The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
ASEE
Paper ID #43017

On the Challenges of Transferring Teaching Practices in Engineering Ethics and an Asset-Based Approach to Developing Ethics Instruction

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Abstract

This theory paper provides the insight that teaching engineering ethics inevitably draws on an individual faculty's knowledge and experience in their engineering field and proposes what we call "an asset-based approach" to developing faculty competencies in engineering ethics instruction. Our position is informed by a literature review showing the following: whereas the ideal of engineering education research seeks to identify and promote "best practices" in engineering education, this goal faces at least three sets of challenges in the practice of engineering ethics instruction. First, the scope of engineering ethics has grown and diversified owing to evolving accreditation criteria and reflections from the engineering education community. Second, teaching practices for engineering ethics also expanded and diverged accordingly to answer the increased and changing needs in engineering ethics education. Third, even when a promising ethics teaching practice is identified, there is a great variation in faculty views about its effectiveness, further compounded by the methodological challenges of assessment and inconsistent perspective changes among students after an engineering ethics education experience.

To provide a case study illustrating how teaching practices in engineering ethics vary greatly among faculty, we reviewed a selection of published articles which outlined their approach to ethics in response to one specific program/student outcome of ABET spanning accreditation cycles from 2005 to 2019, namely Outcome (h): "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context," and we show that teaching practices are highly dependent on faculty's disciplinary backgrounds, experiences, or professional interests. Drawing on our own reflections in teaching-focused positions and findings from other researchers and educators, we propose an asset-based approach to building faculty competencies for ethics instruction and describe three sets of faculty assets for practitioners to consider. Given that questions concerning the more personal, self-directing side of an educator's professional growth have only been systematically explored in literature outside engineering education, we hope that our examination of the roles of faculty and their assets may begin a similar dialogue in engineering education.

Introduction

With the growth of publications and shared resources coming to light for the engineering education community, instructors are continually presented with new approaches and strategies they can apply in their courses. In the research-to-practice cycle, instructors would inform themselves about innovative practices emerging from others' research, improve teaching plans drawing on new information, and assess student outcomes and feed back successful practices (and lessons learned) to the research community. This paradigm has a historical root in modeling engineering education after traditional sciences that have greater consensus on theories and methods, with the goal of elevating engineering education practice to "research" that is generalizable and transferable [1]. Research in the wider institutional context, such as in the mandate for institutional review boards (IRBs) in the US, is further understood as "a systematic investigation […] to develop or contribute to *generalizable knowledge*," where oral history, biography, and historical scholarship are *not* considered research because these activities focus more on individuals or a limited number of people [2]. A survey of book chapter titles in the 2014 *Cambridge Handbook of Engineering Education Research* renders a quick list of examples of generalizable knowledge, comprising "theory," "model," "framework," "method(ology)," and "best practice."

While the emphasis on generalizable categories has contributed to the development of engineering education research, when it comes to engineering education practice, it remains a recognized problem to what extent research outcomes are transferable or scalable. In the systematic review of the literature, scholars have identified several challenges to the transfer of research to practice in engineering education, such as not treating educational practitioners as active participants during the process of adopting research-based practice, not considering an innovative practice's compatibility with the prior knowledge, values, or needs of instructors, not offering multiple options of practices for educational practitioners to choose, as well as not recognizing the constraints of instructional resources and institutional expectations [3]. To address similar questions specifically for engineering ethics education, our article investigates the difficulty of determining best teaching practices and suggests accordingly an asset-based approach to faculty's professional development recognizing different instructional competencies. In the following sections, our paper discusses challenges of transferring practice in engineering ethics education, articulates underlying reasons that are inherent in engineering ethics for the challenges, provides a case study illustrating the dependency of ethics instruction on an instructor's disciplinary backgrounds, experiences, and professional interests, and finally proposes an approach that includes three types of "faculty assets" for engineering instructors to build competencies in ethics education.

