

A Practitioner Account of Integrating Macro-ethics Discussion in an Engineering Design Class

Dr. Ayush Gupta, University of Maryland, College Park

Ayush Gupta is Assistant Research Professor in Physics and Keystone Instructor in the A. J. Clark School of Engineering at the University of Maryland. Broadly speaking he is interested in modeling learning and reasoning processes. In particular, he is attracted to fine-grained models of learning (based in microgenetic analysis, or drawing on interaction analysis). He has been working on how learners' emotions are coupled with their conceptual and epistemological reasoning. He is also interested in developing models of the dynamics of categorizations (ontological) underlying students' reasoning in physics. Lately, he has been interested in engineering design thinking, how engineering students come to understand and practice design, and how engineering students think about ethics and social responsibility.

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Abstract: Engineering education research has started to attend to the idea that the education of a socially responsible professional engineer will, in part, require the weaving of social responsibility and engineering macro-ethics into the fabric of the engineering curriculum. In this paper, writing as an engineering design instructor, I present my own successes and challenges with incorporating notions of social responsibility and macro-ethics in an engineering design lesson. The lesson plan evolved over a period of 10 semesters. I document the process of that evolution and discuss how students' responses to activity prompts influenced that evolution.

Introduction

With few exceptions, ethics education within STEM disciplines has mostly remained separate from courses that provide instruction in what is perceived as technical knowledge (Leydens & Lucena, 2016). This paradigm tacitly reinforces that science, engineering, and technology are value neutral and that ethical considerations arise from the manner of the technology's use rather than in its design phase. Other researchers have shown that over 4 years of college, engineering students' sense of social responsibility and of seeing engineering as socially situated actually decreases (Cech, 2014). Historians have argued how this technocratic illusion is maintained by various institutional structures -- one of which is a separation of the content of science/engineering from their social practice (Slaton, 2015).

In response, some researchers have started exploring how human-centered design can be a site for learning how ethical considerations should inform engineering design (Bucciarelli, 2008; Kenny Feister et al., 2016). Continuing in that vein, I present a practitioner account of how responsive teaching (Robertson, Scherr, & Hammer, 2015) provided a window of opportunity for integrating the social responsibility of engineers into a classroom discussion on technological solutions to enabling faster checkout in grocery stores. During the discussion, students took to pointing out the affordances and constraints of various ideas. This soon turned to include the social impact of some the ideas (who loses jobs, who gains jobs, who gets to shop, usability of technologies, etc.) and revisions to ideas to manage some of the challenges/shortcomings. As an discussion moderator, I was writing students' ideas on the board with minimal editing, occasionally asking a clarifying question. Then one student raised her hand and asked, "Is it our job to worry about this? We are hired by the owner, shouldn't we look out for their economic interest?" In a moment of responsiveness, I turned over the question to the class that led to a 30-minute discussion on the "macroethical" social responsibility of engineers (Herkert, 2005). As an instructor my original intent for this discussion was just to illustrate the power of divergent thinking for doing design. But this was tempered by a commitment to being responsive to the substance of students' ideas and creating space in the classroom to pursue them. This lesson plan has evolved over five years, during which I have built the social responsibility prompt more explicitly in the curriculum. In the paper, I discuss common student responses to the question of the scope of engineers' social responsibility as it played out in my classroom, the evolution of the lesson plan over 5 years, and the how students' responses have changed in response to the curriculum changes. I also argue that there is a need to create greater opportunities for explicit

discussion of engineering ethics within regular science and engineering courses in order to challenge the dominant paradigm that takes technological determinism as default (Bijker et. al., 2012; Smith and Marx, 1994), scaffold our STEM students in understanding the political implications of the nature of their work, and equip them with the tools to examine ideological underpinnings of their own reasoning structures and examine alternative ideologies.

In the narrative I sketch of the lesson plan evolution, I draw on the lesson plans, notes taken during class and pictures of board work, and reflections written after the class. Where students' ideas were similar in pattern across many semesters, I take the liberty of synthesizing them into a single list. Where ideas changed markedly either due to some idiosyncrasy or in response to a change in the lesson plan, I note that. I start with a section on review of relevant constructs before launching into course context and lesson plan evolution.

Background

In this paper, I draw on two constructs to organize my narrative. One, responsive teaching, comes from research on teacher education. The second is two related concepts of technological determinism and social constructivism of technology, that come from science and technology studies.

