Faculty Members' Conceptualizations of Ethics in the Biomedical Engineering Classroom

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***Abstract*—In this WIP study, our primary objective is to begin identifying what faculty perceive as important for ethical practice in biomedical engineering. We analyzed two primary data sources to address this objective. First, we analyzed curricular artifacts developed by five biomedical engineering faculty members at a single large Urban Midwestern University in the USA. Second, beginning with codes established by Katz, we analyzed interviews with these same five faculty members to identify ethical considerations salient to faculty mental models. Through these analyses, we identified nine *ethical considerations* which draw attention to aspects of engineering practice that faculty deem of ethical import. Moreover, these considerations were evident in both curricular artifacts and interviews. The considerations included: Economic; Environmental; Interpersonal; Legal; Organizational; Personal; Professional; Societal; Technological; and Theoretical. We provide descriptions of these considerations along with associated extracts from the curricular artifacts and interviews. These findings can benefit instructors by helping make evident the many and significant ethical considerations salient to engineering. In the future, we aim to more purposefully triangulate the alignment between faculty mental models and the ethical considerations they prioritize in their instruction.**

Keywords*—engineering ethics, mental models, biomedical engineering, faculty learning community

I. INTRODUCTION

Engineering curricula present many opportunities to integrate ethics, as evidenced by various ethics across curricular approaches [1-3]. While more ethics instruction can help enhance students' attainment of ethics-related outcomes [4], faculty hold various mental models of the most important outcomes of and strategies for ethics instruction [5]. As a result, even within a single department or school, educators may prioritize ethics learning differently. This WIP study seeks to identify ethical considerations that permeate a single department at a single university and how these ethical considerations align with faculty mental models. To this end, we synthesize two primary data sources: (1) curricular artifacts and (2) faculty interviews. In this WIP, we address the research questions:

1. Based on course artifacts, what *ethical considerations* do faculty members integrate in biomedical engineering curricula at an Urban university in the Midwest USA?
2. Based on interview data, what *ethical considerations* do biomedical engineering faculty perceive as important to introduce into their instruction?

II. THEORETICAL FRAMEWORK

Katz [5] utilized expert elicitation methods to identify the mental models of engineering faculty regarding "engineering ethics education." Therein, Katz identified ten "areas" of faculty mental models pertaining to engineering ethics education: (1) "what engineering ethics is"; (2) "topics that comprise engineering ethics," (3) "goals of teaching engineering ethics"; (4) "where students learn ethics"; (5) "when students learn ethics"; (6) "when ethics is taught"; (7) "who makes decisions about engineering ethics curriculum"; (8) "who teaches engineering ethics"; (9) how faculty members teach engineering ethics"; and (10) "how students learn engineering ethics" (p. 89). According to Katz, these different areas interact and inform each other, and that "the confluence of each area into a collective whole forms a person's mental model." Fig. 1, taken from Katz's dissertation, shows the potential interaction between Areas 1-3.

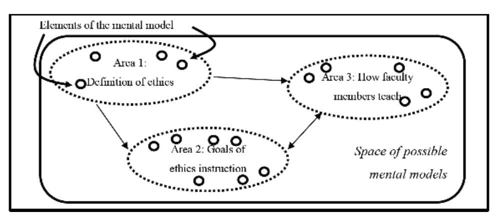

Fig. 1. Katz [5] mental model overview of engineering ethics education

III. METHODS

A. Faculty Learning Community (FLC)

To encourage engineering faculty members to explore novel opportunities for integrating ethics in their curriculums at a large public university in the Midwest USA, we designed a Faculty

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Learning Community (FLC) as an institutional support wherein participants identified how best to integrate ethics into individual courses to support self-defined program outcomes. Thus, the FLC supported faculty members' active inquiry into their personal and professional identities, values, and purposes, including how these intersect and how these inform their teaching practices. Specifically, participants engaged with scholarly work on professional identity, ethical inquiry, community-engaged learning, civics education, and critical reflection as they redesigned courses. Many faculty members engaged additional scholarly literature outside of the FLC, with multiple members even beginning to produce scholarly work associated with their curricula.

B. Participant Overview

This WIP study examines curricular artifacts and interview data. Participants included all (five) biomedical engineering faculty members who participated in the FLC at Large Midwestern University. Each faculty member participated in an intensive FLC (see above). Upon conclusion of the first year of the FLC, faculty members had produced multiple curricular artifacts, including course curriculums and associated ethics materials. In the second year of the FLC, participants implemented the first iteration of their revised course materials. In the following summer, all five faculty members participated in one-hour semi-structured interviews with members of the research team.

