Ethical Tech Innovation: Uniting Educational Initiatives and Professional Practice

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Executive Summary

Background: the issue
Engineers and other workers at the forefront of technological innovation play a central role in shaping the future of our digital economy, and the COVID-19 pandemic has revealed the need to discuss the ethics of how technologies are developed and integrated into society. However, there is inadequate understanding about effective methods for integrating ethical training in engineering academia. Part of the reason for this, in North America at least, is the limited impetus from engineering departments to engage in, let alone document, teaching interventions that seek to foster engineering students' ethical thinking skills and awareness of the broader societal implications of their work. Moreover, such efforts are rarely rewarded within academia. This neglect poses significant challenges for the engineering profession, particularly since it makes it difficult for educators to effectively deliver and assess ethical training. Going beyond engineering, the consequences of this lack are significant: perpetuating technological bias and inequities, environmental degradation, and a culture that is apathetic to the impacts of technological innovation.

Objectives
To better understand the scope of ethical training and education in engineering, and to begin articulating concrete strategies for effectively embedding these interventions, we convened an interdisciplinary group of scholars to achieve the following three specific objectives:

1. Conduct a scoping review of existing literature from the past ten years to identify recent knowledge and gaps on effective approaches to embedding ethics in the tech industry;
2. Conduct semi-structured interviews with key industry leaders and experts about the need for ethics training in engineering; and
3. Disseminate these findings to multiple audiences from academia, industry, professional organizations, and the public.

Results
Our literature review of 337 sources revealed that direct interventions have occurred in over 40 countries, and at least 16 articles describe interventions involving multi-national collaborations. While the trend in publication numbers appears somewhat flat over the first 8 years of study, a marked increase was seen in the two most recent years, with almost 60% more publications in 2020 as compared to 2018. Most published interventions were focused exclusively on academia (87%). Of these, 85% focus on students, with 82% of student-focused interventions targeting undergraduates. This project's results have emerged through analysis of the literature alongside interview data from 10 experts in engineering ethics education (who represent both Canadian and international perspectives). Our main findings are as follows:

Identity & Terminology:
- A narrow definition of "engineering" presents one of the primary impediments to cultivating buy-in for ethical training in engineering.
- A lack of consistent terminology and definitions about the role of ethical thinking in engineering prevents us from achieving widespread consensus about how these ideas align with engineers' core work and values.

Institutions & Infrastructure:
- Accreditation bodies, professional organizations, and industry are all powerful forces of influence on the ways ethics instruction *can* be integrated into engineering programs and *is perceived* as a priority within those systems.
- Current institutional pressures related to funding (for research and for programs), faculty promotion requirements, and timeline expectations often *impede* or *disincentivize* efforts to develop robust ethics-focused curriculum initiatives within engineering programs.

Priority Areas for Cultivating Buy-In & Alignment:

- Engineering should embrace the current reality that technological work benefits from (and often *requires*) input and expertise from a range of disciplinarity perspectives.
- To produce large-scale, meaningful, lasting change in the engineering profession that centres the values associated with ethical thinking and responsible innovation, we need to undertake multiple, simultaneous initiatives across academia, industry, and even government.
- Ethics education research in engineering needs to develop more robust assessment methods for evaluating the efficacy of current and new pedagogical interventions.

Key messages

Governing Bodies (Legislative/Administrative)

- Governing bodies, professional engineering organizations, industry practitioners, and academic institutions should collaborate on new standards and guidelines that prioritize the ethical dimensions and societal/environmental impacts of technology; the resulting legislation will then align with cross-sector initiatives to promote a cohesive approach to responsible innovation.
- Academia and government alike should develop funding opportunities that specifically promote the development of interdisciplinary ethics training; these types of funding should target both academic research and broader industry/community initiatives to help foster collaborations that can resolve the current research/practice gap.
- Academic institutions should prioritize creating research and teaching opportunities for faculty to engage with projects related to tech ethics in ways that are rewarded equally to technical work; these initiatives should support the development of robust criteria for teaching, training, and assessing engineering programs' outcomes related to ethical awareness.

Educators & Researchers

- Educators should build out ethical interventions from what engineers already do and where students are already invested and interested.
- Training in tech ethics and responsible innovation needs to make connections across contexts, clarify relevance between training and professional practice, and engage with stakeholders and contributors from different disciplinary backgrounds.
- In general, training initiatives should move beyond one-off modules/workshops and towards more integrated and embedded approaches for cultivating ethical thinking in the profession.
- Researchers should focus on developing strategies for: assessing the **efficacy** of pedagogical interventions, cultivating **buy-in** to tech-ethics/responsible-innovation principles, and connecting various bottom-up/top-down/inside-outside initiatives in ways that enhance **alignment** of priorities between engineers and various stakeholders (across academia and industry).

Industry

- Industry should actively engage with academic organizations to research the ethical implications of their work, initiate more industry-led training interventions designed to cultivate ethical thinking and promote responsible innovation approaches, and create C-suite-level positions focused on ethics, EDI, and sustainability

Methodology (search methods, selection criteria, data collection and analysis)

Our research question was: **In the past ten years, what approaches have been implemented in the field of engineering training and education that explicitly aim to cultivate ethical understanding and practice?** Following a pre-established protocol, we systematically searched for scholarly articles, finding and screening 4320 articles. Of these, we took a closer look at 1426 papers and found that 337 were relevant to our research question. We took the data included in these papers and summarized the overall findings they describe. In addition to the literature review, we conducted semi-structured interviews with 10 key leaders and experts in the field of tech ethics during May and June 2021, and analyzed the results to form the structure and argument for this report.

Ethical Tech Innovation: Uniting Educational Initiatives and Professional Practice

Background

Engineers and other workers at the forefront of technological innovation play a central role in shaping the future of our digital economy, and the COVID-19 pandemic has revealed with stark clarity the urgent need for ethical conversations about the ways technologies are developed and integrated into society. Companies that develop health tracking apps promise to assist with containing the virus' community spread, but their products also raise concerns about privacy and surveillance (Soltani et al., 2020). Online education platforms that make it possible for children to attend school from the safety of their homes also exacerbate existing socioeconomic inequalities related to technology access (Anderson & Perrin, 2018; Chung, 2014). Conversely, the insidious spread of online misinformation on social media platforms has renewed discussions about the role tech companies and engineers should play in debates surrounding free speech and content moderation (Noack, 2020). The pandemic has also heightened the demand for remote, virtual jobs, which will simultaneously open more widespread possibilities for digitally enabled work (Cognizant, 2020), increase the precarity of gig jobs (Moulds, 2020), and reproduce existing economic and racial inequities embedded in technological systems (Benjamin, 2019).

As these examples demonstrate, the ability to engage in ethical deliberation is becoming an increasingly crucial skill for workers in the tech sector who seek to mobilize technological innovation in response to global challenges like COVID-19 (Bannister et al., 2020; Gernand, 2015; Isaac & Navon, 2018; Loucks et al., 2018). Studies show that these types of "soft" skills are often perceived as secondary — a "check box" to complete at the end of a project rather than a professional or disciplinary priority (Glynn et al., 2010; Kiran et al., 2015). However, calls from industry to make ethics considerations and ideas like "social responsibility" and "technological stewardship" more central in tech fields are growing (Bannister et al., 2020; Hart Research Associates, 2013; *Infusing Ethics into the Development of Engineers*, n.d.; Loucks et al., 2018; Poirier, 2020; Rabb & Greenburg, 2019; Sakamoto, 2019; Sanchez et al., 2017). Propelled by both this new industry-based interest and a growing body of academic work on ethics and tech, **the central research goal of our Knowledge Synthesis project is to determine how we can integrate ethics and ethical thinking as core elements of training and professional practice within Canada's tech sector**.

Our project targets engineering programs as key sites of influence for shaping the values and perspectives of the incoming generation of leaders within the "digital workforce," in part thanks to the prominent role these programs play in shaping innovation. There is a reported gap, however, between the role engineers play and the training they receive to understand the ethical implications of their impact. For instance, A 2017 National Exit Report Survey (n = 2,485) among graduating engineers in Canadian institutions found that only half had studied the engineering code of ethics during their program of instruction (Engineers Canada, 2017). This carries into their reputation and standing among Canadians: a recent national survey (n = 1,200) by Engineers Canada found that while engineers are seen by most Canadians as innovative and highly trained, at least 1 in 5 Canadians feel engineers lack a high set of ethical values (Gibson & Hutton, 2017).

There is, however, a lack of insight about effective methods for integrating ethical training in engineering academia (Beever & Brightman, 2016; Brugnano et al., 2012; Civjan & Tooker, 2020; Freyne et al., 2011; Hasan, 2012; Hassel et al., 2015; Humphries-Smth et al., 2014; Reid, 2011; Zandvoort et al., 2013). In North America, there is limited impetus from engineering departments to engage in, let alone document, ethical teaching interventions, and such efforts are rarely rewarded within academia (Chang & Wang, 2011; Freedman, 2013; Fuhrmann & Mottok, 2017; Itani, 2013; Rulifson & Bielefeldt, 2019). This neglect poses significant challenges for the entire engineering profession, particularly since it makes it difficult for educators to effectively deliver and assess ethical training. Our research efforts are therefore guided by three main questions:

1. Over the past ten years, what pedagogical and training initiatives have been tried to cultivate ethical thinking in academia and industry? What has succeeded/failed and why?
2. How do engineers in academia and industry describe concepts like ethics and tech ethics and their place within their research, teaching, and professional practice?
3. What are the key barriers and opportunities for cultivating ethical interventions in academia and industry teaching and training?