Challenges to Transfer of Best Practices in Engineering Ethics Education

While there has been a growing interest in engineering ethics research, it seems that education practitioners also meet with an increased difficulty in adopting effective strategies for teaching engineering ethics. Reviewing developments of engineering ethics education and the literature, we have identified three sets of challenges making best practice in engineering ethics instruction difficult to transfer, if not untransferable. First, there have been growingly diverging views concerning the scope of engineering ethics and what should be taught, primarily driven by the development of accreditation criteria and reflections from the engineering education community. Expectations that in the past appeared unrelated to ethics, such as being able to understand the relations between technology and society, have been increasingly recognized by educators (e.g. [4]) and accreditation bodies as an integral part of engineering ethics. For example, the ABET criterion pertaining directly to ethics evolved from a mere "understanding of professional and ethical responsibility" in Engineering Criteria 2000 (EC2000) to "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" in the ABET 2019–2020 cycle. The "broad education necessary to understand the impact of engineering solutions in a global and societal context" in EC2000 was joined by the economic and environmental contexts, in addition to "an ability to design […] to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability" in the ABET 2005–2006 cycle. For the 2019–2020 cycle, design further requires "consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors." Furthermore, in light of developments correlating ethical responsibility of engineers to the issues of diversity, inclusion, and equity that have long plagued the engineering field (e.g. [5, 6]), expecting students to "function effectively on a team whose members together […] create a collaborative and inclusive environment…" is now inseparable from ethics in engineering (e.g. [7, 8]). The above developments imply that good practices that addressed ethics topics satisfactorily two decades ago may no longer be sufficient for now because of the evolvement and interconnection of different ethics expectations.[1] Without continuing professional development, all these changes external to the classroom can lead to confusion and uncertainty among many engineering instructors over what qualifies as engineering ethics education [9].

Second, while the expanding scope of engineering ethics makes it more flexible to pick several areas most relevant to the goals of individual engineering programs or courses, pedagogies, strategies, and perspectives surrounding how ethics may be taught have also multiplied accordingly. When the community of engineering education first needed to meet the ethics requirements in EC2000, being able to apply ethical theories (such as virtue ethics) and the National Society of Professional Engineers (NSPE) code of ethics to the evaluation of alternative solutions in an ethics case study was a desirable first step (e.g. [10]). However, when selecting case studies, some educators were already split over using real-world cases (e.g. [11, 12]) or fictional cases (e.g. [13]). The Internet had already made possible the proliferation and availability of both types of case studies by the 2000s, including webpages from the Online Ethics Center for Engineering and Science, the NSPE, the Institute of Electrical and Electronics Engineers (IEEE), the Center for the Study of Ethics in the Professions (CSEP), and individual university professors [4, 14]. At present, the paradigm of primarily using ethical theories and codes of ethics has been challenged (e.g. [15]) and seems to be in decline [16, 17], and ethics pedagogies additionally include the development of case studies, codes of ethics, or decision-making processes by students, community-based engagement and learning, peer mentoring, critiquing ethical theories, and gamification of ethics education [18]. Specific strategies for positioning course activities and modules further include stakeholders and the perspective-taking, communication, and engagement process surrounding different participant roles [19, 20,

[1] ABET requires continuous improvement of engineering programs and in the long run ensures that ethics education, among educational objectives, is up-to-date and meets expectations (or sometimes, conventional standards).

21], uncovering social values embedded in an existing technology (e.g. [22, 23]), analytical frameworks eliciting micro-, meso-, macro-, and meta-ethical questions surrounding the knowledge and practices of engineering [24, 25], and the lens of social justice and equity [26, 27, 28].