Responsive teaching is a relatively new coinage, drawing on and expanding earlier notions of noticing and attending to student thinking. Responsive teaching represents the phenomenon of teachers attending and responding to students' disciplinary thinking and this dialog, in part, then driving instructional decisions (Robertson, Scherr, & Hammer, 2015). Initially, researchers articulated a progression of what counts as more and/or better noticing and attending to student thinking (vanEs, 2011; Sherin & vanEs, 2005). More recently, researchers have turned to articulate the nuances in teacher moves that respond to the disciplinary aspects of students' thinking (Richards, Elby, & Gupta, 2014; Wendell, Watkins, & Johnson, 2016). For example, Wendell et al (2016) recount the tensions they experienced in making in-the-moment decisions on whether to attend to the content of students' science reasoning or the process aspects of their design thinking. In my narrative, responsive teaching comes into play in how specific highlighted instructional moves attended to patterns in students' reasoning as well as disciplinary aspects (design thinking, engineering ethics). Further, observations of patterns in students' reasoning contributed to re-design of the lesson plan, which serves as a longer (in time) feedback loop of responsiveness.

Technological determinism is a cluster of loosely cohering ideas (Smith and Marx, 1994) that see technology as only contributing to progress, expert-novice divide between designers of technology and users, and an unidirectional influence from technology to society. Social constructivism (Bijker et. al., 2012; Smith and Marx, 1994; Pinch & Bijker, 1987) on the other hand views society and technology as linked via multiple feedback loops, and technology as shaping and simultaneously being shaped by the social, political, and economic milieu. As such from a social constructivist perspective, the development of technological solutions is a value laden process, one that is best done when designers and users are partners in a joint enterprise. From a technological determinist standpoint, progress is inextricably linked with technology development, and that might make it more difficult to ask questions such as "who progresses and

who is left behind?”, “how are we defining progress?”, “can we solve an issue without technological development?”, and “how can we develop ecologically-valid solutions in partnership with relevant communities?” I see social constructivism as an essential aspect of ethical engineering. Social constructivism embeds engineering and technology within the socio-political-economic landscape and is thus closely linked to the notion of macro-ethics (Bucciarelli, 2008; Herkert, 2005). In this paper, I illustrate how the lesson plan for the first day of an engineering design course gradually incorporates elements of social constructivism.

The context and the overview of the lesson plan evolution

The narrative for this paper comes from the first day of instruction in an introductory engineering design course (Design Course, in future references) for first-year engineering majors at the University of Maryland, College Park. The course is a requirement for all incoming engineering majors. Section sizes are limited to 40 students each, and each section is staffed by an instructor and an undergraduate teaching assistant. Most of the course features are coordinated across the different sections (typically 14 sections per semester). However, there is a lot of leeway that instructors have in tailoring their own instruction, especially during the first two weeks, when the general agenda is to engage students in design thinking activities and discussion as a pre-cursor to discussing the science/math content that is relevant to their design project for that semester.

In Fall 2011, when I first started teaching the Design Course, I reached out to my colleagues, Monica Cardella and Robin Adams, at Purdue University to share their instructional materials on engineering design, especially on how to introduce students to the notion of design. From those materials, I decided to use a prompt asking students to help solve a problem in the everyday context of long grocery store lines (credit for design of the original prompt: David Radcliffe, Robin Adams, and Monica Cardella at Purdue University). The prompt and how it was used in class is shown in Figure 1.

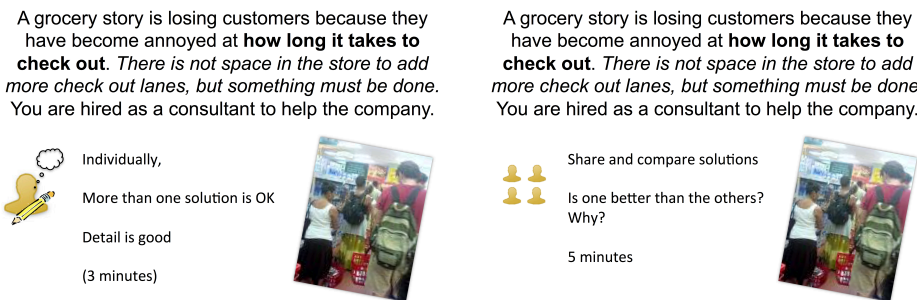


Figure 1: Slides from Fall 2011, showing the first version of the “grocery store” prompt presented to the students

Over time, the lesson plan for the first day has evolved to explicitly include prompts designed to reliably get students to reflect on stakeholders involved in a given design situation and on their role and professional ethical responsibility in that context. The lesson plan in Spring 2017 looked thus:

A grocery store is losing customers; annoyed customers are leaving the store because the checkout queues are too long. There isn't space to simply add more checkout lanes. You are hired as a consultant by the store owner to solve this issue.