Objectives

To answer these questions, the three central objectives of this project were to:

1. Conduct a scoping review of existing literature from the past ten years to identify recent knowledge and gaps on effective approaches to embedding ethics in the tech industry;
2. Conduct semi-structured interviews with key industry leaders and experts about the need for ethics training in engineering; and
3. Disseminate these findings to multiple audiences from academia, industry, professional organizations, and the public.

Methods

Literature review

To accomplish our first objective, we developed and implemented a detailed scoping protocol (see Appendix A). As a first step, we conducted keyword searches in 6 databases to identify literature published between 2011-2021 (see Appendix B); those searches yielded 5467 results.

After results were imported to Covidence for screening, 1147 duplicates were removed. Titles and abstracts of the remaining 4320 studies were screened following a double-blind review to determine if the abstracts described teaching interventions in engineering instruction intended to embed critical thinking about tech ethics. 2593 were excluded based on criteria outlined in the scoping protocol, and a further 85 duplicates were identified and removed at this stage.

Of the remaining 1642 articles, 216 could not be located. 1426 full-text papers were screened for relevance by a reviewer and ranked according to the stage, scope, and purpose of the identified intervention (see ranking criteria outlined in Appendix C). 414 studies were ranked 1 (indicating "specific, already-completed interventions that directly and primarily address the topic of tech-ethics in the engineering field") and advanced to the data extraction process, where their ranking was confirmed by a second reviewer. At this stage, an additional 77 studies were excluded (7 additional duplicates, 1 not located, 69 ranking revised).

Reviewers extracted data from 337 articles ranked 1 based on a framework developed in consultation with our interdisciplinary teams of project collaborators (see Appendix A; the framework built from insights the team gained during a summer 2020 literature review of over 400 articles and books that address the topic of tech ethics). These data, along with the responses to interview questions (details below), inform the results, implications, and conclusions outlined in this report. Additional analysis and synthesis of literature review data was ongoing at the time of writing.

Interviews

In addition to the literature review, during May and June 2021, we conducted semi-structured interviews with key leaders and experts in the field of tech ethics (see Appendix D; the study received ethics clearance through a University of Waterloo Research Ethics Committee, ORE#43156). Participants were identified based on a list of 46 interviewees suggested by the project's core research team and collaborators. From those individuals (which included Canadian, American, and European academics as well as members of non-profit organizations in the United States, United Kingdom, and Australia), 15 target participants were selected, 10 of whom we were able to interview. Together, they reflect a breadth of technical, social science, academic, industry, and non-profit sector perspectives on the project's focus area of ethics in engineering education. Interviewees were:

- 3 faculty members from different Canadian universities;
- 1 program administrator from a Canadian university;
- 4 faculty members from different American universities;
- 1 faculty member from a European university; and
- 1 expert in engineering ethics who directs a US non-profit organization (this participant was educated in and familiar with the Canadian engineering system).

Each interviewee discussed efforts to foster greater awareness of and activities related to the ethical implications of technological innovation in their field of expertise. Questions related to their knowledge of and perspectives on ongoing *initiatives*, *gaps*, and *opportunities* related to embedding ethical thinking into the design, development, and deployment of technology at their institutions or organizations (see Appendix D). The interview transcripts underwent qualitative coding and thematic analysis (Braun & Clarke, 2006; Creswell & Creswell, 2017), and discourse analysis (Gee, 2014). Results from the coding/analysis process (see Appendix E) informed the final revisions of the literature review's data-extraction framework (see Appendix A).

Data generated from these interviews provide the framework for this report's key themes, arguments, and takeaway points. Those data are supported and supplemented by the results of the literature review.

The list of interviewed participants is presented below:

Name	Bio
Alex* (pseud.)	Alex is an Associate Professor and Grad Program Director of Science and Technology Studies at a university in the United States.
Marjan Eggermont University of Calgary, Canada	Dr. Eggermont is a teaching professor in the Dept. of Mechanical and Manufacturing Engineering. She is also the Associate Director of the BME undergrad program. Her research focusses on engineering for the environment, HCI, arts/engineering collaboration, technology and society, and inclusive design. She is working on launching a new systems engineering course.
Steven Flipse UT Delft, Netherlands	Dr. Flipse is an Assistant Professor in Communication Design for Innovation and the Founder/Director of his own consulting company. His research focuses on communication in responsible development, collaboration, interaction design for responsible innovation management, and academic and nonacademic stakeholders.
Colin Gray Purdue University, USA	Dr. Gray is an Associate Professor of CS and of Learning Design & Technology in the Dept. of Curriculum and Instruction in Computer Graphics Technology. His work focusses on instructional design and design pedagogy. He also leads the UX Pedagogy and Practice Lab (UXP2), which focuses on research at the intersection of design education, practice, ethics, and critical theory.

Jane* (pseud.)	Jane is the director of a global organization focusing on social innovation; the intersection of engineering design, business development and social responsibility; and sustainable design.
Darshan Karwat Arizona State University, USA	Dr. Karwat is an Assistant Professor in the School for the Future of Innovation in Society & The Polytechnic School. His research focusses on sustainability ethics, social justice, and human dimensions of science and technology. He is also the co-founder of the Constellation Prize and runs re-Engineered.
Jason Millar University of Ottawa, Canada	Dr. Millar is an Assistant Professor in the School of Electrical Engineering and CS. He's also the Director of the Canadian Robotics and Artificial Intelligence Ethical Design Lab (CRAiEDL). His research focusses on the ethical engineering of robotics and AI; policy and engineering of automated vehicles, artificial intelligence, healthcare robotics, social and military robotics.
Cindy Rottmann University of Toronto, Canada	Dr. Rottmann is the Associate Director of Research at the Troost Institute for Leadership Education in Engineering. Her work focusses on engineering equity, diversity and inclusion, and engineering ethics. She is the lead on three projects: 1) the Engineering Leadership Project II; 2) the Ethics and Equity in Engineering Case Study project; 3) the Engineering Equity, Diversity and Inclusion Leaders project.
Mary Wells University of Waterloo, Canada	Dr. Wells is a Professor of Mechanical and Mechatronics Engineering and the Dean of Engineering at UW. She served as the Associate Dean of Outreach for Waterloo Engineering and chaired its Women in Engineering committee; she also chaired the Ontario Network of Women in Engineering from 2013 to 2018. Her research focusses on Canadian women in engineering/materials and digital factories.
Matt Wisnioski Virginia Tech University, USA	Dr. Wisnioski is an Associate Professor in Science and Technology in Society working with critical participation in innovation communities and reimagining engineering education (both curricula and culture). He is the author of Engineers for Change and co-founder of Human-Centered Design Interdisciplinary Graduate Education Program

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We are grateful to our collaborators, Mark Abbott, Marcel O'Gorman, and Neil Randall who provided valuable support during research planning and data-analysis stages of this project, and who continue to collaborate with us as we undertake Knowledge Mobilization activities.

Sincere thanks to Josh Ng-Kamstra for his valuable guidance while developing and planning the scoping review methodology, and during the data-analysis. We would also like to acknowledge the research librarians at the University of Waterloo, Kate Mercer and Christine Moffatt, who provided helpful input during the research planning phase of this project.

Thank you to all interview participants for so generously offering us your time, knowledge, and insight. Your ideas and examples form the core of this report's results and recommendations.

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Results

Our literature review of 337 sources revealed that direct interventions have occurred in over 40 countries, and at least 16 articles describe interventions involving multi-national collaborations. While the trend in publication numbers appears somewhat flat over the first 8 years of study, a marked increase was seen in the two most recent years, with almost 60% more publications in 2020 as compared to 2018. The literature and interviews revealed little to no description of interventions and training directed at industry. Most published interventions were focused exclusively on academia (87%). Of these, 85% focus on students, with 82% of student-focused interventions targeting undergraduates. Nonetheless, some interventions and interviews described ways to engage ethics within the context of increasing professional competencies, particularly related to capstone design projects and co-operative education.

This project's results have emerged through analysis of the literature alongside interview data from 10 experts in engineering ethics education (who represent both Canadian and international perspectives).

We have identified three critical factors necessary for cultivating tech ethics in engineering: **buy-in, alignment,** and **scalability**.

- We need to secure **buy-in** across institutions and professions, especially among student, faculty and C-suite level executives.
- We need to **scale** it beyond the narrow spectrum of those who have already bought-in across academia and industry.
- We need to **align**: 1) training with practice (to solve the research/practice gap), 2) demand with incentives (to make these subjects appealing *and* accessible), and 3) the big philosophical picture with the practicalities of engineering (to ground theory in practice/application)

We begin with an overview of key *barriers* preventing uptake in tech-ethics training, covering both the "intangible" contexts of engineering *identity* and the *terminology* we use to discuss engineering ethics, and the more "concrete" issues related to engineering education *institutions* and their surrounding *infrastructure*. We then outline a suite of *priority areas* that can be mobilized to *cultivate buy-in and alignment* from across the diverse stakeholders that comprise the engineering community. Our main findings are as follows:

Identity and Terminology

In this section, we describe two key factors that are preventing the widespread **buy-in** and productive **alignment** of goals that would be required to **scale up** initiatives to cultivate meaningful, lasting change. Our focus here is on engineers' ideas about their own professional *identity* and about the meaning and relevance of various *terminology* related to ethics.