Third, even when a promising ethics teaching practice is recognized, there is still a great variation in faculty views about its effectiveness and transferability. In their research, Bielefeldt, et al. [16] attempted to identify ethics teaching exemplars from 35 instructors who were more enthusiastic about ethics and more resourceful in adopting different ethical topics and pedagogics than most other ethics-teaching educators they surveyed (n = 1159). Their data, however, showed that there was more disagreement than consensus among research participants with respect to the overall effectiveness of the 35 potential exemplars and the extent to which participants would be personally interested in using them, making the researchers acknowledge that there will unlikely ever be a "'one size fits all' approach" to ethics education. While faculty in general agree that engineering ethics should be incorporated into multiple courses in the curriculum, those who teach traditional, more technical courses are less likely to think that ethics should be taught in their own courses [29, p. 15], despite the fact that approaches like "micro-insertion" [30] are available for integrating ethics into an existing technical course, in addition to more radical ways to teach ethics in a traditional course like thermodynamics (e.g. [31]). To compound these issues, there have been philosophical challenges to the assessment of engineering ethics education, shedding light on the biases of existing measurement instruments favoring knowledge (instead of ethical behaviors or practices) and certain moral theories [32, 33, 34]. Recent research that employs longitudinal studies on students (i.e. for a prolonged period beyond the duration of a course) further shows that there are no additional effects on ethics-related attitudes (or perceptions) among participants compared to non-participants in nearly all of the activities surveyed by the researchers, which notably (and surprisingly) include formal ethics courses and workshops, study abroad, volunteering trips, non-profit work/internship, engineering professional societies, student government, chapters of engineering-focused service organizations, undergraduate research experience, etc. [35, 36], raising questions at once about the limits of prevalent, course-level assessment of ethics development as well as the long-term effects of most professional development activities on ethics-related growth.

Underlying Reasons for Challenges

Based on our experience in engineering education, we believe there are two reasons accounting for the above difficulties in effectiveness and transferability. The first lies in the dynamics underlying engineering ethics and its educational pedagogy. Unlike engineering sciences and mathematics, whose technical contents are relatively stable and universal over time, the subject matter of engineering ethics deals with the professional responsibility of engineers inevitably situated in a societal and geographical context. For example, case studies may draw on recent events and technological developments that matter to the participant. Expectations of what to teach in engineering ethics, such as the previously-noted ABET criteria for ethics-related learning outcomes, evolve over time to include topics reflecting societal needs. Codes of ethics also receive an overhaul occasionally. Moreover, since engineering ethics considers competing priorities of professional commitments in an ethically uncertain situation, ethics instruction calls for a deliberate approach, including the exercise of critical thinking and open-ended discussions.

Whereas engineering design similarly balances competing design criteria and varying interests of stakeholders to deliver a locally viable engineering solution, engineering ethics (as an essential part of engineering design and other activities) is concerned more about analyzing potential, often unpredictable consequences of engineering practices arising from a particular scenario and developing a sensitivity to human values that are less tangible and measurable.

Second, the dynamics of engineering ethics further intersect with diverse teaching settings and institutional contexts, making best practices unlikely to benefit all education practitioners alike. These practitioners may have received different disciplinary training, teach in engineering programs at various types of institutions with distinct student demographics, have varying degrees of interest and involvement in teaching (as opposed to other responsibilities), and hold diverse teaching philosophies regarding the values of education and of engineering. As an umbrella term, engineering ethics may relate differently to practitioners from separate engineering disciplines and embody a set of ethical problems and issues that are more relevant to a field. For example, whereas in biomedical engineering engineers might prioritize the principle of "do no harm" and informed consent because the potential risk of a malfunctioning medical device is often direct and immediate to a patient's health and safety, in civil engineering practitioners may emphasize sustainability, transparency, and accountability, because potential harm and negligence and their remedy are often determined in the long term. Besides practitioners, existing courses and their differing contents and objectives matter too. A well-developed course may include a detailed semester schedule that arranges each week's activities and assignments in a thought-out sequence to meet a set of course outcomes often designated by an institution. What works for some researchers or educators may not fit without coordinating the course's moving parts and logistics. From an engineering program's point of view, the challenge and considerations of introducing best practices is not dissimilar to those of "technology transfer," which must recognize an organization's own goals, resources, capabilities, and other contextual factors [37, 38].

The contextual factors in the content of engineering ethics, the open-endedness of a particular ethical scenario, and the diversity of instructional settings all highlight that "contexts" of teaching engineering do matter to ethics education. Considering again the difficulties of transferability that we formerly identified in the literature, we believe we should embrace the "contexts" and adapt our teaching of ethics accordingly, instead of solely turning to research or best practices that appear to conquer and iron out different contexts. These contexts include, for example, a faculty member's engineering knowledge and professional interests. If contexts contribute originally to the development of one's own ethics materials, one's approach to ethics may not easily transfer to other educational settings when the other instructors do not share similar knowledge or interest. Indeed, instructors have depended on their knowledge and interest all the time for course development, but we believe the connections between faculty background and the delivery of their course remain underexplored, particularly in engineering ethics education.