C. Data Collection

We analyze two primary sources of data: 1) curricular artifacts (departmental materials, individual course curriculums, and individual course activities) and 2) faculty interviews.

1) Curricular Artifacts

a) Shared Departmental Materials

Collectively, the biomedical engineering department developed two shared tools to aid faculty intentionality in integrating and assessing ethics across the curricula. These tools included: (1) an ethical reasoning heuristic that includes considerations from external sources, including Weston [6] and the Markkula Center [7], and (2) a common ethical inquiry rubric modeled after (but not identical to) existing rubrics such as AAC&U Ethical Reasoning VALUE rubric [8].

b) Individual Course Curriculums

Faculty refined their curriculums at the end of the first and second year of the FLC. Faculty highlighted specific changes to their curriculums that were specifically related to ethics. These highlighted sections were the primary unit of analysis.

c) Individual Course Ethics Assignments

In addition to course curriculums, faculty described ethics activities (e.g., readings, lab experience). These activities were all coupled with a critical reflection script modeled after DEAL [9]. Some faculty members included ethics at a single juncture in the semester, whereas others wove ethics across the semester.

2) Interviews

The research team conducted interviews after the faculty members had participated in the FLC for two years. Thus, interviewees had participated in an extended set of collective learning experiences, had revised an existing course, and implemented the course prior to interviews. The interviews also provided an opportunity for faculty members to reflect on their overall experience in the FLC and to share lessons learned from implementing ethics into their disciplinary courses. Interviews included six primary sections: (1) motivation for participating in the FLC, (2) perceptions of ethics, (3) perceptions of community engagement, (4) perceptions of critical reflection, (5) impact of the FLC, and (6) a summative/closing section.

D. Data Analysis

In reviewing the above materials, we began by employing Katz's mental model categories pertaining to the question, "What is ethics?" as codes, which aligns with "Area 1" of Fig. 1. Theoretically, this informs what topics faculty aspire to teach (Area 2) and how they teach these topics (Area 3). While we began by deductively applying Katz's codes, we slowly iterated to a more inductive process guided by the data. Specifically, we shifted from addressing the question, "What is ethics?" to a related but distinct question, "***What considerations are important for ethical practice in biomedical engineering***?" In addressing this question, we combined multiple codes from Katz's framework that were challenging to discern (e.g., local, global, and macro were all combined into a single societal code). Once we established a set of codes relevant to the curricular materials, we analyzed interviews to identify the important ethical considerations. Thus, in analyzing interviews, we employed deductive coding alone.

IV. Results

We identified nine ethical considerations evident in both curricular artifacts and faculty interviews. In the following sections, we provide a brief definition of each consideration in ***italicized and bolded text***, followed by examples from the data.

A. Economic

Engineering ethics involves considerations pertaining to money or other forms of capital (e.g., profit, business ethics). Interviewees articulated the value of economic considerations through learning outcomes on curriculums and ethics assignments. The learning outcomes situated economic considerations alongside other ethical considerations using the following language: "[students will be able to] demonstrate awareness of ethical and professional responsibilities in global, **economic**, environmental, and societal contexts." Assessment items prompted students to consider the economic impacts of their designs.

Two faculty members discussed the role that money plays in engineering practice. For example, when considering factors that drive engineering work, one faculty member shared that "nobody builds a damn thing unless they think they can make money out of it." Another faculty member shared, "Lives are the most important, but people's time and energy, and money, it all gets wrapped up in ... You can't move things forward just out of altruism." Thus, like the curricular artifacts, these quotes suggest that economic considerations are ethical considerations.

B. Environmental

Engineering ethics involves considering the environment (e.g., nature, animal rights, resource depletion). Similar to the economic considerations, environmental considerations were present alongside other ethical considerations, such as product lifecycle and disposal. The assessment rubric called forth consideration of "all stakeholders," which may include "non-human" entities (e.g., one course had students engage in rodent tissue harvesting followed by ethical reflection).

Interviewees addressed the environmental effects of product manufacturing in course assignments. As one participant stated, "Maybe this certain plastic is the best material, but maybe that plastic will be around on this earth for 2 billion years or something like that, and that's not a good thing. So, getting them [students] to think about environmental concerns as well as concerns of access for patients and things like that." Another faculty member spoke in-depth about animal rights in relation to the tissue harvesting activity.