Key takeaways:

1. **A narrow definition of "engineering" presents one of the primary impediments to cultivating buy-in for ethical training in engineering;**
2. **A lack of consistent terminology and definitions about the role of ethical thinking in engineering prevents us from achieving widespread consensus about how these ideas align with engineers' core work and values.**

Engineering Identity

Engineering: a technical AND an ethical domain

A common theme that emerges when speaking with engineers and reviewing literature about their discipline is the idea that engineering is a primarily technical domain, and that questions and issues related to the ethical or social implications of technology fall outside its scope. Erin Cech's work on the paradigm of engineering offers helpful background to understanding this aspect of the field and engineers' prevailing sense of their own identity. According to Cech, engineering culture is chiefly characterized by two ideologies: *depoliticization* ("the belief that engineering is a 'technical' space where 'social' or 'political' issues such as inequality are tangential to engineers' work" [2013, p. 67]) and *meritocracy* ("the belief that inequalities are the result of a properly-functioning social system that rewards the most talented and hard-working" [2013, p. 67]). She argues that changing the culture of engineering requires making "cultural space" for alternative ideologies, a task that this is especially challenging since the two dominant cultural ideologies mutually reinforce one another and make it easy to dismiss alternative frameworks like social justice, inclusion, and ethics as "irrelevant to engineering practice" (p. 70). Cultivating change in the profession will therefore require educators to confront and "deconstruct" dominant paradigms (p.70); this work should be a focus of pedagogical strategies that seek to encourage engineers' engagement with the ethical dimensions of their work.

Several interview participants confirmed these ideas about engineering culture and identity, pointing to an entrenched status quo in engineering and design that sees technologies, and the process of engineering them, as value-neutral. Within this dominant paradigm, engineering is paradoxically perceived as the field most directly responsible for technological innovation but somehow least responsible for its impacts. Participants consistently described a challenge they face to convince fellow engineers that technology is not value-neutral, that all technologies are political artefacts, and that "engineering is always a political process" (Alex). One participant, Colin Gray, an Associate Professor of CS and of Learning Design & Technology in the Department of Curriculum and Instruction in Computer Graphics Technology (Purdue U), framed this tension in terms of a dichotomy between an old and new guard, where the new guard is "much more interested in ethics in all of its manifestations," including social impact. This dichotomy can also play out between professors and their classrooms. Participant Cindy Rottman, the Associate Director of Research at the Troost Institute for Leadership Education in Engineering (U of Toronto), describes how some students are increasingly pushing faculty to embed ethics, equity and holistic perspectives in their teaching, and professors respond that 'it's not what they're doing.' This perspective is not necessarily divided between older and younger generations of designers and engineers; rather, the distinction lies in the degree to which individuals feel that those who design innovations should also be responsible/accountable for their broader implications.

As these comments demonstrate, not all engineers see engineering as a strictly or even primarily technical discipline; after all, the engineering community comprises "heterogeneous groups of people [who] believe many different things" (Rottman). Indeed, some participants feel that engineering as a whole—and engineering education specifically—already *does* take technology's ethical/social impacts into consideration. One participant, Alex, an Associate Professor and Graduate Program Director in Science and Technology Studies, is explicit about these connections: "all engineering, its work itself, has ethical implications. … Everything is built on a social impact" (Alex). And Mary Wells, Dean of Engineering at the University of Waterloo, situates these ideas firmly within the purview of education:

> "[I]n all of our work [as engineers] we try and develop mathematical frameworks of the way things work, but then apply them to society. So inherent in engineering […] is that knowledge that whatever we do, however we influence our natural environment in creating the built environment, [it] will impact on society. … we need to do that in a very thoughtful and responsible way; so inherent in engineering education is always some aspects related to that."

Other participants were less sanguine about the state of ethical training, however. According to participant Jason Millar, an Assistant Professor in the School of Electrical Engineering and CS (U of Ottawa), and the Director of the Canadian Robotics and Artificial Intelligence Ethical Design Lab (CRAiEDL), "the status quo is that there's still very little of that training [about socio-cultural impacts of innovation] going on." Another participant, Marjan Eggermont, a teaching professor in the Dept. of Mechanical and Manufacturing Engineering and the Associate Director of the BME undergrad program (U of Calgary), echoes these sentiments. She emphasized the troubling implications of what she sees as engineering education's frequent failure to account for broader social contexts: "We just want to focus on this tech, which as we all know results in huge issues for society. And we've seen lots of scary examples where tech goes out of control. … To me it's completely unethical to teach technology in that isolated way."

The need for enhanced training about ethical and social implications of technology was a common argument in the literature, which typically stressed the increasing scale, complexity, and potential impact of technological solutions. Beever and Brightman (2016) explain that "[e]ach year thousands of newly educated engineers join the workforce where they will very likely face novel ethical issues in their engineering practice that require a more sophisticated level of ethical reasoning than they have been trained to use" (2016, p. 276). There is, however, and increasing expectation and even a demand that engineers will be able to recognize and engage with the ethical and social implications of their work (Flipse & Puylaert, 2018; Greenburg & Rabb, 2020).

If we want to shift engineering culture to better address those impacts, we will need to develop pedagogical approaches that prompt students to think broadly and deeply about the extent to which engineering is implicated in technological innovation. As Zandvoort et al. (2013) explain, "If the social responsibility of scientists and engineers implies a duty to safeguard or promote a peaceful, just and sustainable world society, then science and engineering education should empower students to fulfil this responsibility." In doing so, we can begin to foster an engineering mindset in which ethical approaches are valued equally to technical achievement.

Engineers: problem solvers AND problem definers

One potential approach to achieving wider buy-in to the idea that engineering can and should engage more fully with the ethical and social implications of technology is to capitalize on engineers' widespread sense of their own "core" identity as "professional problem solvers" (Jane; Wells; see also MacDougall et al., 2012; Nudelman & English, 2019). To do so, however, will require a shift in how engineers tackle problems, to broaden their typically product-oriented approach to developing solutions. Another participant, Darshan Karwat, an Assistant Professor in the School for the Future of Innovation in Society & The Polytechnic School (ASU), described his enthusiasm for his professional identity in a way that showcased this focus on product development: "as an engineer I feel like I'm doing something, like I touched something. *I built something*. There's a thing, rather than just talking about things." This emphasis on creating—on building new "things"—is central to engineers' identity, but it can come at the expense of broader contextual considerations. "As an engineer," Rottman explains, "you're trained to focus in on a problem and solve *a piece of* something." The decision to hone in on an isolated "piece" of a bigger puzzle may be pragmatic or even necessary at times; however, it risks losing sight of important processes such as conversation and consensus building (i.e. getting the voices in the room). These latter considerations can end up being treated as superfluous and counter-productive.

Getting engineers to broaden the scope of their concerns to consider the social implications of technological innovation will require getting them critically assessing problems in the context of specific communities too. For one Dean of Engineering, a key educational goal in this respect is "to move our engineers to become not just the people that solve problems, but the people that can also help define problems" (Wells). Jones et al. (2017) makes a nearly identical comment about the need to provide engineering students the "means to problem define, not just problem solve" (2017, p. 210). This idea holds excellent potential because it tasks engineers with understanding and framing problems in ways that they can actively participate in solving. By training engineers to define the extent and context of a problem they can "then understand that they might be able to do something about it" (Gray). Furthermore, this approach plays to engineers' strengths. As Rottman explains, engineers' specialized *technical* knowledge makes them uniquely capable of defining and describing the *social* problems that might arise from technological innovation:

> If you know how something works, you can also know how it fails[. … T]hings can fail technically, but they can also fail socially, and I think if engineers are interested in—and many are—thinking about the social implications of what they do, they're probably in a really good

> position to know how that will work, like who will be excluded and who will be included. […] If they choose to answer that question, they will probably be in a better position to answer it than [a non-engineer].

Inviting engineers to become problem-definers in addition to problem-solvers will reverberate in culture more broadly, providing much wider access to nuanced technical perspectives about pressing issues related to technological innovation.

The Holistic Engineering Identity: broad perspectives, critical self-reflection

As a community of professionals whose work bridges technical and ethical contexts, and whose approaches to solving problems begins with a commitment to fully understanding and defining the contexts of those problems, engineers will be well-positioned to embrace an identity focused on the "holistic" mindset that many leaders are currently calling for. These calls are part of an emerging trend towards responsible innovation and technological stewardship (a concept currently championed by Canada's Engineering Change Lab), as well as broader initiatives to cultivate ethical training and critical self-reflection across STEM curricula and engineering practice. For example, one participant, Matt Wisnioski, an Associate Professor in Science and Technology in Society (Virginia Tech), argues that his most critical role as a teacher is to provoke a "sense of constant reflection: Why am I doing what I'm doing? What is the purpose of this?" The importance of this reflexivity is that "the answers are rarely obvious and are never settled"; instead, a self-reflective mindset involves a "constant process of being aware of what you're doing and why you're doing it and learning to live with that" (Wisnioski). In an effort to promote similar ideals, Fore et al. (2018) advocate for STEM practitioners to undergo an "ethical becoming", whereby "ethical thought and action of individuals is modified through participation in and *reflection on*" events relevant to their professionalism (2018, p. 4, emphasis added).

Theories of co-creation and practices of community engagement are often central to these discussions, as in Jane's description of their director work with engineers in global development:

> "[F]or us, one of the things that has been really critical is understanding how do we not just design *for* communities and make it … unidirectional to more, how do we design *with* communities? How do we create a stakeholder ecosystem? How do we ensure that whatever we bring to fruition is viable, desirable, meaningful, and is going to achieve that goal of improving quality of life?"

Rottman also noted how these ideas about co-creation, community impact, and critical reflection are increasingly topics of concern among students: "I hear them saying 'it's not enough to live in your tiny little technical bubble and only solve the problem somebody has given you. You have to think about the context. You have to think about the communities you're impacting, you have to think about your own biases.'" Jordan and Nair (2019) note that these community-based engagements, as well as education about how to do this kind of work have only recently begun to be incorporated into academic curricula in the US.