Case Study

To illustrate our point, we provide a brief, informal case study showing the dependency of ethics instruction on an instructor's disciplinary backgrounds, experiences, and professional interests.

We reviewed educational practices that meet the ABET program/student outcome (h) during accreditation cycles of 2005–2019, namely "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context." We chose this historical outcome because of its ambiguity and flexibility. While there appeared to be four possible contexts to be considered to achieve Outcome (h), the "and" also suggested the four contexts are all required, making Outcome (h) a particularly difficult one to fulfill for many engineering departments and programs (e.g. [23, 39]). Moreover, despite Outcome (h) being "the impact of engineering solutions," some educators pursued the reverse direction and focused instead on how global, economic, environmental, and societal contexts have impacted an engineering solution or design (e.g. [23]). We searched two databases—ASEE PEER Document Repository (https://peer.asee.org/) and Google Scholar (https://scholar.google.com/)—with Outcome (h), reviewed the first 10 search results in each database, and identified articles which explicitly describe specific educational practices to meet Outcome (h) (potentially in addition to other outcomes) and excluded those focused only on theory, assessment, or curriculum. [2] The process yielded 3 and 5 articles, respectively, from the two databases.

We analyzed the connections between an author's teaching practices and their disciplinary backgrounds, experiences, and professional interests, and found that two articles' authors—Riley [40] and Geselowitz and Vardalas [41]—who all have academic backgrounds and professional interests intersecting both engineering and the liberal arts employed readings in their classroom drawing widely on the humanities and social sciences, including history of technology, philosophy of science, and science and technology studies (STS). Three faculty members who earned an engineering degree while having experience and interest in certain topics related to Outcome (h) developed course activities combining domain-specific engineering knowledge and sociocultural issues in their field. For example, Franquesa [42], who obtained a Bachelor's degree in computer science engineering and a Master's degree in sustainability, implemented service-learning activities where students fixed and updated old (and sometimes broken) computers for local communities; Holloway [43], who was the department chair in Electrical and Computer Engineering and the director of an institute bringing policy-side perspectives on power and energy, offered a class on global energy issues; and Bielefeldt [44], who holds a PhD in civil engineering and is interested in sustainability and social responsibility in engineering, employed two case studies consisting of a controversial local water supply project and Hurricane Katrina. Instructors who taught design courses either introduced additional societal and global requirements to existing design projects (e.g. [39]) or developed new "design scenarios" that embed Outcome (h) in student design projects (e.g. [45]). Finally, Brocato [46], who had a degree in English and experiences teaching technical communications, proposed using case studies (one being the Space Shuttle Challenger disaster) that had readings and asked students to analyze and discuss readings or write and present what they find.

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[2] We searched the two databases in January 2024. The search query we used for Google Scholar was: "in a global, economic, environmental, and societal context" "the impact of engineering". We adopted the following search query for the ASEE Repository: "engineering ethics" "in a global, economic, environmental, and societal context" "the impact of engineering". (Note that there is a whitespace character between double-quoted phrases for both searches.) The additional phrase "engineering ethics" was added to the ASEE search to include more articles relevant to engineering ethics in the top 10 results. A formal, more systematic investigation is future work.

An Asset-Based Approach to Faculty Competencies in Ethics Instruction

Given that all the teaching practices we reviewed above are highly dependent on the disciplinary knowledge, experience, or interests of faculty, we propose an asset-based approach to developing faculty competencies in ethics instruction. The assets we describe here are a set of knowledge, experience, values, identities, and professional interests that an instructor has and may develop, in addition to other resources available in one's community of practice that are relevant to their own teaching settings and objectives. Whereas in engineering education, asset-based approaches and other similar strategies have centered around *student assets* that an instructor needs to consider, validate, and empower, particularly when teaching for students from disadvantaged, underserved communities (e.g. [47, 48, 49]), our asset-based approach concerns assets of an *instructor* for the purpose of self-directed faculty development in teaching ethics. On one hand, beyond university engineering education, authors who remind us about individuality of teaching have discussed the personal, spiritual, and autonomous dimension of being a teacher, including one's identities, values, personality, biography, educational background, experience, skills, and capacity [50, 51]. On the other hand, in engineering ethics education, researchers have attempted to survey the nature and variability of teaching practices (including recognized exemplars) and derived certain categories that are related to a faculty's assets, including ethics teaching pedagogies, classroom activities, types of case studies being used, and how ethics components in a course are related to the engineering curriculum [17, 18]. We have referred to our reflections on practices and expanded on literature when developing the following three types of faculty assets relevant to engineering ethics education. A summary of the faculty assets is also provided in Table 1 for readers' quick reference.