Individual Brainstorming

Spend 3 minutes thinking individually. Write/sketch as many ideas as you can - you are going for speed, not detail

Share with your neighbor

Spend 5 minutes sharing ideas in groups of 4. And discuss possible pros and cons of ideas.

Impact of a solution (small group followed by whole class discussion)

What do you think would be the impact on society, economics, corporations, owners, workers, etc. if the solution was scaled up for use across many stores.

Ethics: *Given the impact network, what does it mean to be a “good” (ethical) engineer?*

The visual difference between the lesson plans is because I shifted from using slides to using Google Docs for course discussion. The shift to Google Docs had two advantages:

1. It made it easier to be able to type students’ ideas in real time in a way that their ideas are visible to the class. This meant that students could see other students’ ideas and comment on them. (In previous years, trying to do this on slides meant that I ended up spending a lot of time adjusting font sizes on slides for readability as the amount of text grew)
2. It made it easier to add my post-lecture reflections on the students’ ideas and quickly post class notes to the course website as a link.

On the content of the lesson plans, notice that the initial two prompts in 2017 are almost the same as in 2011; but the 2017 lesson plan includes two new prompts on “Impact of a solution” and “Ethics,” that have been added over the years. Next, I discuss how the addition of these prompts was guided by reflections on students responses and a goal of creating space for challenging technological determinism.

Students’ Responses to the activity and opportunities for challenging technological determinism

A. The brainstorming part of the activity

After the individual and shared small-group discussion portion, I invite students to share their ideas on solutions with the class. The individual thinking time and small-group discussion helps populate the class with many ideas, which is needed for the lesson to play out as intended. As students share their solution ideas, I or the teaching assistant would type the ideas out directly on the Google Docs or write them on the white board.

Invariably, the first ideas that students share are ones that emphasize technological innovations, such as hand-held scanners, scanners attached to carts, walk-through scanners at the checkout, scanners fixed on the shelf itself, or a variety of other solutions based on smartphone technology and/or biometrics. After a few technological solutions are mentioned, some students do also share solutions that targeted the management of human resources in the store, such as having another check-out staff at the counter who helps bag the items as they are being scanned so that the process is faster; providing incentives to check-out staff based on performance; adding more training for checkout staff; or changing hiring practices to select cashiers who are fast at scanning items.

In most years of my running this activity, at this stage students haven't directly brought up equity issues in staffing practices. More crucially, most of the solutions presented initially interpret the problem the same way: that of speeding up the checkout process. When we have created a healthy list of ideas that connect to technological innovation or human resource management, I explicitly press the students for solutions that came up in the discussion which seemed strange. It is then that, sometimes hesitatingly, a few students volunteer ideas such as putting on some form of entertainment (such as TV or magazines) to help assuage the annoyance of the customers, provide seats so those in queue can sit while waiting, or hand out free food samples for those in the queue. These solutions are different from the preceding ones in that they target psychology instead of technology. And they conceptualize the problem differently: making the checkout process tolerable or enjoyable, rather than faster.

Looking across the 10 semesters of this lesson, I make two generalized observations:

1. While there are variations in the actual ideas and the words in which they are stated each year, the larger pattern has held every semester since Fall 2011. Students first offer technological solutions, then they start adding ones that target the management of human resources. And finally, typically on being prompted (though it has happened unprompted on two occasions), they share solutions that aim to reduce the annoyance of customers without reducing the queuing time.
2. The psychological solutions often generate laughter when first shared until I write down that idea on the board, on equal footing with the other ideas, which sends a subtle message that sharing the psychological solution was valid. This usually leads to more such ideas being shared.

These two observations combined tell me that (1) students are creative and are quite capable of multiple and non-standard interpretations of ill-structured problems (2) students might be working under the assumption that they are expected to prioritize technological solutions. It is more a reflection on the technocratic culture within which my entire engineering course is embedded rather than of a priori ideological commitment on part of the students. However, drawing out these ideas creates a space where technological solutions become just one possible way to solve a problem, not the only way. This allows me to explicitly challenge the inevitability of technological approaches to solving problems, and frame the practice of engineering design as encompassing the psychological in addition to the technological possibilities.

