Sci Eng Ethics (2019) 25:1771–1788
DOI 10.1007/s11948-013-9444-5

ORIGINAL PAPER

Using Student Engagement to Relocate Ethics to the Core of the Engineering Curriculum

Mary E. Sunderland

Received: 18 December 2012 / Accepted: 3 April 2013 / Published online: 18 April 2013

Abstract One of the core problems with engineering ethics education is perceptual. Although ethics is meant to be a central component of today's engineering curriculum, it is often perceived as a marginal requirement that must be fulfilled. In addition, there is a mismatch between faculty and student perceptions of ethics. While faculty aim to communicate the nuances and complexity of engineering ethics, students perceive ethics as laws, rules, and codes that must be memorized. This paper provides some historical context to better understand these perceptual differences, and suggests that curriculum constraints are important contributing factors. Drawing on the growing scholarship of student engagement approaches to pedagogy, the paper explores how students can be empowered to effect change in the broader engineering curriculum through engineering ethics. The paper describes a student engagement approach to pedagogy that includes students as active participants in curriculum design—a role that enables them to critically reflect about why ethics is a requirement. Including students in the process of curriculum design leads students to reframe ethics as an integrative tool with the capacity to bring together different engineering departments and build bridges to non-engineering fields. This paper argues that students can and should play an active and important role in relocating ethics from the periphery to the core of the engineering curriculum.

Keywords Education · History · Pedagogy · Student engagement

Ethics is central to engineering. The importance of ethics is evident in the mission statements of many engineering schools, which aim, for example, to "improve the lived experience of people from all corners of the planet," (http://engineering.mit.

M. E. Sunderland (✉)
Center for Science, Technology, Medicine, and Society, Office for History of Science and Technology, University of California, 543 Stephens Hall #2350, Berkeley, CA 94720-2350, USA
e-mail: mary.sunderland@berkeley.edu

edu/about/) and teach students to "care about issues where technology can make a difference" (http://www.coe.gatech.edu/content/vision-mission). It is uncontroversial to describe ethics as a standard part of the curriculum, yet studies suggest that students do not experience ethics in this way. Indeed, there appears to be a significant disconnect between faculty and student perceptions and experiences of engineering ethics (Holsapple et al. 2012). This paper draws attention to the historical roots of this disconnect by exploring how ethics has been presented to engineering students. To help address this ethics divide, the paper argues for the adoption of more student engagement approaches to pedagogy (Smith et al. 2005). As a concept, student engagement has two central elements: a student component and an institutional component. Student engagement refers both to the amount of time and effort that students put into their studies, broadly construed, and to how institutions allocate their resources to facilitate students' participation in their learning. Focusing on student engagement enables an assessment of the relationship between student behaviors and institutional practices, and facilitates institutional reflection about effective practices (Wolf-Wendel et al. 2009).

The historical analysis provided in this paper brings into focus the general lack of student engagement in engineering ethics education. Although different strategies have been used to incorporate ethics into engineering curricula, these can generally be categorized into four basic approaches: (1) offer stand-alone ethics courses, (2) insert ethics modules into existing technical courses, (3) offer a stand-alone ethics course in conjunction with ethics modules, and (4) offer ethics education online. Not surprisingly, studies have revealed that all of these approaches have some undesirable features (Borenstein et al. 2010; Lincourt and Johnson 2004; Huff and Frey 2005). More unsettling though are the findings that fundamentally question the general effectiveness of engineering ethics education (Drake et al. 2005). Despite educators' best efforts, studies suggest that students are not meeting the intended learning outcomes of ethics courses. This paper asks why this might be the case, suggests that ethics education would benefit from more student engagement, and advocates for a particular student engagement strategy: including the involvement of students in the process of curriculum design. Involving students in the development of curricular materials allows students to make ethics meaningful by bridging the cultural and generational divides that often exist between students and instructors (Fielding 2001; Giles et al. 2004; Cook-Sather 2009; Alpay 2011; Bovill et al. 2011). Students also bring fresh perspectives with the potential to identify fundamentally new approaches to engineering ethics.

The paper opens with an overview of the history of engineering ethics in the context of the larger history of engineering educational reform. The next section tracks how ethics, the humanities, and social sciences have been presented in course announcements. The historical account highlights ethics' peripheral location in the broader curriculum. Although many institutions are currently making efforts to communicate the moral dimensions of engineering, the paper suggests that these efforts are weakened by historical curriculum constraints, particularly, although perhaps counter-intuitively, by the 1960s reforms that mandated humanities and social science requirements. Many engineering schools continue to require their students to take multiple courses in the humanities and social sciences, usually with some restrictions.[1] Although the social sciences and humanities are steadily described as a necessary part of engineering education, students often perceive these sorts of courses as irrelevant and often cumbersome requirements that must be fulfilled. They appear to be distinct add-on, non-critical, non-technical courses in an otherwise integrated curriculum (Adams et al. 2011; Wisnioski 2009, p. 754). This perception also applies to engineering ethics. The closing section explores how student-centered strategies might help to relocate ethics to the core of the engineering curriculum.

The paper's argument to embrace and support student-centered educational reform is motivated by the rationale that curricular change needs to include bottom-up approaches. While there have been many top-down initiatives to evaluate and modify the engineering curriculum to meet the challenges of the future, as evidenced by the National Academy of Engineering's report *Educating the Engineer of 2020: Adapting Engineering Education to the New Century* (National Academy of Engineering 2005), these visions of change are mediated by a variety of hurdles to curriculum reform, including the challenges of interdisciplinary coordination and communication, financial constraints, limitations to classroom size and space, instructional staff time, and skepticism of whether student learning will really improve (Borrego et al. 2010). Rather than focusing on these institutional hurdles to curriculum reform, this paper looks to how students might play a more formative role in shaping their educational experience. Doing so reveals that increasing student participation in curriculum planning actually helps to overcome some of these long-standing challenges. Drawing on the growing student engagement scholarship that explores how students can become active participants in the design and implementation of their education, this paper outlines student-centered approaches to engineering ethics currently being piloted at the University of California, Berkeley's College of Engineering (Fielding 2001; Giles et al. 2004; Cook-Sather 2009; Alpay 2011; Bovill et al. 2011).