1) Knowledge about Courses in an Institutional Setting

Most engineering faculty, particularly those in teaching-focused positions, fulfill expectations to teach certain courses necessary in an engineering program's curriculum. Factors that are important to consider for ethics instruction include course levels (e.g. first-year, senior-year, and graduate-level) and whether in the curriculum a course's learning objectives have traditionally been technically-oriented (e.g. a course on calculus, unit operations, structural analysis, and thermodynamics[3]) or more inclusive of ethics-related topics because of non-technical skills, design components, or interactions with humans and the environment (e.g. first-year introduction to engineering, chemical plant design, environmental engineering, and mechanical design[4]). Even though literature often advocates developing a certain type of ethics knowledge or skills in students, it is important to consider the characteristics of one's courses and identify strategies for integrating ethics materials. For example, while a technically-oriented course makes it more practical to use a micro-insertion approach (e.g. [30]), developing an insider knowledge about how our courses are related to the rest of the curriculum may allow us to make an additional connection to ethics-related topics in other less technical courses and thereby embed ethics across the curriculum. Likewise, for those teaching a design class, having a comprehensive knowledge about the nature of the student projects allow an instructor to evaluate the

[3] The example courses listed here correspond respectively to technical courses in first-year (or general) engineering and majors in chemical engineering, civil engineering, and mechanical engineering. We drew these courses from the engineering curricula of our universities.

[4] See the previous footnote for the engineering programs each of these courses may correspond to.

applicability of different ethics instruction strategies (e.g. analyzing the multi-faceted impacts of a design to different stakeholders) and develop relevant ethical materials, assignments, and activities (e.g. designing an immersive ethics case study pertinent to the scope of a design project).

2) Individual and Personal Assets

Individual and personal assets are those assets uniquely possessed by an instructor that are relevant in the classroom. When teaching an engineering topic, instructors may draw on personal knowledge and experience to enrich their teaching and engage students in learning. In engineering ethics education, individual and personal assets tend to play a greater role in one's teaching compared to teaching a traditional, more technical subject. They often vary greatly among colleagues in engineering departments and may include our academic background (e.g. studying an engineering discipline in a particular school/cultural context and knowing similar educational experience), industry experience and professional interests (e.g. practical experience or interests in safety engineering, inclusive design, or privacy and cybersecurity), teaching experience with certain pedagogies or classroom activities (e.g. being able to lead ethics discussions or debates in the classroom), values (e.g. prioritizing sustainability and biodegradability over affordability and product durability), identities (e.g. having experience in an engineering discipline makes one more inclined to consider ethical issues in the field), interests in ethical issues and implications of emerging technologies (e.g. generative artificial intelligence, virtual and augmented reality, and neurotechnology), and personal experience related to ethics (e.g. former supervisors requesting not to disclose safety concern to clients).

3) Community Assets

Community assets consist of resources an instructor has access to in the community of education. When planning for a course or designing a classroom activity or assignment, engineering faculty may learn from their colleagues, involve students in the active learning process, as well as considering resources from the wider education communities. In engineering ethics education, community assets may include our colleagues' individual or personal assets that contribute to our teaching (e.g. learning from a colleague teaching ethics before), student experiences and interests (e.g. letting student pick what emerging technology to focus on to explore ethical issues), knowledge from liberal arts programs (e.g. inviting faculty who research on and teach ethical issues of engineering for a guest speech), university programs and resources (e.g. consulting with centers that support faculty in teaching strategies that work at one's institution), and effective practices and ethics materials available from the Internet, workshops and conferences, or in the published literature.