At the most expansive end of ideas about cultivating lasting culture change in engineering is a call for momentous transformation of the current paradigm to "reframe the engineer's relationship with technology and their understanding of their role in society and as it pertains to ethics" and help them adopt "the big picture view" (Jane; Eggermont). As our later discussion of curriculum reform will detail (see section "Update Curricula"), some leaders in ethics education believe that a total overhaul of the current education establishment (a "breaking apart of the university" as it is currently conceived [Karwat]) is required to make this happen. Others, however, invite us to see how changes to engineering ethics instruction can and should be integrated within the *existing* engineering paradigm. The goal, they propose, should be more about refocusing on essential priorities that are *already* core to engineering and contained within the oath that all engineers take. As Alex notes, "engineers are always looking out to address these [societal] needs and also address the economic opportunities that come with those needs."

Across all these perspectives is a recognized need to better train engineers to recognize the implications of their work. "[W]e ultimately are concerned with ensuring that [engineers] are not hurting people, whether physically or with respect to their quality of life in terms of how they interact within the community or with the greater ecosystem" (Jane). By keeping these goals at the centre of new pedagogical initiatives, there will be opportunities to bridge current gaps between technical and ethical values and to build from engineers' investment in solving problems towards the bigger picture project of defining and understanding those problems in all their complexity.

Terminology and Definitions

The Problem: a lack of consistent terms and definitions

A pervasive problem inhibiting these efforts, which emerged through both our interviews and our literature review, relates to terminology: we currently lack a stable and coherent set of terms for engaging with the ethical issues related to either technology's role in society or engineers' responsibility for the societal implications of their work. The general opinion among participants was that terms like "tech ethics" and "responsible innovation" lack consensus definitions. As Millar explained, "when I hear those terms […] my first reaction is they're too vague, too nonspecific; they're general," and they serve primarily as "placeholders for translation work that needs to happen in practice." Jane remarked that these words "resonate" and "feel familiar" across engineering contexts; however, the compiled data we reviewed indicates that words and phrases are not used consistently, nor are they understood to mean the same things across disciplines or even within cohorts.

While discussing issues related to engineering ethics and societal impact, participants invoked a broad range of concepts such as *holistic, inclusive, values sensitive, human-centred,* and *bio-inspired design*, which also appear in the literature (Cawthorne & Cenci, 2019; De Greef et al., 2013; Gipson et al., 2015, 2015; Molina-Carmona et al., 2017). These terms were often perceived to align with *equity* and *sustainability* perspectives, and to be most relevant to a cluster of specific engineering subdisciplines that are united in their aim to consider the role of technology and engineering in society: *humanitarian engineering, engineering for good, global engineering, renaissance engineering, peace engineering,* and *holistic engineering* (to name a few; see (Emmett et al., 2020; Gopakumar et al., 2012; Hariharan, 2015; Jordan et al., 2019; Rulifson & Bielefeldt, 2019; Zandvoort et al., 2013)). These fields seek to cultivate environmentally and socially responsible innovation by considering the full scope of social and environmental impact in ways that are life-centered rather than merely human-centered. As this range of concerns suggests, the subject of tech ethics/responsible design is so diverse that it does not easily fit into a single or precise definition, especially because it engages an interdisciplinary range of concepts, disciplines, and methodologies.

This broad scope can become an impediment to uptake since it risks creating an impression among engineers that ethics is in some ways extraneous or that there is no room for it. One participant noted that using a word like "ethics" moves it outside of the domain of engineering: "I think calling something *ethics* sort of 'others' the importance of these questions. It's like, 'No, this is just the practice of engineering'" (Karwat). These comments return to dominant paradigms of engineering identity, namely the idea that this primarily technical (practice- or product-focused) domain is not responsible for socio-cultural, political, and environmental impacts. When asked to define tech ethics, several participants mentioned how their mind goes to non-engineering disciplines like Philosophy, which they see as the home for experts in topics like "ethics in the more traditional sense" (Wells), or Science and Technology Studies (STS), with its explicit focus on social impacts related to technological innovation. These examples illustrate how inconsistent or blurry use of ethics-related terminology can exacerbate disciplinary silos. We end up with the notion that Philosophy departments make ethicists, STS programs make social science experts, Engineering departments make engineers, and each speaks its own separate language.

Without a clear set of definitions and terminology, various other challenges crop up: collaboration between the various stakeholders involved in these discussions is hard to navigate, pedagogical efforts to foster ethical thinking within the engineering community are hard to initiate and sustain, and agreement about what falls within the domain of tech ethics is hard to come by (see, for instance, Flipse & Puylaert, 2018; Reid, 2011; Roncin, 2014). People may assume common understandings of terms like ethics that do not necessarily match those of others, allowing people and institutions to co-opt words like "ethics" to mean whatever they want. One participant noted the difficulties this definitional fluidity poses for research and scholarship: "one of the questions we always get when we write papers in the HCI [Human Computer Interaction] space in particular is 'So what do you mean by ethics?' Or when talking about ethics with practitioners: 'Did you define it? And if you didn't define it, how do we know that we should trust your results?'" (Gray). In the literature, other sources similarly described problems stemming from a lack of terminology definition, including a lack of standardization of methods (Flipse & Puylaert, 2018).

This imprecision has also contributed to a sense that ethics is often deployed as a rhetorical buzzword. As Wisnioski confessed, his "first thought" in response to hearing the words "tech ethics" and "responsible innovation" was "tech companies trying to cover themselves from backlashes in the public, or trying to get on the bandwagon of what they know they need to be doing in order to change their public interest." Among STS scholars like Alex, who hold positions embedded in engineering programs, the word "ethics" can also be seen as problematic: "I think our focus is on *values* education and we resist *ethics* education because of the politics of our discipline [in STS], which has to do with being more radical. We disavow the sort of use of ethics as a means of just propping up the profession."

In the context of engineering education, these issues with terminology can create negative associations among students and faculty towards embedding ethical instruction. As one participant put it, "When I hear the word ethics, I hear boring" (Karwat): "boring" because it is seen as non-relevant. Believing that the study of ethics is boring and belongs to another field can make engineering students and faculty wary of devoting too much attention to the topic. Connecting back to the previous section, these perceptions on *terminology* also further entrench perceptions among engineering students about their *identities* as engineers. As Alex explained, "students enter [postsecondary engineering programs] with a certain kind of identity," one that they perceive as diametrically opposed to students in the humanities/social sciences disciplines. Because they have "already developed an identity going in," their response to non-technical course content can be simply "this isn't what I signed up for." Working within the space of that student concept of engineering identity while simultaneously attending to issue of language and communication, is therefore critical (Chang & Wang, 2011; Genova & Gonzalez, 2016; Hasan, 2012).

The Ambition: create resonant and consistent terminology

Several interconnected strategies are available to overcome the problems that stem from inconsistent and unappealing terminology. For academics and professionals invested in cultivating buy-in from the engineering community, changes in word choice may be the simplest way of overcoming the "image problem" for ethics. Interview participants suggested avoiding terms like "ethics" and "implications," and instead using product- and problem-oriented language to frame issues in contextually relevant ways for engineering students. For example, Millar described how he adjusted his approach to ethics training by using an engineering-friendly lexicon: "I … stopped using the word 'ethics' in my talks and just started trying to use terms that engineers were familiar with. So 'safety,' 'risk,' whatever, just to just to get them to realize that what I was talking about was already familiar to them using different terminology and that part of the task here was to expand their acceptance of different topics." This example reinforces Gray's argument about making ideas "fit for purpose": "it's not enough for there to be knowledge: the knowledge has to feel resonant and connected, or connectable to the present situation that you're working in."

These strategies implicitly contribute to the broader project of encouraging engineers to see their professional identity as *already connected* to questions of social impact and ethical responsibility. They are part of what Gray calls the "resonance piece" (and also "one of the biggest challenges that we've seen"): the need to have engineers recognize the importance of these terms to their profession. Ideally, this type of translation work will help accomplish one Dean of Engineering's ideal vision: a world in which the engineering disciplines treat ethical considerations as an integral part of "engineering competence" rather than as an add-on philosophical component (Wells).

From the opposite perspective, interviewees also stressed the idea that engineers themselves need to cultivate the ability to communicate across contexts; to do so, they need to be able to quickly familiarize themselves with, adapt to and adopt the language of the stakeholders with which they are working (see also (Rulifson & Bielefeldt, 2019)). As Wells put it, "we need to provide for students opportunities for them to understand the language and the approaches so that they can speak together and appreciate and understand what the other person is saying." Similarly, Jane felt that the future of engineering will be multidisciplinary, and that "engineers have to be able to crossover. So that means that terminology and language become that much more important and we have to train engineers to better navigate those conversations to be able to arrive at common meanings, even if the terms are different."

Of course, both approaches would be much easier if the terms were *not*, in fact, "different." Indeed, stable and consistent terminology would be immensely helpful for cultivating ethics in engineering. As Jane states: "We have to be talking about the same things. We have to agree on definitions. It's really important." For one thing, common terminology can empower individuals to recognize ethical dilemmas in their own domains and work collectively to articulate and address them. Reflecting on ethical blind-spots in his previous professional experiences, one participant highlighted the importance of having access to consistent terminology that could bridge between academic and practitioner contexts:

> In some ways it wasn't until I started doing this tech ethics work more directly that I was able to get in touch with some of my past experiences and sort of realize why some of the issues were problematic and that I should have acted, and I knew that something was off, but I didn't dig deeper, or that I just didn't have the vocabulary to even understand that something was problematic and thus wasn't able to pursue it further. (Gray)

In this statement, we see how unifying language leads to common terminology that everyone can use to frame ethical issues. Significant work to these ends is already underway by organizations like the United Nations, whose Sustainable Development Goals (SDGs) are, in Jane's words, "creating a unified framework for dialogue across the world" (and, by extension, offering opportunities for "mass education" and global collaboration). Additional efforts to prioritize linguistic consistency about tech ethics are now needed at all levels—from classrooms to academic institutions to (inter)national accreditation boards; and from companies to professional organizations to governing/regulatory bodies.