Balancing the Curriculum

Why are engineering students increasingly required to study ethics? And how does portraying ethics as a requirement shape students' perceptions of ethics and of engineering? The short answer to the first question is ABET (Accreditation Board for Engineering and Technology). In 2001, ABET, which evaluates and accredits engineering programs, especially in the United States, implemented new ethics-related criteria. ABET requires engineering schools to demonstrate that their students have an understanding of professional and ethical responsibility, and an understanding of how engineering solutions work in a global/societal context (Felder and Brent 2003; Mitcham 2009). The challenge of meeting these outcomes ignited a variety of debates and inspired philosophical reflections about engineering

[1] For example, University of California Berkeley's College of Engineering requires students to take two courses in a series (i.e., two course from the same department, where at least one is an upper-division course) (www.coe.berkeley.edu/hssreq).

education. Some suggested, for example, that engineering should be the new liberal arts education of the twenty-first century, or that we are now in a post-engineering era (Seely 2005; Mitcham 2009). There was hope that ABET's new criteria would help to initiate a much needed transformation of engineering education, as evidenced by prominent reports such as *The Engineer of 2020*.

One of the problems, however, with requiring ethics was the very fact that it became yet another requirement. Donna Riley draws attention to why this framing is problematic with her critique of ABET's outcomes-based education approach (Riley 2012). Instead of students considering why ethics might actually be an integral part of engineering, ethics becomes yet another specific outcome that must be measured and achieved, thus quashing intellectual curiosity. Rather than enabling radical curriculum reform, ABET's emphasis on measurable outcomes reinforces traditional pedagogical strategies that emphasize the acquisition of technical content and scientific expertise as superior goals (Seron and Silbey 2009). This section looks at ethics as the most recent humanities-type requirement that has been layered onto the engineering curriculum. By looking at the longer history of efforts to incorporate social and ethical consideration into engineering, this section argues that engineering students need an opportunity to reflect more broadly on engineering education as a whole in order to address their preconceptions about ethics as a requirement. The historical context provided in this section suggests that the perceptual problem with ethics stems from the fact that students have faced an increasing number of requirements but have not had the time or space to consider why these requirements, especially the non-technical requirements, might be relevant and important.

It is misguided to think that ethics only entered the engineering sphere at the turn of the twenty-first century. On the contrary, these new outcomes were rephrased from earlier ABET requirements that emphasized the importance of understanding safety considerations alongside the social, economic and ethical dimensions of engineering (Mitcham 2009, p. 43). Looking even further back reveals a much longer historical effort to effectively balance the engineering curriculum by infusing it with the humanities and social sciences. Previous historical studies of engineering education reveal long-term efforts to redesign curricula to balance instruction in design, engineering science, and math together with the social sciences and humanities (Reynolds and Seely 1993; Seely 1999; Wisnioski 2009; Brown et al. 2009; Harwood 2006). This section locates ethics in this broader history of curriculum reform.

In contrast to other professions, such as medicine or law, which often trace their ethical roots back to ancient philosophers, engineering developed many of its ethical codes during the twentieth century. Professional societies played an important role in establishing these codes, including the American Institute of Consulting Engineers, which adopted an ethics code in 1911, the Institute of Electrical and Electronics Engineers (IEEE), which established a code in 1912, and the National Society of Professional Engineers, which established their code in 1946 (Barry and Ohland 2009). These codes largely functioned to guide business practices and raise the professional status of engineering until a mid-twentieth century shift directed more attention toward public safety (Pfatteicher 2003). Notably, in 1947 the Engineers' Council for Professional Development (ABET's precursor) suggested that engineers are not only responsible to their clients, but also to the wider public (Barry and Ohland 2009).

Concerns about public safety were linked to a larger post World War II shift in the engineering culture. Prior to World War II, research was not generally emphasized in academic engineering programs. The post World War II influx of federal research money to educational institutions changed the engineering educational environment (Reynolds and Seely 1993). The new focus on research was coupled to an educational shift that emphasized engineering's scientific foundations (Seely 1999). During this period new research-oriented fields emerged, such as nuclear engineering and computer science. By the 1960s, the societal implications of these new fields were becoming evident, which helped spur major efforts to modify the engineering curriculum. Those at the helm of the reforms hoped to educate a new generation of citizen engineers– leaders for the technologically oriented society (Wisnioski 2009, 2012).

In general, three core approaches were used to incorporate the humanities and social sciences into the engineering curriculum. The first approach involved warning students that technology had adversely affected civilization and that learning the humanities would help engineers to be better decision-makers for society. The second approach involved social scientists developing courses that would equip engineers to become policy-makers, and the third approach aimed to make engineers more introspective by assigning readings that would enable them to use tools from the social sciences and humanities just as they used mathematics and science. Each of these approaches engrained the notion of inevitable technological progress through a variety of explicit and implicit means (Wisnioski 2009). Although most of these programs and courses did not last, they caused a shift in the broader engineering culture and curricula, which held onto the idea that technology would inevitably progress, that managing this progress was the engineer's responsibility, and that incorporating the humanities and social sciences into the engineering curriculum would help students to learn these management skills (Brown et al. 2009; Wisnioski 2009).

According to the standard narrative, engineering ethics, as distinct from these earlier liberal arts initiatives, emerged as a focus of attention in the mid-1970s (Weil 1984, 1985). Indeed, it was in 1974 that the Engineers' Council for Professional Development revised their ethics code to include the statement "engineers shall hold paramount the safety, health, and welfare of the public in the performance of professional duties"—language that is now evident in most professional engineering codes (Barry and Ohland 2009). Attention to public safety was becoming widespread. In some institutions, the growth of engineering ethics was linked to the origins and growth of the "science, technology, and society" (STS) movement (Hollander and Steneck 1990; Cutliffe 1990). STS programs were established in response to a new social awareness about technology, spurred by the social and political upheavals that have since come to characterize the 1960s.