B. Getting students to talk about the impact of the solutions

For the first few semesters I taught this lesson plan, (Figure 1), I asked students to talk in groups to share and compare solutions based on their affordances and constraints. After about 3 minutes of small-group discussion, I invited them to share some ideas with the whole class. Some of the shared responses drew attention to technical difficulties that might arise in the implementation of a given solution (for example, errors in scanning, the maintenance required for electronic equipment, a scanning solution would require tagging every single item to be effective, including produce, or that some solution might actually require more floor space which was the issue in the first place). But almost every semester, the bulk of the responses shared drew attention to how the implementation of technological solutions will impact the stakeholders closest to the issue,

the store owner, the store workers, and the shoppers. For example, students have noted that solutions relying on new equipment would add to the store-owner's expenses, or that it will require that the staff be trained to handle the new equipment or help customers use the new equipment. Students have noted that shoppers have quite a range of disparity in how comfortable they are with using new technology and so solutions relying on new technology might exacerbate the problem for some shoppers; or that solutions based on smartphones would marginalize shoppers who did not have them. Students have expressed concerns that particular solutions might make it even easier to infringe upon digital privacy rights of shoppers. Students note how particular solutions might lead to the loss of cashier jobs, sometimes sharing personal stories of having worked at a grocery store. Students mention that even if the number of jobs remains the same, it would lead to a change in who benefits from those jobs if the skill set required is changed by the new technological infrastructure. In other words, thinking about the pros and cons of solutions reliably got students to talk about how engineering design impacts a variety of stakeholders.

After a few semesters, I started noting that the discussion in some semesters had been richer than in others in this phase of the lesson. Sometimes students would be raring to offer many ideas, while at other times, the stream of ideas remained a bit thin. In response, I made the following changes:

1. I focused in on a single technological solution from among the students' ideas for this discussion
2. I changed the text of the prompt to read: "*what do you think would be the impact on society, economics, corporations, owners, workers, etc. if the solution was scaled up for use across many stores?*"
3. I started representing students ideas as a network of stakeholders who might be impacted by the large scale implementation of a solution.

Figure 2 shows the network drawn on the white board at the end of the class discussion on this prompt in Spring 2017. These changes had some positive affordances. It was easier to create a visual representation that integrates the different students' ideas and allows them to build on one another's ideas. The focus on a single solution allowed the class to focus on stakeholders rather than compare solutions for their impact. As a result, new stakeholders emerged, widening the span of who is impacted; and it was easier to notice the links between different individuals/communities. For example, in Spring 2017 (see Figure 2), students noted that the solution of installing scanners on carts might give rise to new industries that manufacture the required scanners and carts. They also noted that if equipment rendered obsolete (such as older carts) were discarded they would contribute to landfills which might negatively impact communities situated near landfills, often lower socio-economic status communities. One student noted that this implementation likely changes the profile of the clientele, shifting towards those with greater technological proficiency and access. Another student built on this idea to say that this will likely lead to changes in the store inventory, which will in turn impact "folks who make discontinued products." And so on.

This discussion and the generated representation typically allows me to draw students' attention to two aspects that challenge technological determinism:

1. The work of engineers is situated in communities of people and has consequences, for better and for worse, for people not unlike them; that improvement in quality of life is not the inevitable outcome of technological development, at least not for everyone.
2. Social and political power, in part, shape how engineering solutions are implemented and influence who accrues the benefits of new technological developments and who does not.