Institutions and Infrastructure

In this section, we discuss how larger infrastructure issues create concrete barriers to **buy-in** and **scalability** for ethics education initiatives in engineering, exacerbating (or even creating) the more "intangible" obstacles outlined in the previous section. We focus on some of the most pressing challenges that exist within academic institutions and industry contexts to impede both new and ongoing efforts to cultivate ethical thinking as part of the engineering mindset.

Key Takeaways:

1. **Accreditation bodies, professional organizations, and industry are powerful forces of influence on the ways ethics instruction *can* be integrated into engineering programs and *is perceived* as a priority within those systems.**
2. **Current institutional pressures related to funding (for research and for programs), faculty promotion requirements, and timeline expectations often *impede* or *disincentivize* efforts to develop robust ethics-focused curriculum initiatives within engineering programs.**

Academic Systems

Accreditation

Accreditation bodies like the Canadian Engineering Accreditation Board (CEAB) and its American counterpart (the Accreditation Board for Engineering and Technology [ABET]) play a decisive role in establishing nomenclature and framing concepts like engineering, ethics, and sustainability for engineering students and faculty. These topics appear within multiple target attributes/outcomes for engineering students (emphases added below):

CEAB "Graduate Attributes"

- (3.1.4) "Design: An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs *with appropriate attention to* health and safety risks, applicable standards, and *economic, environmental, cultural and societal considerations*."
- (3.1.9) "Impact of engineering on society and the environment: An ability to analyze *social and environmental aspects of engineering activities*. Such ability includes an understanding of the interactions that engineering has with the *economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions*; and the concepts of sustainable design and development and environmental stewardship."
- (3.1.10) "Ethics and equity: An ability to apply professional *ethics, accountability, and equity*."

ABET "Student Outcomes"

- (2) "an ability to apply engineering design to produce solutions that meet specified needs *with consideration of* public health, safety, and welfare, as well as *global, cultural, social, environmental, and economic factors*"
- (4) "an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must *consider the impact of engineering solutions in global, economic, environmental, and societal contexts*"

Numerous sources in the literature address the role of accreditation as a standardizing force on engineering education programs (see, for example, (Carroll et al., 2015)), and as a pathway to more ambitious ethical education like cultivating understandings in engineers about social responsibility (Bielefeldt & Canney, 2014) and sustainability (Brunell, 2020). Because these agencies act as an external force "coming from on high," with power to endorse or censure academic programs, the language they use to describe required ethics-focused attributes/outcomes holds significant weight. It can create pressure for engineering programs to change, and it can serve as a persuasive tool for instructors who want to make a case for incorporate ethical thinking into their teaching.

However, despite the benefits accreditation organizations provide by mandating the inclusion of curriculum that targets ethical thinking and the social/cultural/environmental/economic implications of technology, accreditation language can serve to water down ethical concerns. Without clearly defined assessment metrics, participants note, the above curricular directives are so general and nebulous in scope that even minimal engagement with ethical issues can be considered sufficient to "check off" the requirement. For this reason, some participants felt more stringent accreditation requirements were necessary to achieve meaningful culture change—as Eggermont put it, "I think in a way that Engineers Canada accreditation is a place to start." Accreditation bodies serves as an important standardizing force, yet participants noted a greater need for more robust, concrete standards from those boards.

This perspective suggests a potential approach to mobilizing the power inherent in professional accreditation bodies: if external pressure (whether from within academic programs or from other organizations) can prompt CEAB or ABET (or their international equivalents) to modify the way they frame the ethical components of engineering education, there is huge potential for widespread impact. Professional organizations have an important role to play here: they can influence the development of new accreditation standards by setting out policies that prioritize ethical approaches. One participant spoke at length about the impact of the American Society for Mechanical Engineers (ASME), which "has a history of developing codes and standards and being a neutral party convener that's meant to advance the profession, engineering profession at large, and the entire mission is to advance engineering for the benefit of humanity" (Jane). International organizations like the IEEE Standards Association play a similar role in other engineering disciplines (Koene et al., 2018; Shahriari & Shahriari, 2017). In concert with pressure from within the academy, these influential, *collective* professional voices can help shape the direction of future accreditation standards, which in turn will lead to more robust integration of ethical competencies across engineering programs (see, for instance, The IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems).

"Jam-packed" Engineering Curriculum

A perennial question that emerges in any conversation about strategies for embedding ethical thinking and the social implications of technology into engineering curriculum is, in Eggermont's words, "Where do we put it?" After all, due to the requirements set out by accreditation bodies (and, of course, the variety of high-level of technical knowledge professional engineers need to master), engineering programs are notoriously "jam-packed" (Wells; see also Fuhrmann & Mottok, 2017; Harun et al., 2017). As Alex reminds us, these "highly compacted" programs" are "trying to basically offer a professional degree in four undergraduate years"; that fact complicates any effort to find space for any new interventions, even if they are approved in principle. As Jane summarizes it, "The engineering curriculum is very full. It is. There's a large debate about what else can be added and what can be taken away to ensure that we produce engineers that are in fact qualified for the job." This overpacking presents a further challenge to supporting student engagement, since "students are very interested in these topics, [but] there's not always a place for them within the curriculum" (Rottman).

These tensions play out at various levels within an institution, from administrators who are juggling "stringent" accreditation requirements (Eggermont) to individual faculty members who are "reluctant to give up" (Wells) any part of their courses, but also struggle to negotiate the disconnect between the limited "time you have available in a class" and the daunting "number/scope of learning objectives you're supposed to cover" (Rottman). Even the question of when to introduce these topics to engineering students was seen as a major hurdle (Rossmann, 2015).

The resulting student experience is, to put it mildly, "overwhelm[ing]" (Rottman)—a fact that was reflected in nearly all interview comments and across numerous sources in the literature review (see, for instance, (Committee et al., 2016; Fuhrmann & Mottok, 2017; Riley, 2015)):

- "First year engineers have no space in their schedule to put anything" (Rottman);
- "You don't have much room for electives and things" (Wells);
- "We have way too many hours" (Wells);
- "There is no room to maneuver" (Alex);
- "There's too much content" (Alex).

The literature described students who were left feeling there was too much to know, that assignments were overly ambitious (Brugnano et al., 2012), and that the work they did was not seen as relevant to their profession (Hasan, 2012). Faculty, meanwhile, described feeling ill-equipped to tackle these complex topics in a meaningful way (Hasan, 2012).

When the notion of incorporating ethical thinking into engineering training is perceived as "jamming yet another thing into an already overfull can," then it's no wonder that so many members of the educational community feel that it's simply asking too much: "You can have a limit, right?" (Alex).

Research (Dis-)Incentives: grant program gaps, tenure requirements

If a jam-packed curriculum impedes attempts to integrate ethical thinking more fully into the *student* experience, existing academic funding structures and tenure reward metrics play the equivalent role in terms of *faculty*-level engagement.

An ever-present question for scholars interested in projects that foster ethical thinking in the engineering profession is: "How do we get more resources?" (Karwat). Some participants described an untenable position in which funding for this type of research can be hard to come by, at least in Canada, because it seems to fall into the gaps between grant programs that prioritize technical or scientific projects (e.g. through NSERC) and those that fund humanities/social science work but tend to shy away from education-focused research (e.g. through SSHRC). This is not to say that grants are impossible to secure (one participant related how her interdisciplinary team "got a [Social Sciences and Humanities Research Council] SSHRC Insight Development Grant for engineering" even though colleagues had said "oh, you can't get such a thing" [Rottman]). However, the broader patterns indicate a need for funding programs that explicitly invite interdisciplinary work (such as the Canadian Tri-Agency's "New Frontiers in Research" grants or the University of Waterloo's "Interdisciplinary Trailblazer Fund") to make this research more accessible and appealing to a broader range of scholars.

Without adequate funding to support research into strategies for developing effective ethical training, specializing in this area can even pose a risk to job security. As one participant noted, engineering departments are more likely to hire technical experts over ethical experts (Alex). Doing research in this space is also hindered by perverse (dis)incentive structures within the tenure system, which push engineers towards valuing certain kinds of outputs and avoiding others. All academics (especially those early in their careers) are required to ask, in Wisnioski's words, "What is the goal and what is [my] responsibility … on the ground? And *if [I] don't get a paper out of it, is it valuable*?" If research in engineering ethics and engineering ethics education is perceived as less significant than technical engineering work, but also requires the "difficult" task of managing a multidisciplinary research team and tends to produce less traditional outputs (such as community engagement initiatives [Wisnioski]) that "[are]n't rewarded within the Academy" (Gray), fewer emerging scholars are likely to assume the professional risk of making this subject matter their primary focus.

Additional (Dis-)Incentives: university funding models, institutional timelines

University funding structures and expectations for a speedy ROI provide additional barriers to the type of interdisciplinary, slowly evolving research and teaching projects that are required for engineering ethics pedagogy to develop to the point where it can produce clear effects and lasting change within the profession.