Many of these new STS-oriented courses and programs were formed in institutions with engineering colleges. Scholars hoped to teach engineers about the "true" impacts of their work. In doing so, many STS scholars openly questioned if science and technology were good. Attempts to classify technology as either good or bad usually implicitly or explicitly convey some kind of “pro-technology,” or “anti-technology” philosophy (Cutliffe 1990). Not surprisingly, the engineering community did not always welcome anti-technology criticisms about the “truth” of engineering. Despite some unwelcome criticisms, many engineers partnered with scholars from the humanities and social sciences to form courses about the social implications of technology, and/or engineering ethics. By the 1970s, STS programs had been established in a variety of institutions, professional societies were devoting time to social issues, and the NSF was funding ethics and values research (Hollander and Steneck 1990).

These activities prompted the Hastings Center, an institution devoted to professional ethics, to commission a study of the “resurgence of interest” in teaching ethics. The study, published in 1980, was dually motivated by a desire to understand the “indifference and outright hostility” that ethics education often engendered (Baum 1980, p. v). The report’s introductory section provides an overview of the engineering profession, including an entire chapter, “Characteristics of Engineering Students and Engineers,” dedicated to describing the “homogeneous group” of white, middle-class, male engineers who viewed the profession as a way to attain “upward mobility on the socioeconomic ladder.” The seemingly sweeping generalization was supported by recent statistics that showed fewer than 10 % of the graduating engineers in 1979 were female. The report contains many familiar stereotypes, including the notion that engineers prefer working with things rather than people, and that they are “uncomfortable dealing with and expressing personal feelings and emotions.” The report cited data from the Graduate Record Examinations to highlight that engineering is the only field where students score very poorly on the verbal section and fare exceptionally well on the more quantitative sections (Baum 1980, p. 11).

These generalizations are highlighted here because Robert Baum, the report’s author, argues that they reflect the preconceptions that many engineering students bring into an ethics classroom. Students see ethics as subjective and science as objective. In general, Baum describes engineers as ethical relativists who believe that “ethical knowledge is subjective and based on internal intuitions of individual persons, they believe that there is no basis whatsoever for resolving disagreements among individuals concerning ethical matters.” (Baum 1980, p. 12) To address these preconceptions, Baum emphasizes the importance of teaching about the philosophy of science and metaethics and suggests that ethics instructors need to clarify their own, hopefully different, epistemological starting points (Baum 1980, pp. 12–13).

Baum was worried that most engineers believed “the myth that it is possible to correct the difficult set of problems created by technology, economic injustice, and even fundamental human nature by running students through a one-semester course on this or that or something else.” The problem was compounded because there was “little recognition that students come into the curriculum with a deeply engrained set of values and basic outlooks and beliefs about all aspects of the nature of reality, including human nature, social values, and the meaning of life in general” (Baum 1980, p. 26). The only way, Baum concluded, to really change the ethical orientation of engineers was to change the selection criteria and admission process for entering the profession (Baum 1980). Baum was disillusioned with the state of engineering ethics education and deeply skeptical that revising an ethics course, or adding a new one would make a difference.

Much has changed in the thirty-plus years since Baum's 1980 report. The importance of engaging students' preconceptions, for example, is widely recognized in the broader education literature. If students' preconceptions are not met, students may appear to be learning, for example, they might achieve a high score on an exam, but outside of the classroom, they will continue to rely on their preconceptions to guide their decision-making (National Research Council 2005). Also, since Baum's report there have been many studies that show ethical learning does continue into adulthood and indeed can take place in a classroom setting. However, some of his concerns continue to resonate with today's climate. In part, this is because of the historical divide that exists between scholarship in engineering education and the learning sciences. There have been recent appeals to "bridge" this divide, but much of the scholarship in engineering education does not engage the learning sciences and vice versa. For example, one of the landmark learning sciences publications, which describes the importance of engaging preconceptions, *How People Learn*, centers on history, science, and math—not engineering (Johri and Olds 2011; National Research Council 2005).

Furthermore, it is still true that from many perspectives engineers continue to look somewhat homogenous. There are still far more males than females and a distinct lack of minorities. Engineering is still touted as the university degree that can make you the most money, a fact that surely helps to motivate many engineering students. The engineering curriculum still seems to be very technologically oriented and jam-packed with required courses. A 2010 study that used data from the National Survey of Student Engagement to compare the undergraduate experience of engineers to a variety of other majors determined that engineering students spend considerably more time preparing for class and less time working off campus for pay. The study's authors argue that engineering's programmatic restrictions make it more difficult for engineering students to participate in activities that contribute to social growth (Lichtenstein et al. 2010). It also makes them resentful when they perceive that further restrictions are being implemented to their curriculum. From the perspective of engineering students, ethics is yet another course requirement that must be met. Examining how ethics has been communicated in course announcements provides some historical context to better understand the roots of this assumption.

Communicating Ethics in the Curriculum

To appreciate why it is necessary to reconceptualize ethics as an integrative force rather than a discrete requirement, it is revealing to look at how the profession of engineering has been and is conveyed to prospective engineering students. Looking to course announcements provides a window to how the moral dimensions of engineering have been communicated to students, both implicitly and explicitly, before and after ABET's new demands.

"Should you be an engineer?" To help prospective students to answer this question, the University of California, Berkeley's College of Engineering (UC Berkeley's COE) publishes an annual course announcement, designed to introduce and guide students through the engineering curriculum. Many engineering institutions produce these kinds of "announcements." Often schools will keep a record of past announcements, as well as announcements from other schools, to help students, faculty, and administrators to navigate the curriculum, especially transfer students who are trying to determine if they have completed required courses. UC Berkeley's COE Student Services Office, for example, keeps an archive of announcements dating back to the 1930s. These announcements provide a window on the historical development of engineering education, an area that has attracted historians as a way to see how the societal roles of engineers have been communicated both explicitly and implicitly (Brown et al. 2009; Harwood 2006). Announcements are particularly revealing because they offer a philosophical frame to the curriculum in the form of a "letter to the prospective student," rich with thoughts about what it means to be an engineer. Although the details of the announcement have been edited throughout the century, many of the core ideas have remained constant.