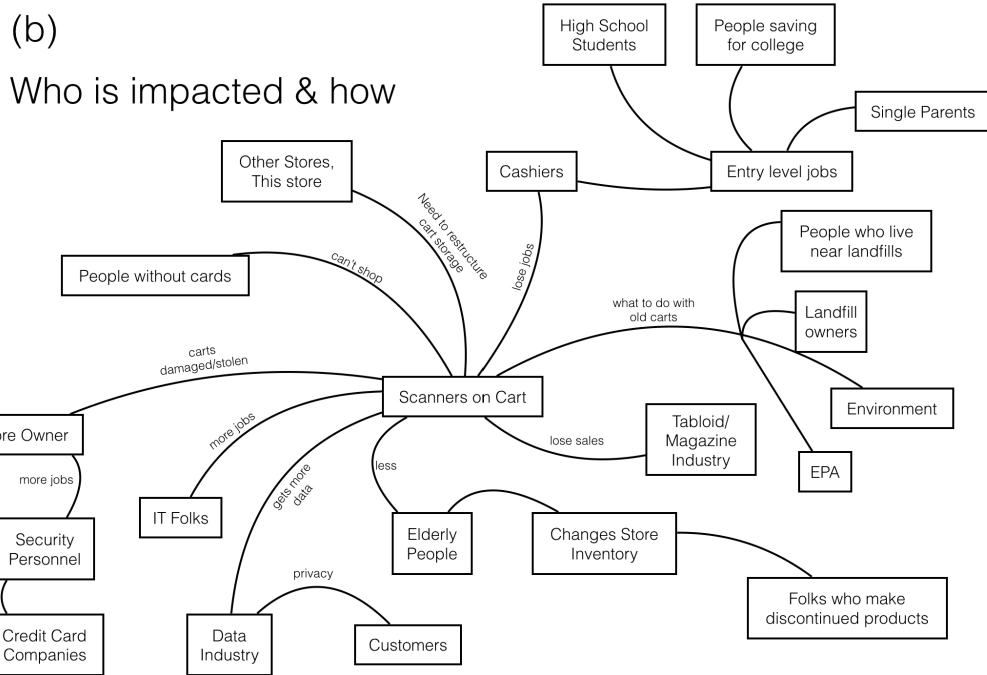
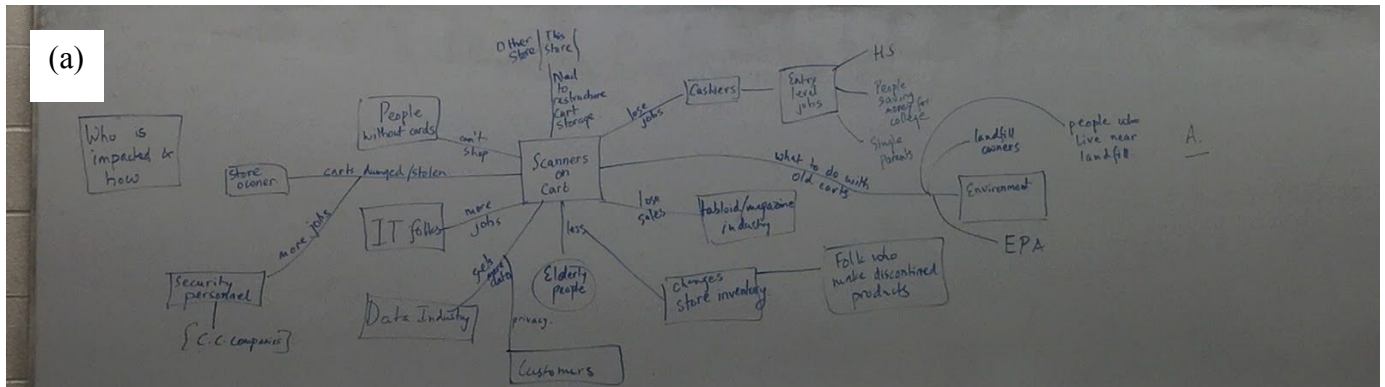


Figure 2: (a) White Board Image of network of stakeholders if there was wide-scale adoption of carts with scanners and (b) digital reproduction of the network drawn on the white board in (a)

C. The roles and responsibilities of engineers

The first semester that I conducted this activity, in fall 2011, about 10 minutes into sharing pros and cons of the different solutions, a student raised her hand and asked if it was their responsibility as engineers to be concerned about the various other stakeholders besides the

client (store owner) who has hired them. I turned that question over to the class inviting other students' opinions. Discussion was spirited with arguments made on both sides, drawing on notions of who an engineer should feel accountable to. While I hadn't planned for this conversation to happen, I thought that this made for a good ending to the whole grocery-store redesign activity. However, there was no reliability that a student, in any given semester, will ask the question about engineers' responsibility. It did happen organically on a couple more semesters, but not in others. When it did not emerge organically, I tried raising the question myself. It did not always lead to a very rich discussion. So, I tried a few different ways of framing the question. Ultimately, it led to me formally adding the following prompt to my lesson plan:

Given the impact network, what does it mean to be a "good" (ethical) engineer?