In terms of funding structures, because many university budget models pit various organizational units against one another in a competition for student enrollments, self-interest becomes a requirement for financial survival. Alex explained the fallouts of this approach in stark terms: "we play to our disciplinary and personal interest and … misunderstand autonomy with the failure to … recognize the responsibility that comes [with] it, … to really pay attention to students and their needs"; in this participant's specific institutional context, the result of these budget-based priorities was a type of faculty-level "turf war" in which humanities, social sciences, and engineering faculty members stake out inflexible claims to their own areas of expertise, and a "you aren't going to take that from us" mentality quashes any potential for interdisciplinary pedagogical collaboration—which, as we discuss below, is essential for developing effective and holistic engineering ethics training.

The move towards more corporate operating models also means that university systems can be less accepting of the slow pace of "reform work" (Wisnioski) in education—the fact that, as Eggermont notes, "It's always this belated gratification, students coming back ten years later, saying, hey, that was actually quite OK" (even if they didn't enjoy a class while they were taking it). Because culture change takes time and commitment (especially within entrenched academic institutions where curriculum changes can take years to implement), and because educational experiences frame future perceptions (and those influences are not always apparent until years later), university leadership will need to make commitments to these types of projects and be willing to support them through the long term.

Industry Priorities

Several participants described the challenges associated with current norms and accepted practices within the "corporatized" university system (Eggermont), many of which emerge from the close connections that bind university-based engineering programs to industry. "The biggest challenge to try to overcome," according to Karwat, "is the financial and business and economic aspects of this [system]": much of the funding for engineering is shaped by the private sector, which will undoubtedly set parameters and push research to focus on product-development.

The broader industry context is an essential counterpart to any academia-based initiatives to foster ethical thinking and societal awareness in engineers, since industry positions are the aspirational career destination of most engineering students. Recent academic research, however, echoes the increasingly urgent tone of public discourse about the ethical shortcomings and failures of the tech industry (Benjamin, 2019; Noble, 2018; Zuboff, 2019). We hear concerns about transparency and ethics as barriers to AI implementation in industry (Castellanos, 2018). And several prominent researchers note a lack of research on the cultural nuance of ethical tech development around the world, including Thomas H. Davenport, the President's Distinguished Professor of Information Technology and Management at Babson College in Wellesley, Massachusetts and Tim O'Brien, Microsoft's AI policy and ethics officer (Davenport, 2019). Furthermore, according to a 2019 Global Business Ethics Survey published by the Ethics & Compliance Initiative, nearly half of employees see a lack of strong commitment to ethical leadership in their organization, and a third see a lack of strong commitment to organizational values (Ethics and Compliance Initiative, 2019). Similarly, only a third of respondents to the Deloitte survey said that "organization's leaders spend enough time thinking about and communicating the impact of their digital initiatives on society" (Kane et al., 2019). While companies like Google and DeepMind increasingly support research into the ethics of AI and Automated-Decision Making (ADM), there has been increasing scrutiny from academia about the degree of "undue influence" these companies have to shape policy and broader conversations about the responsibilities for tech firms and data management companies (Benkler, 2019; Williams, 2014).

All participants agreed that industry needs to play a key role in encouraging engineering culture change. As Gray explained, "there's a real opportunity there, but it's only going to be an opportunity if the C-Suite realizes that the people are actually riled up for something important." An important starting point for industry is to take responsibility for visibly supporting and promoting ethical issues in all aspects, from hiring to training and product development. Industry support would also provide a tangible need for ethics training that engineering faculty could point to—a way to show disinterested students that engineering ethics has professional relevance. In this way, ethics could be seen as "not so much an outlier anymore, but core business", according to participant Steven Flipse, an Assistant Professor in Communication Design for Innovation (TU Delft), as well as the founder and director of his own consulting company. By assuming a position of leadership, industry can drive positive change within engineering education: as Wells mused, "I think if industry started demanding graduates had these [ethical] competencies, [academic engineering programs] would sit up and listen with the other engineering programs in terms of what they want from their students."

The Double-Bind of Ethical Frameworks

Ethical frameworks are important tools with uses that extend across academic and industry-based training spaces. They are often used as instructional aids, helping students (whether at the university-level or within professional development contexts) frame and grapple with the expanse of the ethical issues they will need to engage as part of their engineering work. However, the ostensibly comprehensive frameworks that different "ethical toolkits" provide can have negative and limiting effects. Gray notes that "they try to create such a pervasive presence that then they're too monolithic to actually encourage an individual practitioner to act." Without sufficient grounding of how to apply these frameworks, they can provide the pretense of ethical action and justify unethical conduct.

> I'll give you an example that came up in one of our studies a couple of years ago: we asked a set of design students—in this case, it was UXers and it was also people from industrial engineering—and we put them into a room, gave them a design task for an hour and we gave them a really evil design task. But something that practitioners would actually be asked to do. And they rationalized, actually, with the ethical frameworks that they've been taught, but in the in the wrong direction. In this case they knew the ethics stuff, but in the moment, addressing the tasks that they were asked to with no strings attached—I mean they could have said "no, we think that task is evil. We're going to do something different." But they didn't. Classic deception study kinds of stuff, but it's that ability to shift and reframe in the moment, recognizing that the frame itself has an ethical component that I feel like most ethics education program just don't do a good job of addressing. (Gray)

As this example reveals, having a normative framework can inadvertently obscure ethical obligations by limiting nuance of ethical thinking. A framework, as the name implies, frames attention and focus, and gives users a common means of acknowledging problems. However, this framing can also exclude and omit issues—with potentially dire consequences. Karwat describes how mandates can provoke tunnel-vision, whereby organizations focus narrowly on achieving their mandate to the exclusion of pressing societal, cultural, and environmental issues. There remains a need for critical reflection on what exists beyond the frame.

Even with a robust set of ethical frameworks, there will likely be outlier topics that are ignored or excluded. Whose responsibility will it be to ensure these concerns are addressed? Critical theory, critical speculation, and approaches like values sensitive design can and do play a significant role here, prompting and provoking sustained ethical introspection to account for changes wrought by innovation, but engineers—and engineering educators—must remain vigilant.

Priority Areas for Cultivating Buy-In, Alignment, and Up-Scaling

The challenges outlined in the previous two sections require a multi-pronged, multi-directional approach from diverse stakeholders if we want to succeed in the goal of solidifying ethical thinking as a core value and priority within the engineering community. Although many questions remain open regarding the best approach, methods, and targets for achieving this ambition, evidence points us towards several productive strategies for cultivating the ideal engineering-ethics "trifecta" of stakeholder **buy-in**, cross-sector **alignment**, and **scalability**.

In this section, we present a suite of strategies and examples that we hope will serve as models and jumping-off points for future engineering-ethics initiatives in policy, practice, and research.

Key Takeaways:

1. **Engineering should embrace the current reality that technological work benefits from (and often *requires*) input and expertise from a range of disciplinarity perspectives.**
2. **To produce large-scale, meaningful, lasting change in the engineering profession that centres the values associated with ethical thinking and responsible innovation, we need to undertake multiple, simultaneous initiatives across academia, industry, and governing bodies.**
3. **Ethics education research in engineering needs to develop more robust assessment methods for evaluating the efficacy of current and new pedagogical interventions.**

We need to foster interdisciplinarity

Why should engineers embrace interdisciplinarity?

Across both expert interviews and the literature review, interdisciplinarity emerged as a critical component in cultivating ethical thinking in engineering. Interview participants largely treated interdisciplinarity as an inevitable and ongoing paradigm, especially within newer programs (Wells). According to Jane, "engineering is becoming inherently multidisciplinary. It has to. Because we're seeing there's no such thing now as a pure mechanical engineer or pure electrical engineer." (Jane) As a result, it both prudent and necessary to train engineers to thrive within this multidisciplinary context: "The bigger the [disciplinary] tent, the better in my opinion" (Gray).

Despite the emphasis on interdisciplinarity in the interviews, the literature review found that only 30% of studies describing direct training interventions over the last ten years to cultivate engineers' capacity for ethical thinking were interdisciplinary. And despite the emphasis placed on philosophy and humanities departments as experts in ethical instruction, only 12 studies of interventions overall involved the humanities (of which only 4 involved philosophy departments). This could be because, as participants mentioned, interdisciplinary projects can be hard to initiate, requiring additional consultation and collaboration, even compromise, and often these efforts are deemed less valuable than mechanical and technical training by students and faculty alike.

Yet there are several reasons to encourage interdisciplinarity, ranging from conceptual to practical levels. The main reason participants cited for its importance was the perceived complexity and scale of today's technological challenges. As Eggermont put it, "some of these issues are too big for one profession, […] engineering can't be everything." An embrace of interdisciplinarity, she proposes, means "being humble enough to say, OK, this is beyond me and inviting the right people." Jane similarly described the problems associated with relying on one profession to solve large-scale challenges. Within the "inherently multidisciplinary" field of engineering for global development, they noted, "you're not going to be able to arrive at a solution without working with a variety of disciplines. One of the things we talk about is that while engineers are problem solvers, we don't know what we don't know, right? Otherwise, [we will] be faced with guaranteed failure." (Jane)

Interdisciplinarity can also serve to create productive "friction" (Karwat) between disciplines, which can draw attention to critical blind spots and also begin filling in those ethical gaps. Gray spoke in detail about this dynamic, explaining that given the myriad legal, educational, and technical requirements inherent in engineering, (i.e., "the tensions that make this work so complicated"), cultivating interdisciplinarity is "key to surfacing some of these issues." It helps stakeholders **"**find not just what is technologically possible, but what we actually want to happen. … [W]e need multiple voices to do that." This participant felt that "if people have critical scholars on their faculty, they're going to be much more likely to make that transition" from ethical awareness into action (Gray). He also claimed that interdisciplinarity has been key to raising the profile of EDI and social justice issues within technical contexts: "the humanist traditions are the only reason why [conversations about these topis] are happening now in engineering and design education" (Gray). Millar echoes this sentiment, noting that "the kind of language that we're developing in the humanities and social sciences just doesn't exist in engineering and computer science to any great extent" (Millar).