Efforts to incorporate more humanities and social sciences into the curriculum are evident in the 1960s announcements (Wisnioski 2009). Some worried that the many math and science requirements might lead to the impression that the engineering curriculum was too restrictive, even to the extent that it might be viewed as dehumanizing. In 1967, George J. Maslach, Dean of the College of Engineering at UC Berkeley opined to prospective students, "You will not, of course, stop being human when you become an engineer" (University of California, Berkeley, College of Engineering 1967, p. 18). Maslach promised worried students that there will be "ample room in your program for humanities and social sciences and, indeed, these subjects are considered part of your professional education." According to Maslach, the humanities and social sciences mattered because engineers serve people, and serving people "requires understanding them, communicating with them, and appreciating at all times the needs of society." Maslach concluded that this unique combination of "technical ability with a humanistic perspective" would enable the engineer to be an "important figure in the modern world" (University of California, Berkeley, College of Engineering 1967, p. 19). Albeit, a figure "concerned primarily with the design of circuits, machines, processes, and structures, or with combinations of these components into plants and systems" (University of California, Berkeley, College of Engineering 1967, p. 18).

For the most part, the humanities and social sciences are described as a way for engineers to find "balance" and "freedom" in their busy course schedule. The 1971 announcement boasted, "Each curriculum has great freedom of choice for the student. Some permit more than one third of the unit requirements to be devoted to humanities, social sciences, and other subjects of your choice" (University of California, Berkeley, College of Engineering 1971, p. 6). The end goal was to educate engineers who were able to "combine technical expertise with a humanistic perspective" (University of California, Berkeley, College of Engineering 1973, p. 5). What does having a humanistic perspective imply? Is it the same as an ethical perspective?

In the 1980s the humanities and social sciences are explained as a "standard part of the curricula" that help engineering students to understand their profession's "profound impact on human welfare," a task with implicit moral dimensions (UCS 1983, p. 3). The 1980s also mark the first explicit reference to meeting ABET criteria. Throughout the 1990s, the humanities and social sciences requirement continues to be explained as necessary for a "well-rounded background" and something that is "needed to understand and contribute to today's society" (University of California, Berkeley, College of Engineering 1990, p. 3). Although values are implied in the earlier announcements, the language of ethics is not explicit until the 2000s, which coincides with ABET's new ethics requirements. The bioengineering undergraduate program began requiring students to take one course "with a substantial ethics component," selected from a list of approved options. Similarly, the nuclear engineering program reframed its educational goals to include attention to ethics, stating that it aimed to "produce graduates" who were capable of understanding the "broad social, ethical, safety, and environmental context" of nuclear engineering (University of California, Berkeley, College of Engineering 2005).

Since at least the 1960s, the social sciences and the humanities are steadily described in the course announcement as a necessary part of the engineering education. After 2005 ethics becomes a part of this explanation. However, there is not always a separate ethics course requirement. Specific requirements typically vary slightly from department to department, as indicated by the 2005 decision by the bioengineering department to include an explicit and specific ethics course requirement. Although the specific word, "ethics," only enters the course announcements very recently, there is long tradition of explaining the role of the engineer in terms of societal goods. Engineering programs educate engineers to solve technological problems that are important to society. Engineers are expected to use their education to do something useful, to make a contribution. This value-laden language implies that engineers will also need to learn how to identify and articulate the important problems and distinguish the role that they might play in solving them. Students are aware that the humanities and social sciences are meant to make them more well-rounded, but it is not clear how being well-rounded maps onto gaining knowledge about the ethical problems that are inherent to engineering. ABET now requires engineering schools to demonstrate that their graduating students have an understanding of professional and social responsibility, but they offer no specific guidance about how this might be achieved (Barry and Ohland 2009; Mitcham 2009; Shuman et al. 2005). And although we know the importance of engaging students' preconceptions, it is still not clear how to do this in the context of engineering ethics. Is it best, as Baum suggested, to teach engineering ethics as a multidisciplinary crash course in the philosophy of science and technology studies, the history of engineering and science, and science and technology studies, plus more traditional philosophical approaches to teaching ethics (Baum 1980)? The following section argues that the problem with many of these previously advocated pedagogical strategies is that the focus on content does not leave room for student engagement.

Student Engagement in Engineering Ethics

Student engagement is considered fundamental to student success in higher education. Although student engagement is a capacious concept, all definitions of engaged learning depict students as active agents in the learning process (Wolf-Wendel et al. 2009). Active learning implies more than a shift away from rote learning. In active learning, students become aware of their own learning processes. This awareness opens the possibility for new knowledge acquisition, but more fundamentally, it enables students to challenge their most deeply held assumptions. The student- engagement perspective holds that students have a unique perspective on learning and teaching that should be heard and engaged, and furthermore that learning is deepest when students become their own teachers (Bovill et al. 2011). This section suggests implementing and supporting student-led ethics initiatives as a way to achieve broader curriculum reform.

Student engagement has received much attention in the learning sciences where studies have demonstrated that although students may prefer the ease of passively listening to a well-prepared lecture, they retain much more through active learning. A particularly thought provoking study discovered a significant mismatch between students' perceptions of their learning and their actual performance (Yadav et al. 2011). Although students' believe that they learn more from lectures, results show that they actually learn more from problem-based learning (PBL). To explain this disconnect, Yadav et al. (2011) point to the overconfidence phenomenon: students become overconfident about their cognitive abilities after quickly reading a textbook chapter, or after listening to a well-delivered lecture because they mistakenly perceive the author's or lecturer's knowledge to be their own (Glenberg and Epstein 1987; Yadav et al. 2011). Furthermore, engineering students are so well accustomed to participating in lecture-based courses that they develop the assumption that learning depends on listening to lectures. Some resistance should be expected, therefore, when students are asked to take responsibility for their own learning (Felder and Brent 1996; Yadav et al. 2011).