The revised prompt proved quite reliable in generating the discussion on the tensions with respect to engineers' professional responsibility, at least in the past 3 semesters when I have formally used this prompt. I did not attempt to define "good" or ethical, hoping that drawing on students' intuitive notions about ethics might lead to a richer discussion. Some of the ideas that students share in response to this prompt are:

- 1. you are in charge of the ideas, not the implementation*
- 2. if you are involved in the decision process then it is your responsibility to look at the impact*
- 3. ethical concerns can affect reputation of the company, and so it might be important to consider the impact*
- 4. we also need to use the tech that we help produce*
- 5. ignoring ethical concerns can lead to unethical implementation even if the engineers aren't involved in final implementation*
- 6. My responsibility should be to express all the ethical concerns, but leave the decisions on the client*

While typically there is no consensus on the summative judgment of where the responsibility of the designer/engineer lies, what makes the discussion productive is the variety of warrants that students articulate and share with the whole class. Some of these warrants challenge technological determinism, while others don't. Notice that , #4 bridges the gap between end-users and designers, an idea that challenges technological determinism and reinforces social constructivism. Similarly, #2 and #6 make the decision making process continuous, to some extent, with impact evaluation and implementation respectively. On the other hand #1 and #6 above de-couple the ideation and implementation of solutions, reinforcing ideas within technological determinist standpoint.

Often students ask my opinion on this question, on what's the "right" thing for them to do as engineers. Over time, I have formulated language for a response the gist of which is that I urge students to keep this as an open question through their professional trajectories, one that they revisit for further reflection. And I include some of this reflection in the notes I post to the class. Here's an excerpt from class notes posted in Fall 2014:

"We also had some discussion around the ethics of the situation; of laying off workers. Is it your job as a consultant to worry about that? Once again we had a spirited discussion

... another issue that does not have a clear cut answer. There are codes of ethics for engineers - as with anything else, the application of the codes is also dependent on interpretation. Exploring this sense of values and ethics is, I feel, one of the most important aspects of developing as an engineer. I have strong views on this, but I think it is most productive if you keep coming back to this question of where and when ethical considerations are important (and how) throughout your 4 years and later. That will define what kind of an engineer you are. But if you have more thoughts, and want to talk about it or hear my views, I am also happy to talk to you about that during office hours or by appointment.”

Discussion & Conclusion

In this paper I briefly summarize the evolution of my lesson plan on a design thinking activity to highlight how design thinking and engineering ethics, particularly macro-ethics (Herkert, 2005) can be brought together for pedagogical purposes. Technological determinism has often been described as characterizing the culture of engineering and our classrooms (Cech, 2014). But as with other aspects of culture (McDermott & Varenne, 1995; Secules, Elby, & Gupta, 2016; Secules, Gupta, Elby & Turpen, accepted), this is also emergent from seemingly innocuous actions of engineers, educators, policy makers, institutions, corporations, and a host of other actors. This also gives us hope, in the sense that the cultural “construction” of technological determinism can be locally interrupted. I give evidence that students can engage in social constructivist thought, challenge technological determinism, consider the interests of a wide range of stakeholders, and attend to issues of power, privilege, and marginalization, at least in the context of a carefully designed lesson plan, for the duration of the lesson. I also document how the lesson plan evolved in response to students’ ideas (both what was expressed and what was not expressed) as well as in response to aspects of the discipline that were important to me as an instructor (Robertson, Scherr, & Hammer, 2015).

Currently, the majority of engineering ethics resources are geared towards use in courses or seminars that are specifically for discussion of ethics, rather than for use in engineering design or engineering science courses (Leydens & Lucena, 2016; Hollander & Arenberg, 2009). Out of class experiences, in service learning environments (Johnston, Caswell, & Armitage, 2007; Mihelcic, et al., 2008; Ramirez, et al., 2011) do provide students with opportunities to engage with stakeholders, macro-ethical concerns, and participatory design in ways that integrate technical and ethical aspects of practice. Engineering design courses are also starting to be framed as sites where engineering ethics can be integrated into the curriculum (Bucciarelli, 2008; Kenny Feister, et al., 2016; Richards & Gorman, 2004; Van de Poel & Verbeek, 2006). This paper adds to the documentation of ways in which engineering ethics discussions can be integrated in engineering design courses.

To push back on my own argument, research indicates that stand alone courses and one-off seminars are inadequate in scaffolding a sustained and sophisticated grasp of social responsibility (Cech, 2014). I acknowledge that a single lesson is rather limited in the impact it can have on students’ sense of their roles and responsibilities as engineers or in helping them understand social constructivism or challenge technological determinism. Future work in our field should push for greater curricular and pedagogical resources for the inclusion of engineering ethics

more widely throughout the engineering curriculum in engineering design and engineering science courses.

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