components that the team had to ensure were safe to avoid shock hazards for students who are blind and visually impaired. In his interview, he discusses the ethical implications of these decisions:

> R: Um, I guess, um [pause] because we're dealing with electrical circuits, you know, we don't want to leave anything—like, we don't want to make anything that's like too cheap or exposed wires or something where students can actually shock themselves or something along those lines. So we want to make sure that everything's sealed up from them.
> I: Okay, so, when you think about that example, why is that ethics to you and not just, like, good design work? You know what I mean?
> R: Um, because I mean, it would be—in a sense, I guess they're kinda similar.
> I: Mmm hmm.
> R: Because I mean, it would be like [pause] Because I mean, you could like—there's a lot of products people make really cheap, and I guess—I mean, it is just bad design work, but also, I mean, it would be easier for us, and I think the ethical thing to do would be to take our time and to design it properly, in a sense.

In this case, Bruce describes the tension between beneficence – providing a product to the classroom quickly—and avoiding harming the students by delivering a rushed, sloppy product (nonmaleficence). He also provides the justification for choosing to spend more time on design and more money on high-quality parts, recognizing that doing so creates a safer product.

Other teams discussed similar issues, mentioning shock hazards or possible injuries related to certain aspects of their design. As Reid states about his team's prototype:

> Um, I think the main reason we switched from a mousetrap to a spring was that the mousetrap was unreliable as well as very unsafe, and I think that was probably the only

ethical thing we considered really, is that, you know, a fifth grader shouldn't be messing around with a mousetrap, that's just a bad idea.

These decisions to balance beneficence with nonmaleficence emerged in lab meetings and in interactions with users. Regardless of closeness to the user, most teams appeared to reflexively discuss issues of safety during this stage of the design process. However, teams working closely with their partners appeared to extend their conceptual design ethical decision-making processes into detailed design, but incorporated more consideration of non-maleficence at this stage. For teams working at a distance from users, the boundaries between conceptual and detailed design were far fuzzier, particularly as lack of user interaction led students to 'skip' to technical issues earlier in the design process.

Delivery

The delivery phase proved a complex and dynamic stage for ethical decision-making, as the "rubber met the road" for teams making final design decisions. In addition to managing the pressures of producing a final prototype, teams that delivered their product attempted to do so at the end of the semester, a highly busy season for the undergraduate student engineers. As a result, students were often forced to grapple with time constraints and user needs, class expectations and messy team dynamics.

At this stage, teams interacting closely with users had to confront user feedback on final prototypes, and even those teams distanced from their project partners also discussed issues of user autonomy, at times wondering if their prototype met the expectations of their project partners. For instance, some teams working with specific users often emerged from detailed design phases intending to deliver a product to their partner only to discover their partner did not like it. For instance, in her interview about her current project, Adele reflects on what she learned based upon her past experience designing for an older woman with a disability. She describes delivering their prototype to the user:

> Most of us were on [Team 3] and so from that side of things, we saw that what was delivered to Patty wasn't what she wanted, but then when we changed it and gave it to her, that was what she wanted.

In this example, Adele and her team balanced the desire to deliver the product quickly (beneficence) with the desire to make it exactly what the project partner wanted (autonomy). In this exchange, she shares how this experience informed her priorities and decision-making for their current project.

> Jacob, on a team designing homes for low income communities, expresses a similar sentiment:
> R: Right. Well, I would say the only issue is, towards the end of the semester, trying to get a product to [the non-profit organization] at the expense of making it like as much of what [the organization] wanted as possible. Granted, nobody's really going to be *hurt* by that, but, you know, I guess [pause] when we took on this project, we wanted to make it like the best thing possible for [the organization], and if we're rushing it at the end, that's kind of [pause]
> I: Could be, you know, is this the right way to go about it type of thing?
> R: Yeah.

In this statement, Jacob recognizes the tension between delivering a product to the user within their time constraints (beneficence) and respecting and incorporating the partners' interests (autonomy).

Furthermore, Jacob states that, in the beginning of the design process, his team wanted to make the "best thing possible for [the organization]," but toward the end, they felt the pressures of the deadline and the temptation to deliver a product less aligned with the partner's interest. This statement reflects differences in some team's sense-making between the beginning and the end of the design process. In the early phases of design, most students are concerned with providing benefits to their users in ways that align with the partner's desires. However, although the team continues to try to deliver a beneficial product at the end, recognizing the users' interests can pose more of a temptation to 'cut corners' rather than form the basis for their design and ethical decision-making.

During the delivery phase, issues of justice became more salient to many students as well, often interacting with issues of beneficence and autonomy in more visible ways. Jacob reflects on delivering an online game to their project partner the previous semester, and honestly conveys his doubts about whether or not it was what the community wanted *and* whether or not it was an accessible product to the community:

> R: But is that really what [the organization] wanted, you know? Like [pause] like what [pause] (sigh)? Like, are all the new homeowners going to be able to take that back with them? Like, I don't know how many of them have computers at their house, you know, stuff like that.
> I: So like accessibility, kinda, that type of thing?
> R: Yeah.