Instead of exploring the merits of implementing PBL in engineering ethics, which I have done elsewhere (Sunderland 2013), this paper asks how students can play a more active role in their learning by participating in the design and implementation of new curricular material. Involving students in curriculum design requires a shift away from traditional hierarchical models of expertise, prominent in education, in which students are subordinate to the teacher (Bovill et al. 2011). Student voice theory offers philosophical grounding and practices that can help to initiate a shift in power dynamics and enable students to become active agents in educational reform. The theory and practice associated with student voice draws on the student engagement scholarship and is dependent on the premise that students' unique perspective on learning and teaching deserves the attention of educators (Fielding 2001). Student voice work seeks to develop ways that will allow students' voices to play an active role in the shaping of their education. Including students' voices and perspectives in educational planning is a strategy that is meant to identify and ultimately reform the social conditions and power structures that constrain learning. In this sense, student voice work is a kind of critical pedagogy that is inspired and informed by the larger goals of social justice and the removal of oppression (Cook-Sather 2007). Recent student voice work considers how students' voices have been oppressed in the context of their own education. Students, unfortunately, usually lack agency in the administrative structures that undergird teaching and learning in institutes of higher educations (Bovill et al. 2011). As a result, students have generally been excluded from educational reform initiatives—a point that has been recognized by scholars in engineering education (Pawley 2009).

Here, I refer to student engagement as an overarching pedagogical approach that draws on both active learning and student voice work. It is important to emphasize that these pedagogical approaches are widely supported by the learning sciences, which show that learning is always driven by preconceptions. Ignoring preconceptions forces students to adopt a learning strategy that focuses on content memorization. While memorizing allows students to perform well, sometimes exceptionally well, on assignments and exams, it fails to hold beyond the confines of the classroom where even top students resort to relying on their preconceptions (National Research Council 2005). A student engagement approach to learning offer a way to effectively address students' preconceptions by providing a place for their voices to articulate preconceptions and by creating an environment in which they can challenge these core assumptions.

The pedagogical strategies described here are rooted in the idea that it is necessary to critically engage students' preconceptions about engineering, as well as engineering ethics before it is possible for students to become involved in ethical learning. Effectively introducing ethics into the engineering curricula is contingent on how students' conceptualize the societal role of the engineer. I argue that providing students with an active role in defining engineering and their place in it allows them to articulate the ethical and moral underpinnings that may or may not have inspired their interest in engineering. This broad reflective exercise encourages students to address their preconceptions about both engineering and ethics. Bringing a student engagement approach to engineering ethics helps to relocate ethics from the periphery of the curriculum to its core by empowering students to investigate ethics in the ways that are most meaningful to them.

There is a lot of anecdotal evidence as well as published studies that show an increasing diversity of approaches to teaching ethics, including a number of studies that introduce forms of student engagement, such as service learning (e.g., Baillie and Catalano 2009; Riley et al. 2009; Riley 2011). These recent developments are exciting and potentially transformative, but it is important to place them historically to better understand how standard forms of ethics instruction have become widespread and embedded in a variety of institutions. Early engineering ethics is sometimes criticized as being too focused on the individual, or the "micro" level. These critiques suggest that a more "macro" focus is needed, one that addresses institutional and societal elements (Conlon 2011; Herkert 2005; Kline 2001; Lynch and Kline 2000). On the other hand, critiques of this more social science-oriented approach point out that events sometimes appear inevitable when personal agency is downplayed (Davis 2006). A survey of the more specific pedagogical approaches reveals the popularity of case-based instruction in engineering ethics. The prominence of cases is made evident in a range of popular engineering textbooks. Indeed, Harris et al. (1996) argue that there is “widespread agreement” that cases are the best way to teach engineering ethics. But there is an ongoing debate about the best way to use cases and very little evidence that actually demonstrates the effectiveness of case-based instruction (Barry and Ohland 2009). Case-based instruction has been criticized for oversimplifying the issues faced by engineers, overemphasizing the role of the individual, and for creating a forum in which the actions of actors are analyzed as autonomous and categorized as either ethical or unethical—an approach that ignores, or downplays, the interactions and relationships among individuals and their social, cultural, and institutional contexts (Lynch and Kline 2000; Kline 2001). Another problem with cases is that the information has already been deliberately organized and synthesized for the student. This is a problem because ethical issues in the real world are messy, disorganized, and unclear. These reasons have motivated some to advocate for a PBL approach to ethics, in which open-ended problems rather than well-formed cases are used to encourage self-directed learning and free inquiry (Barrows 1996; Jonassen et al. 2009; Jonassen and Cho 2011; Yadav et al. 2011; Sunderland 2013). In the end, the question of how to best teach engineering ethics remains open.

Relocating Ethics with Student-Centered Initiatives

Despite the significant funding and research efforts that have been dedicated to improving engineering ethics education, especially through initiatives like the National Science Foundation’s Ethics Education in Science and Engineering Program, engineering students continue to perceive that ethics is about learning laws and rules. While some faculty indeed interpret ethics as teaching about laws, ethical codes, and black-and-white solutions, they also aim to highlight more complex situations. Students, however, do not seem to perceive the latter. Instead, their experience of ethics is overshadowed by the need to memorize rules, laws, and codes. This discrepancy suggests that educators need to take steps to better understand the ways that faculty, administrators and students perceive ethics education and to understand the educational environments in which these different perceptions occur (Holsapple et al. 2012). The student engagement approach to developing new ethics pedagogy brings forward the student perspective.

Although students have been given “freedom” to select courses to meet their humanities and social sciences requirements, they often feel burdened by the need to meet yet another requirement.[2] The burden on students is especially heavy because these courses appear to be irrelevant in the otherwise integrated curriculum. Students, unsurprisingly seek out courses that can do double-duty (i.e., simultaneously meeting both a humanities and social sciences requirement, and an ethics requirement). Like the humanities and social sciences, ethics is seen as just another non-technical add-on. However, preliminary evidence from my experience teaching undergraduate students suggests that this is not students’ initial perception, but rather one that emerges from years of managing curriculum constraints. Students’ inspirations to begin engineering programs are reflected on the institutional websites

[2] This interpretation is based on the author’s interactions with engineering undergraduate students.

that promise engineers will learn to "tackle and mitigate humanity's biggest calamities" (http://eas.caltech.edu). Students know that these problems are not value free. On the contrary, they know that they are ethically wrought and in need of interdisciplinary attention (Sunderland 2013).