Table 1: Types of faculty assets in engineering ethics education

Type	Asset	Examples
Knowledge about courses in an institutional setting	Knowledge about the nature of a course	Considering a course's levels and learning objectives helps identify appropriate opportunities or strategies to include ethics (e.g. a micro-insertion approach)
	Knowledge about the curriculum	Developing an understanding of how one's technical course is related to other less technical courses in the curriculum helps make a connection to ethics topics and embed ethics across the curriculum
	Knowledge about the nature of student projects in a design course	Knowing the scope of student design projects helps an instructor identify effective ethics instruction strategies and develop relevant ethical materials and activities
Individual and personal assets	Academic background	Studying an engineering discipline in a particular school/cultural context and knowing similar educational experience
	Industry experience and professional interests	Practical experience or interests in safety engineering, inclusive design, or privacy and cybersecurity
	Experience with certain pedagogies or classroom activities	Being able to lead ethics discussions or debates in the classroom
	Values	Prioritizing sustainability and biodegradability over affordability and product durability
	Identities	Having experience in an engineering discipline makes one more inclined to consider ethical issues in the field
	Interests in ethical issues of emerging technologies	Generative artificial intelligence, virtual and augmented reality, and neurotechnology
	Personal experience related to ethics	Former supervisors requesting not to disclose safety concern to clients
Community assets	Colleagues' individual or personal assets	Learning from a colleague teaching ethics before
	Student experiences and interests	Letting student pick what emerging technology to focus on to explore ethical issues
	Knowledge from liberal arts programs	Inviting faculty who research on and teach ethical issues of engineering for a guest speech
	University programs and resources	Consulting with centers that support faculty in teaching strategies that work at one's institution
	Effective practices and materials available elsewhere	Internet, workshops and conferences, or in the published literature

Conclusion

A significant portion of our paper discussed the challenges of transferring teaching practices in engineering ethics and provided our explanations about what contribute to the difficulties. While we designated the paper as a "theory paper" because of the theoretical perspectives we derived from analyzing the developments of engineering ethics education and the literature, we have been concerned with the practical implications of our findings and proposed an asset-based approach to ethics instruction considering different types of faculty assets. We intend the asset-based approach to be a practical resource for practitioners to build their competencies in engineering ethics education. The plural "competencies" suggests that there are widely different paths of professional development in engineering ethics instruction, depending on the assets that a faculty personally has or has access to in their community. In light of the ethics-across-the-curriculum movements [52], we hope the asset-based approach we proposed (and will continuously develop) is relevant to both individual instructors and program coordinators of engineering programs. Foregrounding the importance of a faculty's assets entails greater autonomy and responsibility of an educator over their own teaching and professional growth (e.g. [53]). As far as we are aware of, the only literature body that has systematically contributed to the understanding (and indeed, debates) of "teacher autonomy" lies in language education (e.g. [54, 55]). While the effectiveness of the asset-based approach remains to be evaluated in the lead author's institution, we hope that our examination of the roles of faculty and their assets may begin a similar dialogue in engineering ethics education (and potentially in other engineering educational areas that are less technical, such as liberal education, communication education, and leadership development).

As Parker Palmer [51, p. 10] has reminded us, "good teaching cannot be reduced to technique; good teaching comes from the identity and integrity of the teacher." He continues, "[i]f identity and integrity are more fundamental to good teaching than technique—and if we want to grow as teachers—we must do something alien to academic culture: we must talk to each other about our inner lives—risky stuff in a profession that fears the personal and seeks safety in the technical, the distant, the abstract" [51, p. 12]. His position, however, is not to replace techniques or best practices with one's identity. He suggests, instead, "as we learn more about who we are, we can learn techniques that reveal rather than conceal the personhood from which good teaching comes" [51, p. 25]. We have reason to believe that Palmer's view is applicable to engineering ethics instruction, not only because good teaching materials and methods depend on different instructors. It is also because for engineering ethics, the authenticity of teaching inevitably draws on who we are, including our knowledge and experience and how they interact with unsettled, emerging ethical questions arising from the accelerated development of growingly diversified yet specialized areas of engineering where no one can claim the only expert. The asset-approach we describe above are meant to provide inspiration for faculty to understand and leverage their assets, so they may identify teaching practices from colleagues or in the literature that are likely to work for them and eventually develop their competencies in engineering ethics education.

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