In this exchange, Jacob's verbal and nonverbal communication convey his questioning of whether their final product truly met the needs of the community. While they were able to deliver a product to the user, he wonders if that was "what [the organization] wanted." Through his pausing and sighs, he communicates a sense of dissatisfaction with a product not aligned with the users' interests. As a result, he wonders whether their device was actually accessible to the community. In sum, he debates whether or not they properly balanced justice and autonomy concerns alongside their desire to deliver the product (beneficence).

Another student design team reflects on whether their product was accessible to those who have disabilities—something that did not emerge in the design process until the end. When describing the mousetrap cars designed by his team, Reid admits, "You really had to kneel down and sit there and wind it up. I don't think a kid in a wheelchair could have done the activity." He then states:

> I think if the project partner had said that, like, "Hey, you know, you need to make sure the student in a wheelchair could use it," I think we would've, but I didn't really think that there was much of a need for it, being that only one of the students could use the car, anyway, out of the four in each group.

In this statement, Reid illustrates how the presence of user input (autonomy) would have likely changed their design. As the project partner had not said anything, a justice-oriented concern was overlooked in favor of delivering the product to the user. In this example as well, the team grappled more openly with issues of autonomy, beneficence, and justice, often linking justice concerns to user feedback.

For some teams who did not interact closely with their partners, the reflexive questioning of their ethical decision-making appeared likely to emerge during the delivery phase as students received feedback from project partners, professors, and others during their "Design Review" and through the documentation processes. According to Reid, the realization that their product may not be accessible to students with disabilities occurred while his team was documenting their design and reflecting on their decision-making:

> I: Yeah, okay. So did you consider it all, or did you just realize afterwards?
> R: Um, we realized it during the documentation, actually. Because I think that they were talking about a similar thing, like ethics, and I know Krista went off on something about that for a while, talking about how you need to consider everyone.

Thus, the delivery phase appeared to force a certain amount of reflection from the teams, whether they were interacting with the feedback from the user, the feedback from their design review, or the documentation process in which they formally articulated their design decision-making. In this stage, students engaged in ethical decision-making with more ethical principles readily visible, such as issues of autonomy and justice. Thus, even though teams working closely with users interacted with their desires and feedback more readily throughout the semester, the delivery phase served as a form of 'reckoning' in ethical decision-making for teams that operated at a greater distance from users.

Theoretical and Practical Implications for Design and Ethical Decision-Making

The findings portrayed a patterned split in ethical reasoning between teams working closely with their partners and those designing at a greater distance. This theme reflects earlier studies on human-centered design, in which increased user engagement resulted in more "comprehensive" understandings of design among undergraduate students [16]. As Zoltowski [16] explains, "As the student designers understand users and the context better, they are then confronted with the need to take more factors/aspects into consideration into the design" (p. 48). This, in turn cultivates in a more 'comprehensive' understanding of design. This present study extends this concept to ethical decision-making, begging the question of whether or not a more user-focused engineer is a more ethically competent engineer.

Some prior research has explored the ethical undertones of human-centered design and its implications (e.g. [5]), suggesting that a human-centered approach is inherently more ethical. This study does not argue that students working more closely with partners are more ethical per se, but the findings do suggest that these students are more likely to self-consciously and critically engage ethical challenges. Prior research has indicated that the mere confrontation with information from the user does not necessitate a response that attends to their needs. For instance, Sugar [17] describes how some students reverted to simplistic solutions that did not critically engage user feedback. For instance, they may merely eliminate the element of their design that the users engaged. Or they may resort to a "Band-aid" solution that fails to truly address the users' concerns. In the present study, some evidence of these approaches emerged among teams, however, only within those that interacted infrequently with their users. The teams that engaged in sustained, meaningful contact throughout the course of the design process appeared to critically, reflexively engage the users' feedback.

The implications of this finding are more pronounced when considering the core tenets of reflexive principlism. A principlist approach does not suggest that user autonomy is the superior

moral principle per se. In fact, Beever and Brightman [10] discuss specific instances when autonomy ought to be intentionally constrained for the greater good. Thus, the moral imperative of reflexive principlism is not that individuals should prioritize one specific principle, but that trained, critical reflection on the manifestation of those principles in a given context is the key to effective ethical decision-making. Beever and Brightman [10] argue that this repeated act of reflection hones the critical thinking skills necessary for negotiating the ever-evolving messy situations engineers will encounter. Thus, contexts in which student engineers encounter user perspectives are fertile ground for the cultivation of these ethical reasoning skills.

Therefore, this study highlights the practical value of service learning engineering programs in which students encounter authentic design situations involving real people in real places, rather than theoretical scenarios contrived in engineering classrooms for design assignments. Furthermore, these findings shine a spotlight on the value of a human-centered approach to design that facilitates students' interaction with users throughout each stage of the design process. In this particular service learning program, students are encouraged to seek partner approval before the beginning of each subsequent design phase, thereby infusing each phase of the process with the negotiation of user feedback. Unless students ignore or reject this feedback, they are then forced to interact with these ideas, weigh them against their own, make decisions, and engage in reflective processes that continue to train their reflexive ethical reasoning skills.