Providing students with opportunities to discuss how they might engage these problems on multiple levels helps them to break the stereotype that engineers are primarily technicians. Students do not want to be pigeonholed as technicians, however they feel that they are lacking opportunities to develop their thinking about the moral dimensions of the problems that drive the engineering profession. Students need a place to engage in dialog and to be creative. Rather than imaging and dictating ways for them to do this, the student engagement approach actively involves them as partners in the development process. Students are best equipped to identify the issues that personally matter to them. The instructor's role is not to tell students what to care about. Instead, the instructor should facilitate a discussion that will allow students to cultivate and express how and why ethics fits into their picture of engineering.

At the University of California, Berkeley, we are experimenting with this approach by involving students at both the undergraduate and graduate levels in the process of curriculum review and design. One initiative that facilitates student-led curriculum design is UC Berkeley's DeCal program. The student-run DeCal program has been empowering and enabling undergraduate students to teach their peers since it was established in 1965 (www.decal.org). The listing of DeCal courses is always eclectic, ranging from courses about Disney to Gardening to Stem Cells—what brings them together is the shared student perspective that is so often absent from more traditional courses. The spring 2013 semester marks the beginning of the first engineering ethics DeCal, "Be-ethiCal: Developing Technology for a Better Society." The two student instructors, Alexandra Giesemann, a senior from the Department of Industrial Engineering and Operations Research, and Andrew Serpa, a senior from the Department of Nuclear Engineering, are teaching the course through the Materials Science and Engineering Department. It is appropriate to report on the course before the end of the semester because the process of taking the course through the approval process was an exercise in interdisciplinary student engagement.

The seemingly simple fact that the course is being offered took a significant amount of administrative effort and the support of engineering faculty and administrators from across departmental divides, all of which have been identified as significant hurdles to curriculum reform (Borrego et al. 2010). The course signals that engineering students care about ethics and that they think it is worth their time and effort to bring these issues to their peers. Furthermore, the design of the course is organized to give engineering students a better platform for discussing ethics. The course centers on two core assignments. The first involves students contributing to building an engineering ethics Tumblr account (http://be-ethical.tumblr.com) and the second involves developing new ethics-oriented activities for future ethics classes as well as more technical engineering courses. The course is designed to generate more student voices in engineering ethics and empower more students to imagine how they might play an active role in shaping their educational experience. Rather than being passive receptors of expert knowledge, the student engagement approach, exemplified by the DeCal class, makes students play a more active role.

The idea for the ethics DeCal class emerged from another student engagement activity, inspired, in part, by research conducted by Esat Alpay at Imperial College London. Alpay developed an ethics activity for new undergraduate engineering students that challenges students to propose and develop resources for ethics education that would be relevant to their peers (Alpay 2011). At Berkeley, I assigned a similar activity that was adjusted to meet the learning outcomes and general course objectives of the specific upper-division ethics class, “Engineering, Ethics, and Society,” in which it was implemented. The student engagement philosophy that undergirds the ongoing development of Ethics, Engineering, and Society is informed by an overarching commitment to find ways to bring emotion into the engineering ethics curriculum by addressing students’ preconceptions and meeting them where they are (Roeser 2012; Sunderland 2013). Building on Alpay’s model, the Berkeley activity tasked students with developing materials with the potential to inspire their peers to engage in meaningful ethical reflection or action. Students were given significant flexibility with the end product. Students have produced small movies, designed games and posters, and sketched out a variety of outreach activities and student programs. One group of students submitted the idea of developing and teaching a new ethics class—a DeCal class. Those that initially proposed the DeCal idea are not actually teaching the course, but they are enthusiastic to have other students take the lead in making their idea a reality. This anecdote points to new levels of student collaboration that extend beyond the classroom both temporally and spatially.

Conclusions

Looking to the history of engineering ethics helps us to understand why students and faculty tend to hold very different ideas about the meaning and usefulness of ethics in the broader curriculum. History highlights that previous reforms to the engineering curricula, especially initiatives to introduce more humanities and social science requirements, are often perceived by students as constraints. A historical perspective also draws attention to the lack of student engagement in previous pedagogical reforms. Students’ lack of agency in their own learning provides little incentive for them to reflect about the meaning and coherence of their curricula, as they have not historically been empowered as agents of change in their learning and education. On the contrary, students are motivated to meet curricular requirements as efficiently (and painlessly) as possible. Often, engineering students have little time to pursue extra-curricular activities—at least when compared to other majors (Lichtenstein et al. 2010), and seek out courses that can meet two requirements at once (i.e., a writing requirement and an ethics requirement).

This paper draws on historical data to argue that the pervasive framing of ethics as a requirement continues to shape how today’s students perceive ethics. Shifting away from the mindset that ethics is nothing more than a list of rules, laws, and codes to be memorized requires a different kind of framing. Rather than telling students that they need to learn ethics, this paper suggests that we need to ask students what ethics means to them, and more broadly that we need to provide students with opportunities to reconceptualize engineering. When students articulate new definitions of engineering and are then tasked with proposing ethics-related curricular activities that complement the definition, ethics becomes relevant. Giving students an active role in curriculum development enables students to shift their perspective about ethics because it actively engages any preconceptions that they might hold, especially the "ethics is an irrelevant requirement" perception. The new student-taught engineering ethics DeCal course at UC Berkeley's COE is evidence that students are critically important agents in relocating ethics to the core of the engineering curriculum. The engineering ethics DeCal is transforming ethics from a requirement into a bridge that allows engineering students to make meaningful connections with students from other disciplines (e.g., there are many non-engineering students enrolled in the class).

The historical analysis draws attention to the engineering community's long-standing commitment to education. Efforts to effectively balance the curriculum have been almost ongoing since the early twentieth century and continue today, with the added complexity and challenges posed by the emergence of various online education possibilities, including MOOCs (massive open online courses), which have led many to reconsider the value of the physical classroom (Pappano 2012). Students are also questioning the value of being in the classroom, and their perspectives are fundamentally important. The student engagement approach presented here offers strategies that will enable students to articulate their perspectives, and help institutions to develop the capacity to respond to these suggestions. Curriculum reform is not easily achieved; indeed there are many barriers that impede the adoption of innovative approaches (Fairweather 2008; Borrego et al. 2010; Riley 2012). Students, however, should not be additional barriers. Students should be partners. I've argued here that a student engagement approach to ethics education can help to relocate ethics to the core of the engineering curriculum. More importantly, empowering students to participate in curriculum reform has the potential to achieve unforeseeable, transformative results.