C. Interpersonal

Engineering ethics involves considering interactions between self and others (e.g., relationships, partnerships). The shared departmental ethical reasoning heuristic emphasized the importance of considering relationships with others, stating:

> Ethics is central to our human experience and provides an organizing dimension to human interaction. Because it invokes questions that consider morals, values, and principles, and because it seeks to consider and respect alternate viewpoints, it is a key component to living within a society in a civilized way.

While this beginning text ostensibly framed the critical role of relationships, throughout other artifacts, it was difficult to identify interpersonal considerations in the data. While artifacts prompted students to reflect on the role of self (see *personal* consideration below) or the importance of others (usually quite broadly defined – see *societal* code below), rarely did these artifacts emphasize relationality between self and others. Nonetheless, this framing was potentially implied by the myriad ethics-related teamwork and discussion activities.

Faculty interviews revealed a shared belief that considering interpersonal relationships' role in ethical action highlights ethics' contextual nature (i.e., what an ethical course of action might be is a function of the relationships present in the situation). These relationships motivate an evaluation of who or what might be affected and *how* they might be affected.

D. Legal

Engineering ethics involves considering the law (e.g., regulations; policies). By legal, we refer to any set of governing 'rules' or 'standards.' Legal considerations were generally less present in curriculums and ethics assignments compared to other considerations and had their greatest presence in a senior design course wherein students considered FDA regulations.

Legal considerations had a slightly greater explicit presence in interviews than curricular artifacts. For example, one faculty member who did not explicitly include legal considerations in their curriculums or assignments noted the importance of being aware of and responsive to laws to avoid litigation, stating:

> Companies have to be more aware of some of the decisions they make so that they want to avoid getting into that sort of ... all the litigations that might happen if they happen to make the wrong decision. I think that's the other driving force, another benefit of training people to be more ethically aware.

E. Organizational

Engineering ethics involves considering organizational culture (e.g., organizational values, codes, procedures). Organizational considerations were not explicit in most curricular artifacts; rather, they had a presence by considering specific organizational artifacts. For example, one faculty member introduced Medtronic's "Mission Statement," and the ethics assignments prompted students to consider the unique needs of organizations, including how organizations ought to interact with regulating bodies.

Like the legal considerations, organizational ethical considerations tended to have a greater presence in interviews than in curricular artifacts. As one interviewee stated, "if you're [in] industry, you work within a company, and the company has certain rules that by agreeing to work there, you kind of have to follow because that's just how things are."

F. Personal

Engineering ethics involves personal considerations (e.g., one's own beliefs, values). In course curriculums, personal considerations were exhibited through language, suggesting that students will "recognize their own values and morals" and "will be asked to engage this issue and reflect on what it means to you in terms of your core beliefs." Personal considerations also appeared in all five faculty members' course assignments through prompts to examine one's understanding of an ethical dilemma. Often, these examples were very explicit, such as the reflection questions from *separate* courses asking, "Which option leads you to act as the person you want to be?"; "Does this agree with your personal ethical standard?"; and "Can you elaborate on which of your core values/beliefs are most in conflict about what you saw and why?"

Interviews revealed that faculty members largely linked ethics to morality, wherein they defined morality as (largely) a personal set of principles. Faculty shared that ethical action requires "apply[ing] your own personal morals when acting" and is "driven by your moral compass inside." Similarly, faculty members shared that ethical inquiry is needed for engineering work "becomes very personal because everyone's going to have different moral standards." This framing aligned with the topics related to identity introduced in the FLC.

G. Professional

Engineering ethics involves thinking about good practices associated with being a professional in my discipline (e.g., disciplinary codes of ethics). Similar to *economic* and *environmental* considerations, a common learning outcome across courses called attention to the role of professional ethical responsibility in engineering work. Seldom were "professional responsibilities" explicitly defined in ethics prompts, with a few exceptions, such as the Biomedical Engineering Society (BMES) code of ethics [10]. While course learning goals seemed to differentiate between professional and other ethical considerations, the relationship between the two was apparent in some assignments. For example, one interviewee noted on an ethics-based assignment, "a part of your responsibility as a biomedical engineer (and a human) is to engage in ethical inquiry within the profession."