However, these implications do not suggest that human-centered design and service learning are the only ways to cultivate students' ethical reasoning skills. Engineering educators should explore how to replicate this reflexive process in engineering education environments when user interaction is not always readily available. Thus, educators should consider how to creatively incorporate feedback from multiple stakeholders and seek to construct more 'authentic,' real-life environments in which abstracted moral principles are brought down to earth and worked out amid the messiness of real design situations.

Similarly, human-centered design is not necessarily the silver bullet to solve all the pedagogical problems in developing students' ethical decision-making. In fact, this study portrayed how some students overemphasized the role of the 'human' in human-centered design, essentially short-circuiting their ability to engage in critical ethical decision-making on their own. This theme reflects findings in studies of human-centered design in which students hyper-associate ethical decision-making with user interaction [5]. As in the case of Reid stating that his team would have considered users with disabilities had their project partner mentioned it, an overemphasis on user input can lead students to outsource ethical decision-making to the user, believing that their input encapsulates the entirety of potential ethical considerations in a given project. As a result, they do not consider the breadth of potential ethical implications for their design decisions.

Implications for Reflexive Principlism

Although the findings portray students' negotiation of ethical decision-making as balancing relevant principles in a micro-level moment of ethical reasoning, the longitudinal nature of the design process illustrates how the act of balancing principles also operates at a higher level— *across* the design phases. For example, many teams in the conceptual design phase attempt to design a prototype that meets all of the needs of the user. However, this design can easily surpass the technical ability of the project team. Thus, once the team enters the detailed design phase and

begins ordering parts for their prototype, attempting to code or CAD various aspects of the design, they encounter feasibility constraints. As a result, teams may scale back on the features that met 'every' need of the project partner (autonomy), so that they can realistically complete a prototype that meets the user's basic needs (beneficence). In the interviews, students who had completed design projects in the past demonstrated greater recognition of this process—mentioning that getting a "minimal viable product" to the user that semester should be more important than addressing all the details of the partner's needs.

Negotiating tensions between principles throughout the course of the design process was highlighted during the delivery phase, when principles engaged in earlier design phases seemingly 'stacked' on top of each other. In this way, the delivery phase proved a culmination of the various ethical decisions that teams made, often placing them in a pressure cooker given the unique challenges of the delivery process.

This trend illustrates how, when using reflexive principlism as a pedagogical tool, educators should consider how balancing principles operates in everyday design decisions as well as across the design process. Furthermore, as this study reaffirms the importance of reflexivity in design, engineering educators should consider how to incorporate assignments or activities that enable students to reflexively consider their design decisions and their ethical implications. Although not all students in these teams immediately engaged in reflective discussions concerning their design decisions, the findings illustrated how feedback from peers, professors and users and documentation of their design decisions facilitated reflection on their ethical reasoning.

Furthermore, we encourage the adoption of reflexive principlism as a way to structure ethics pedagogy and reinforce the value of reflexivity. After analyzing interviews with a reflexive principlism framework, we suggest being more explicit and detailed in describing how higher order moral principles materialize in the design process. As students are likely familiar with the concept of design constraints, we suggest framing the processes of specification, balance, and justification within 'constraint' language, thereby drawing more visible linkages between abstract moral principles and concrete engineering design decisions. We contend that doing so extends reflexive principlism's utility more tangibly into engineering contexts and enables students to consider how constraints are not necessarily technical, a-moral design decisions, but often carry larger ethical implications.

Although we consider reflexive principlism to be a highly useful tool in explicating the everyday, situated nature of ethical decision-making, applying this lens to students' retrospective accounts of ethical decision-making has its limitations. We recognize that a prescriptive framework for ethical reasoning presents an 'ideal' for ethical decision-making. As ethical reasoning does not operate in an 'ideal' space, students' selfish—arguably unethical—decisions, are not well captured by the reflexive principlism framework. We recognize this as a limitation of our study and an opportunity for further research and expansion of the reflexive principlism model. As educators seek to instruct students in moral and ethical reasoning, they should equip them to evaluate what constitutes an unethical decision and how to identify it. We suggest that more thoroughly discussing the unethical would further extend the utility of reflexive principlism for engineering educators.

Conclusion

In sum, this project explicates the ethical decision-making of undergraduate students as they grapple with messy, real-life design situations. By tracking these processes throughout the stages of the human centered design process, it reveals how students' negotiation of ethical issues unfolds and shifts over time. By using reflexive principlism as an analytical approach, this project also identifies how students who engage more directly with end users also engage in more ethical reflexivity. Given engineering educators' interest in developing ethically competent future engineers, we aim to provide helpful description of how students engage in these processes as well as direction for engineering educators seeking to cultivate critical ethical reasoning skills among their undergraduate students.

Acknowledgements

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