Acknowledgments I am grateful to all of the engineering students who candidly shared their ideas, especially to Chris Merian, Rohit Upadhya, Brigette Badro, and Ricky Nolan, who originally proposed the DeCal idea, and to Alexandra Giesemann and Andrew Serpa who made the engineering ethics DeCal a reality. I am thankful to Ronald Gronsky, Mark Asta, and Wanda Capece from Berkeley's Department of Materials Science & Engineering for supporting the DeCal. Thanks also to Mary Howell from Engineering Student Services for introducing me to Berkeley's collection of course announcements and for helping me to navigate the engineering undergraduate curriculum. I appreciate the insightful and encouraging feedback that I received from three anonymous reviewers. This material is based upon work supported by a seed grant from the University of California, Berkeley College of Engineering and the National Science Foundation (NSF) under Grant No. 1237830. Thanks to my NSF grant collaborators: Cathryn Carson, William Kastenberg, and Joonhong Ahn.

References

Adams, R., Evangelou, D., English, L., Dias de Figueiredo, A., Mousoulides, N., Pawley, A. L., et al. (2011). Multiple perspectives on engaging future engineers. *Journal of Engineering Education, 100*, 48–88.

Alpay, E. (2011). Student-inspired activities for the teaching and learning of engineering ethics. *Science and Engineering Ethics,*. doi:10.1007/s11948-011-9297-8.

Baillie, C., & Catalano, G. (2009). *Engineering and society: Working towards social justice part III: Engineering: Windows on society*. San Rafael, CA: Morgan & Claypool.
Barrows, H. S. (1996). Problem-based learning in medicine and beyond: A brief overview. *New Directions for Teaching and Learning, 68*, 3–12.
Barry, B. E., & Ohland, M. W. (2009). Applied ethics in the engineering, healthy, business, and law professions: A comparison. *Journal of Engineering Education, 98*, 377–388.
Baum, R. J. (1980). *Ethics and engineering curricula*. Hastings-on-Hudson, NY: The Hastings Center, Institute of Society, Ethics, and the Life Sciences.
Borenstein, J., Drake, M. J., Kirkman, R., & Swann, J. L. (2010). The engineering and science issues test (ESIT): A discipline-specific tool for assessing moral judgment. *Science and Engineering Ethics, 16*, 387–407.
Borrego, M., Froyd, J. E., & Simin Hall, T. (2010). Diffusion of engineering education innovations: A survey of awareness and adoption rates in U.S. engineering departments. *Journal of Engineering Education, 99*, 185–207.
Bovill, C., Cook-Sather, A., & Felten, P. (2011). Students as co-creators of teaching approaches, course design, and curricula: Implications for academic developers. *International Journal for Academic Development, 16*, 133–145.
Brown, J. K., Downey, G. L., & Diogo, M. P. (2009). The normatives of engineers engineering education and the history of technology. *Technology and Culture, 50*, 737–752.
Conlon, E. (2011). Macro, micro, structure, agency: Analyzing approaches to engineering ethics. In *1st world engineering education flash week*. Lisbon, Portugal.
Cook-Sather, A. (2007). Resisting the impositional potential of student voice work: Lessons for liberatory educational research from poststructuralist feminist critiques of critical pedagogy. *Discourse: Studies in the Cultural Politics of Education, 28*, 389–403.
Cook-Sather, A. (2009). From traditional accountability to shared responsibility: The benefits and challenges of student consultants gathering midcourse feedback in college classroom. *Assessment & Evaluation in Higher Education, 34*, 231–241.
Cutliffe, S. H. (1990). The STS curriculum: What have we learned in twenty years? *Science, Technology and Human Values, 15*, 360–372.
Davis, M. (2006). Engineering ethics, individuals and organizations. *Science and Engineering Ethics, 12*, 223–231.
Drake, M., Griffin, P. M., Kirkman, R., & Swann, J. L. (2005). Engineering ethical curricula: Assessment and comparison of two approaches. *Journal of Engineering Education, 94*, 223–231.
Fairweather, J. (2008). Linking Evidence and Promising Practices in Science, Technology, Engineering, and Mathematics (STEM) Undergraduate Education: A Status Report for The National Academies National Research Council Board of Science Education, Commissioned paper for workshop on Linking Evidence and Promising Practices in STEM Undergraduate Education for The National Academies National Research Council Board of Science Education, Oct. 13 & 14, 2008, http://www7.nationalacademies.org/bose/PP_Agenda_October13and14_2008.html.
Felder, R. M., & Brent, R. (1996). Navigating the bumpy road to student-centered instruction. *College Teaching, 44*, 43–47.
Felder, R. M., & Brent, R. (2003). Designing and teaching courses to satisfy the ABET engineering criteria. *Journal of Engineering Education, 92*, 7–25.
Fielding, M. (2001). Students as radical agents of change. *Journal of Educational Change, 2*, 123–141.
Giles, A., Martin, S. C., Bryce, D., & Hendry, G. D. (2004). Students as partners in evaluation: student and teacher perspectives. *Assessment and Evaluation in Higher Education, 29*, 681–685.
Glenberg, A. M., & Epstein, W. (1987). Inexpert calibration of comprehension. *Memory and Cognition, 15*, 84–93.
Harris, C. E., Davis, M., Pritchard, M. S., & Rabins, M. J. (1996). Engineering ethics: What? why? how? and when?. *Journal of Engineering Education, 85*, 93–96.
Harwood, J. (2006). Engineering education between science and practice: Rethinking the historiography. *History and Technology, 22*, 53–79.
Herkert, J. (2005). Ways of thinking about and teaching ethical problem solving: Microethics and macroethics in engineering. *Science and Engineering Ethics, 11*, 373–385.
Hollander, R. D., & Steneck, N. H. (1990). Science- and engineering—related ethics and values studies: Characteristics of an emerging field of research. *Science Technology Human Values, 15*, 84–104.