The general argument that unites these various perspectives is that it's professionally and ethically enriching to embrace interdisciplinarity. Or, in Rottman's words: "stop swimming in the water that you were trained in, and start swimming with others" (Rottman).

What should interdisciplinarity look like?

The actual meaning of "interdisciplinarity" (and related terms, such as "multidisciplinarity" and "transdisciplinarity") remains somewhat open to interpretation, a fact that represents an initial hurdle to overcome when developing visions for productive interdisciplinary collaboration in engineering. Like with the terms "tech ethics" and "responsible innovation," frequent use means that "the very term interdisciplinarity has lost a lot of its analytic charge" (Alex) and sometimes stands as a rhetorical buzzword that means competing ideas to many groups. In particular, participants noted a lack of consensus about who gets included: for some, interdisciplinarity extends only within the engineering disciplines (e.g., mechatronics working with civil engineering). This rhetorical slippage could easily allow engineering programs to champion their pursuit of interdisciplinarity entirely absent any engagement with social sciences and the humanities. That disciplinary isolation is not always present, of course. As multiple participants noted, inherently interdisciplinary engineering domains—such as peace engineering and engineering philosophy—already do exist, and interdisciplinary approaches drive technological work in fields like sustainability and design. Without external, non-technical interlocutors and collaborators, though, the capacity for nuanced reflection on societal implications and ethical complexity is diminished.

Thinking about what interdisciplinarity could look like in practice, Wells describes their ideal in terms of precisely this technical/non-technical crossover:

> […] all technical people have to go from disciplinary thinkers to what I'm calling transdisciplinary thinkers, where they get used to working with non-technical people outside their domains of knowledge and understand the language, understand some of the concepts so that together they can work in this kind of multi-dimensional team to come up with the best solution considering all these other aspects.

Likewise, when Jane described the importance of cultivating interdisciplinarity, that same focus on traversing beyond familiar contexts appears as central: "We see that there is tremendous value and, frankly, that is the future of engineering from our perspective: that it's going to be multidisciplinary. Engineers have to be able to crossover."

As engineers strive to envision and plan for an interdisciplinary future for the profession, it will be important to acknowledge how the methods of one discipline can also serve as productive models for another. Several participants note how aspects from other domains can model what is needed to integrate ethics into engineering projects, including frameworks for ethics training. Describing her work at the intersections between bioethics and engineering, for example, Millar explains that regulated professions like bioethics and clinical ethics "provided the model that [he] needed for engineering to start talking in engineering terms [about ethics]." This exchange was described as a kind of translation work, and viewed as a critical component of making interdisciplinarity successful and allowing the disciplines to fully benefit from the collaboration. Jane similarly describes how the framework for their ethical training models were adapted from existing tools found in other disciplines:

> There are ethical considerations that are part of training and part of practice for a variety of other professions. […] What other professions can do is help us understand what works well in their field and what constructs already exist and what could be adapted. […] To get more of that insight would be tremendously meaningful; to say "alright, well, this is out there. How can we adapt it? How can we make it more tailored and better understood by engineers?"

Recognizing positionality within one's research is therefore critical, especially when considering its implications within specific contexts. Many participants themselves held interdisciplinary backgrounds, which enhanced their ability to advance uptake of ethical content in engineering disciplines. Describing the role of interdisciplinary teachers in this regard, Alex explains that "[b]ecause of their complex trajectories, those folks bring a variety of backgrounds and perspectives, and they also to negotiate it locally as they create […] engineering courses."

These remarks suggest several additional key elements of successfully interdisciplinary collaboration: strong leadership (ideally from individuals with both technical and non-technical backgrounds who can steer projects away from "chaotic" dynamics [Wisnioski]), open dialogue (focused on a willingness to recognize different collaborators' abilities and positionalities), and a commitment to activating relevant contextual understanding and skills—that is, to making space for each discipline to play to its strengths and complement one other. As Alex points out, "you always have to unpack [interdisciplinarity] in terms of the specific disciplines and the institutional context in which people from these different disciplines are absorbed." Wells describes a best of both worlds approach in which faculties with expertise in ethics could work with engineers, as "carriers of that deep knowledge," to "help teach our students alongside us."

The benefits of these collaborations extend to the students as well, since it allows them to see the paradigm of engineering from an alternate lens; that is, as part of larger socio-cultural framework that can help engineering students recognize the implications of their work in the future. Returning to the issues of language and terminology discussed earlier, Wells explains the benefit of this pedagogical approach: “you need to bring in that other expertise, but we need to provide students opportunities to understand the language and the approaches so that they can speak together and appreciate and understand what the other person is saying.”

These ideal visions for interdisciplinary engineering practice promise to overcome many of the obstacles outlined in earlier sections of this report: engineering students are exposed early and often to the idea that ethical thinking and social responsibility are valued within their profession; a common set of vocabulary begins to be established among the various stakeholders involved in technological development; disciplinary silos no longer prevent engineers from benefitting from the knowledge and insights that other departments can provide (and vice versa). The key to growing buy-in will be emphasizing relevant and contextual knowledge, since, as Gray proclaims, engineering needs “more people that are trained in discipline-specific ethical concerns that reference the ways that the work is actually going to happen in industry and society more broadly.” Engineers have valuable perspectives that will be necessary for other disciplines to do this work, and should seek out opportunities to be involved.

Sustainability: a model for interdisciplinary praxis

Through both interview conversations and the broader literature review process, sustainability emerged as an important field of study adjacent to (and often overlapping with) engineering that provides a model for pursuing ethical thinking in the tech sector. In this section, we offer a brief overview of the ways in which sustainability intersects with the discourse of tech ethics, highlighting approaches and strategies that the engineering community might adopt to enhance this area of the profession more broadly.

In both the literature and in interviews, sustainability was closely associated with engineering ethics education, and in some cases viewed as inextricable (Minano et al., 2017). Eggermont noted her tendency to equate sustainability with ethics, describing how she perceived them as “closely linked.” This connection was also evident in the ways participants stressed the importance of cultivating student understanding around topics like “environmental racism” (Eggermont), “environmental justice” (Karwat), and “a cradle to grave mentality” (Eggermont; Wells) as part of ethics training.

Engaging with sustainability frameworks can shape what counts as “engineering ethics,” and push engineers to think about ethics and ethical thinking in new ways: “Ethical problems in sustainability are unpredictable and consequences cannot be evaluated simply as right or wrong. ... [These problems] require students to learn a different set of ethical skills than is ordinarily required by professional ethics.” (Sadowski et al., 2013). Interview participants described how studying sustainability concepts, including in domains like STS and Philosophy, can offer ways to think critically about the practice of engineering and its connections to diverse contexts. A focus on sustainability, in these instances, provides students with exposure to the broader impacts of technological innovation (whether environmental, social, political, economic, etc.). For example, Karwat credits his involvement with STS and engineering philosophy as the reason he was “able to marry questions that [he] ha[d] about the actual technical aspects of engineering” to bigger picture ethical issues. But this impact can also occur in engineering courses. Karwat notes that “study[ing] combustion chemistry in relation to air pollution and climate change impacts” prompted him to think critically about sustainability in engineering.

On the flip side, ethics frameworks offer ways for sustainability-focused engineers to balance the multiple competing factors that their work must juggle, bringing “social and ecological aspects” into the picture rather than casting them as secondary to “the economic aspect, which so powerfully drives engineering activity” (Castro-Sitiriche et al., 2012). This productive dynamic was present in interview discussions of “engineering for global development,” which is “about working with other sectors and other disciplines in order to arrive at a better, more sustainable solution” (Jane). Indeed, an influential framework for approaching the concept of sustainability comes from the UN Sustainable Development Goals (SDGs). These goals serve as a focal point for educators, faculty, and researchers to frame the scope of sustainability topics in engineering and provide a rationale and impetus for integrating sustainability into research and teaching. Wells, for instance, stressed the importance of the UN SDGs in orienting change efforts at the institutional level: “I’m really pushing for this idea of our need to engage with the UN Sustainable Development Goals. I've been working with all the engineering Deans across the country around identifying and articulating some kind of Canadian engineering [goals]. Grand challenges we’re calling them, which are rooted in the UN Sustainable Development Goals.”

According to Wells, broadening this perspective of what engineering is and how it can contribute to sustainability is key to attracting a more diverse cohort of engineers: “I think if we can shift the conversation narrative around what engineers do and their place in the world to more on sustainability, we will inherently attract more women.” When it comes to engineering departments becoming more concerned with equity, diversity and inclusion (EDI), Karwat notes an increase in conversation about EDI “in engineering faculty meetings or engineer organizations,” and acknowledged a need to better connect EDI and questions of social and environmental justice “to the design of technological systems themselves.”

In the literature, the number of published studies on engineering ethics training interventions has gradually increased over the past decade (as seen in Figure 1), and about a quarter of those initiatives engage with sustainability. However, less than 1 in 10 engaged with EDI topics (a number that remains constant over the past decade).