Interviewees more explicitly unpacked professional ethical considerations. As one faculty members shared:

> Being ethical is, “Am I consistent with those ethical guidelines of my profession?” For me, it may be the Biomedical Engineering Society, it might be the IEEE, it might be the American Physiological Society. It's usually professional societies based around a discipline…

H. *Societal*

Engineering ethics involves considering social contexts (e.g., social systems, local or global concerns, local or global communities). In some instances, this code captures considerations concerned with the specific concerns of a local or global community. However, more often, this code seemed to call forth normative considerations concerning the roles or responsibilities of engineers in society, writ large. Faculty members introduced students to societal considerations through discussions about stakeholder groups and course assignments. For example, in ethics-based assignments, faculty members encouraged students to reflect on the prompts such as: 1) “Who are the stakeholders and societal groups affected?” and 2) “Which option best serves the whole community?”

Societal considerations were also common across interviews, with many participants discussing the interactive effect between societal ethical considerations and other ethical considerations. For example, one participant spoke about how laws are social constructs, stating:

> To get to the understanding [of] ethics, for me […] it's multilayered, so broader societal norms and ethics, right? We've got our laws. If you break laws, if you don't follow societal norms that are codified in policy that can be deemed unethical, assuming that they're good laws, right?

I. *Technological*

Engineering ethics involves thinking about the technologies that engineers develop, manufacture, or produce, and (often) their impacts (e.g., minimizing negative impacts of technology, ensuring technology benefits others). Curricular artifacts often framed technological consideration with respect to other ethical considerations, such as *theoretical* considerations pertaining to maximizing goodness and minimizing harms. As a specific example, one assignment prompted students to reflect on medical device recalls presented in a documentary, asking, “How many patients is ‘too many’ to be affected adversely [by medical technology] and have a company consider making a move?" In addition to developing and implementing an ethics assignment to meet FLC requirements, this faculty member administered an assessment at the end of the semester that included items related to medical device recalls.

These sentiments were common in interviews, too. One faculty member discussed implications of unintentional misuse of technology (measurements displayed on an electrocardiogram device) that highlights technological considerations as ethical considerations:

> Somebody's going to be making a decision on your health or somebody you care about based on these squiggly lines. If they don't properly attach the ground what you would worry about mostly is that you missed something, that there's an arrhythmia, for example. And the clinician just is reading the chart but they just blow it off because they didn't have the right ground on, so that must be it. It's not an arrhythmia - this person's never shown anything like that before.

J. *Theoretical*

Engineering ethics involves thinking about philosophical moral considerations (e.g., Justice, Utilitarianism). Outside of the Student Ethical Reasoning Framework, which outlined five “ethical perspectives” (utilitarian, rights, justice, common good, and virtue), explicit language about theoretical considerations were minimal in course artifacts and interviews. However, general language (as opposed to explicit language) that implied deliberate considerations associated with theoretical ethical considerations were pervasive. For example, the Belmont Report was presented in one course, and considerations pertaining to the Belmont principles were presented without explicit mention of those principles in reflection questions (e.g., three faculty members prompted their students to think about what might do the “most good and least harm”).

V. CLOSING DISCUSSION

In this study, we extended Katz’ mental model framework to discover if and how curricular artifacts and faculty interviews can begin to reveal faculty members’ mental models associated with the question, “What is ethics?” While we found many codes directly aligned with Katz, we found ourselves shifting from a focus on *ethical topics* (see Figure 1) to *ethical considerations*. Due to this shift, we introduced multiple new codes. We do not posit that these codes represent considerations that were absent from Katz’ work; some codes absorbed multiple aspects within Katz work. For example, Katz’ “micro-ethics” topic is ostensibly represented by the *interpersonal* considerations and Katz’ “local,” “global,” and “macro-ethics” codes are ostensibly represented by the *societal* code.

In total, we identified nine significant ethical considerations in faculty products. While we presented these as discrete codes, the considerations they represent are entangled. Thus, they do not function independently from each other. Moreover, we do not wish to purport that these considerations are exhaustive of all considerations that are worthy of consideration in ethical engineering practice.

The language that faculty members used in artifacts and interviews to describe each consideration varied. Thus, we sometimes struggled to identify succinct codes in the form of adjectives that captured all ideas. For example, we developed but removed a code that captured express considerations pertaining to diversity and equality (e.g., the ethical reasoning heuristic prompted students to consider “Which option treats people equally?”).

We intend that this study will guide future research seeking to address the question, “How do individual mental models inform the ethical considerations they bring to the classroom?”

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