Holsapple, M. A., Carpenter, D. D., Sutkus, J. A., Finelli, C. J., & Harding, T. S. (2012). Framing faculty and student discrepancies in engineering ethics education delivery. *Journal of Engineering Education, 101*(2), 169–186.

Huff, C., & Frey, W. (2005). Moral pedagogy and practical ethics. *Science and Engineering Ethics, 11*, 389–408.

Johri, A., & Olds, B. A. (2011). Situated engineering learning: Bridging engineering education research and the learning sciences. *Journal of Engineering Education, 100*, 151–185.

Jonassen, D. H., & Cho, Y. H. (2011). Fostering argumentation while problem solving engineering ethics problems. *Journal of Engineering Education, 100*, 680–702.

Jonassen, D. H., Shen, D., Marra, R. M., Cho, Y., Lo, J. L., & Lohanni, V. K. (2009). Engaging and supporting problem solving in engineering ethics. *Journal of Engineering Ethics, 98*, 235–254.

Kline, R. (2001). Using History and sociology to teach engineering ethics. *IEEE Technology and Society Magazine, 20*, 13–20.

Lichtenstein, G., McCormick, A. C., Sheppard, S. D., & Puma, J. (2010). Comparing the undergraduate experience of engineers to all other majors: Significant differences are programmatic. *Journal of Engineering Education, 99*, 305–317.

Lincourt, J., & Johnson, R. (2004). Ethics training: A genuine dilemma for engineering educators. *Science and Engineering Ethics, 10*, 358–385.

Lynch, W. T., & Kline, R. (2000). Engineering practice and engineering ethics. *Science, Technology and Human Values, 25*(2), 195–225.

Mitcham, C. (2009). A historico-ethical perspective on engineering education: From use and convenience to policy engagement. *Engineering Studies, 1*(1), 35–53.

National Academy of Engineering. (2005). *Educating the engineer of 2020: Adapting engineering education to the new century*. Washington, DC: The National Academies Press.

National Research Council. (2005). *How students learn: history, mathematics, and science in the classroom*. In M. S. Donovan & Bransford, J. D. (Eds.) Committee on *How People Learn*, A targeted report for teachers. division of behavioral and social sciences and education. Washington, DC: The National Academies Press.

Pappano, L. (2012, November 2). The year of the MOOC. *The New York Times*.

Pawley, A. (2009). Universalized narratives: Patterns in how faculty members define “engineering”. *Journal of Engineering Education, 98*, 309–319.

Pfatteicher, S. K. A. (2003). Depending on character: ASCE shapes its first code of ethics. *Journal of Professional Issues in Engineering Education and Practice, 129*, 21–31.

Reynolds, T. S., & Seely, B. E. (1993). Striving for balance: A hundred years of the american society for engineering education. *Journal of Engineering Education, 82*, 136–151.

Riley, D. (2011). Hidden in plain view: Feminists doing engineering ethics, engineers doing feminist ethics. *Science and Engineering Ethics*,. doi:10.1007/s11948-011-9320-0.

Riley, D. (2012). Aiding and abeting: The bankruptcy of outcomes-based eduction as a change strategy. *American Society for Engineering Education*.

Riley, D., Pawley, A. L., Tucker, J., & Catalano, G. D. (2009). Feminisms in engineering education: Transformative possibilities. *Feminist Formations, 21*(2), 21–40.

Roeser, S. (2012). Emotional engineers: Toward morally responsible design. *Science and Engineering Ethics, 18*(1), 103–115.

Seely, B. E. (1999). The other re-engineering of engineering education, 1900–1965. *Journal of Engineering Education, 88*, 285–295.

Seely, B. (2005). Patterns in the history of engineering education reform. In *Educating the Engineer of 2020: Adapting Engineering Education to the New Century* (pp. 114–130). National Academy of Engineering.

Seron, C., & Silbey, S. (2009). The dialectic between expert knowledge and professional discretion: Accreditation, social control and the limits of instrumental logic. *Engineering Studies, 1*, 101–127.

Shuman, L. J., Besterfield-Sacre, M., & McGourty, J. (2005). The ABET “professional skill”—Can they be taught? Can they be assessed? *Journal of Engineering Education, 94*, 41–55.

Smith, K. A., Sheppard, S. D., Johnson, D. W., & Johnson, R. T. (2005). Pedagogies of engagement: Classroom-based practices. *Journal of Engineering Education, 94*, 87–101.

Sunderland, M. E. (2013). Taking emotion seriously: Meeting students where they are. *Science and Engineering Ethics*,. doi:10.1007/s11948-012-9427-y.

University of California, Berkeley, College of Engineering. (1967). *Announcement of the College of Engineering, 1967–1968* (Vol. 61, Number 12). Berkeley: University of California.

University of California, Berkeley, College of Engineering. (1971). *Announcement of the College of Engineering, 1971* (Vol. 65, Number 10). Berkeley: University of California.

University of California, Berkeley, College of Engineering. (1973). *Announcement of the College of Engineering, 1973* (Vol. 67, Number 9). Berkeley: University of California.

University of California, Berkeley, College of Engineering. (1990). *Announcement of the College of Engineering, 1990–91*. Berkeley: University of California.

University of California, Berkeley, College of Engineering. (2005). *Announcement of the College of Engineering, 2005–06*. Berkeley: University of California.

Weil, V. (1984). The rise of engineering ethics. *Technology in Society, 6*, 341–345.

Weil, V. (1985). Ethics in engineering curricula. *Research in Philosophy and Technology, 8*, 243–250.

Wisnioski, M. (2009). "Liberal education has failed": Reading like an engineer in 1960s America. *Technology and Culture, 50*, 753–782.

Wisnioski, M. (2012). *Engineers for change: Competing visions of technology in 1960s America*. Cambridge: MIT Press.

Wolf-Wendel, L., Ward, K., & Kinzie, J. (2009). A tangled web of terms: The overlap and unique contribution of invovlement, engagement, and integration to understanding college student success. *Journal of College Student Development, 50*, 407–428.

Yadav, A., Subedi, D., Lundberg, M. A., & Bunting, C. F. (2011). Problem-based learning: Influence on students' learning in an electrical engineering course. *Journal of Engineering Education, 100*(2), 253–280.