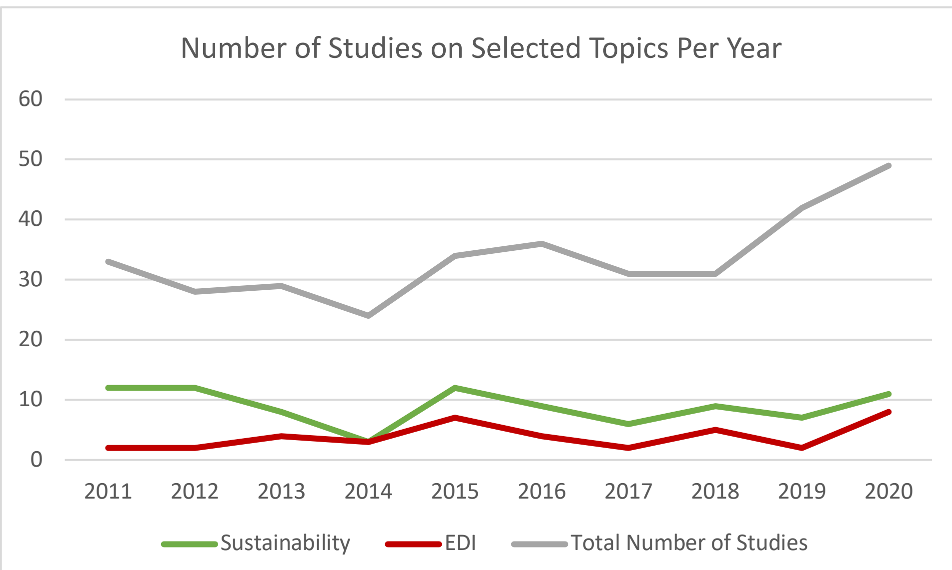


Figure 1: Number of Studies on Selected Topics Per Year

Given the perceived overlap between sustainability and ethics, sustainability design courses were noted as the most accessible sites of integrating ethical training interventions into engineering curriculum, often due to their grounding in the UN sustainable development goals (Rottman), “sustainability principles and indigenous knowledge, knowledge systems and social entrepreneurship” (Eggermont). These design courses were identified as ideal sites to infuse more ethics-based education (Eggermont).

We need to mobilize a variety of levels of intervention simultaneously

An array of approaches exists for cultivating an engineering mindset that prioritizes tech ethics and responsible innovation. Because efforts to accomplish this ambition must contend with a complex network of barriers (as described in the sections above), it will require multiple interventions from multiple areas of engineering—individual classrooms, program-wide curriculum decisions, national accreditation boards, professional organizations and industry partners, as well as legislative bodies—if we want to reach the crucial “tipping point” in buy-in and uptake (Lajoie et al., 2020).

It is essential therefore to create strategic alignments between learning pathways that stress the academic and professional relevance of tech ethics material. As Jane emphasised, engineering disciplines need to “think more constructively or be more structured in our thinking about the learning objectives that are coming out of our training schemes, [including] how those line up to what’s needed on the job, and then furthermore how that aligns to what’s being provided within traditional training on the academic setting or elsewhere and how we can create those bridges so that you can now take that training.” Ideally, a combination of “top-down,” “bottom-up,” “inside-out,” and “outside-in” initiatives will work in concert to achieve these alignments, each being tailored to its own specific regional, cultural, and institutional context. The sections below offer suggestions for specific ways to begin implementing such a multi-pronged approach.

Embed Ethics Interventions Throughout Engineering Studies

Across the literature and in interviews, educators and researchers asked questions about *how much* ethics training is needed for it to be most effective. As Gray put it, “Currently the main war is over ‘do we do it in one course container or do we distribute it across the curriculum?’ And I think the answer is both.” As this statement implies, single-course interventions are *part* of the answer, but cannot stand on their own. Other participants were blunt about the perceived inadequacy of single interventions. Reflecting on her range of experiences teaching “drop-in workshops” on equity and ethics for engineering students, Rottman said “[she] didn’t find it educationally useful.”

With only one intervention, participants noted a need to cram too much content into a single session, leaving students and faculty feeling overwhelmed. The lack of broader curriculum can lead to inconsistencies and repetitions across interventions. Institutions also tend to rely on those single shot moments instead of developing more systemic curricula, which becomes another obstacle for rolling out broader ethical interventions across departments.

This limited uptake from institutions means the content can be dismissed by students as peripheral and non-essential or lost in the bigger picture of the other competing academic demands. As we noted earlier (see “Jam-packed” Engineering Curriculum), students typically lack the time or space in their course selection to take these single interventions, particularly if these are provided as electives or discipline specific.

In the cases where ethics modules are mandatory, faculty delivering the content have little opportunities to build trust and rapport with students. For instance, Rottman describes an instance at the end of a mandatory three-hour module where political and ideological differences were raised by students that had to be left unaddressed. As she explained, “It’s not my class, [but] if it's my class for 10 weeks I could slowly ease into something, but I'm hopping into somebody else’s class. I don't know that context.” These challenging classroom dynamics also point to the issue of leaving ethics instruction to single modules, or even a series of modules, specifically when the topics concern social justice and sustainability: the content can seem so politicized that some students refuse to absorb it.

As both interviews and literature made clear: one-off interventions are insufficient and multiple interventions are preferred. As Fleischmann (2004) puts it, “a single course is not enough to change the culture of a school – especially when the course is taught by faculty outside of the engineering discipline” (p. 370). A single intervention approach presents several challenges that limit the potential for buy-in from faculty and students, and, by extension, to achieve lasting impact. If engineers will incorporate new ideologies so long as these are viewed as professionally relevant (Cech, 2013), then changing the culture of engineering beyond its present technical paradigm requires long-term education goals embedded in the department and its curriculum (Bernacki, 2008; Fore et al., 2018). Further, this content must be provided in a coherent and sustained fashion, and throughout academia into professional contexts. As Rossman (2015) explains, “a sustained effort in ethical instruction, infusing several courses, offers students more chances to consider the material, more opportunity for growth and reflection, and better retention of both content and ethical reasoning skills."

Update Curricula

Responses from participants demonstrate a spectrum of approaches and outcomes for modifying ethical training, ranging from widespread culture change to moderate enhancements to engineering practice based on accreditation requirements. These calls align with and are in some cases based on developments in the literature.

Literature has described efforts to revise syllabi (Mitcham & Englehardt, 2019) to ensure alignment between community, academia and industry (Fraaije & Flipse, 2020; Ribeiro et al., 2018). This can involve the development of instructional materials (Mulhearn et al., 2017; Torrence et al., 2017; Watts et al., 2017), including the use of case studies (Antes et al., 2009; Beever & Hess, 2016; Mitcham & Englehardt, 2019; Mulhearn et al., 2017; Warford, 2016; Wilson, 2013). Meta-analyses evaluating these curricular developments have noted several effective methods including criteria and model-based compliance measures and approaches that stress decision-making processes (Torrence et al., 2017). Standard compliance education had the most substantial effectiveness in ethical instruction; this included stressing the importance of compliance with professional ethics codes in both field-specific and field-general contexts (Mulhearn et al., 2017; Torrence et al., 2017). These same analyses have also determined several ineffective methods, including generalized content (Torrence et al., 2017; Watts et al., 2017), and narrow coverage. In other words, courses that superficially embed ethics are ineffective and can be counter-productive to ethical development (Torrence et al., 2017). Field specificity in training content is key (Watts et al., 2017).

Our literature review revealed a wide variety in methods for teaching ethical content. Of the 336 interventions identified: 90 described using case studies, 63 used lectures (9 involved guest lecturing), 35 integrated assignments, 10 introduced games. At least a third (n= 115) used a mix of these methods. At least 43 were new courses (including 7 capstone design courses), which included a mix of content. 14 interventions described using of problem-based learning.

One notable intervention described in the interviews is an approach called *engineering plus* that would enhance engineering training in the form of new certifications and degrees, "where we [offer] a masters in Ethics and Society or Public Policy or something like that so that we give [students] one extra year to gain some of these skills" (Wells).

This array of methods is seen as both an opportunity and a challenge among participants. On the one hand, this variety allows educators flexibility to determine their own approach to teaching: "in the United States you can have tremendous variation because a lot of these decisions are decentralized" (Alex). This variation is important, as Alex explains, because "[n]eeds are different, students are different, faculty commitments are different… overlapping jurisdictions and regional economic and industrial interests are different"; as a result, "local culture will determine to a great extent what kind of ethics-related and other values-related content are introduced." Similarly, Jane argues that successful ethical training must be 'sector-specific': "in the digital platform and community that I lead [at an organization globally focused on engineering for social innovation, social responsibility, and sustainable design], we look at 8 sectors associated with quality of life, water, sanitation, energy, agriculture, habitat, information and, communication technology (or ICT) transport, and health. In any of those you have niche elements or very specific aspects that are incredibly important." On the other hand, most participants feel that this decentralization, combined with its interdisciplinary scope and the overpacked curricula leads students and teachers alike to feel overwhelmed by the scope of ethics training. As Eggermont explained, "there are so many ways to go with this stuff. It's like falling down a hole." (Eggermont)

One of the primary challenges facing ethical instruction is its current compartmentalization within academia. Ethical materials are often delivered in elective or non-engineering courses, and so are seen as tangential or irrelevant (Cech, 2013, 2014). Scholarship has instead called for a need to develop an extensive framework that engages ethical decision making across curriculum and into the engineering profession (Alpay, 2013; Cech, 2013, 2014; Engel-Hills et al., 2019; Gray & Boling, 2016; Kisselburgh et al., 2014; Lau, 2004; Taebi & Kastenberg, 2019; van den Hoven, 2019; Walling, 2015).

Support Faculty

Research has found that ethics training is most effective when provided by professional ethics instructors. More specifically, students were more receptive to the content and found they understood the relevance to their own profession, and were therefore more likely to engage with ethical training, when it came from an accredited individual (Fore et al., 2018; National Academy of Engineering, 2017; Plumb & Reis, 2007). Flipse put it bluntly: "Whether or not [ethics training] works is very much dependent on who actually offers and supervises and manages it." As Gray notes, "[W]hat that is going to require is that we actually have people trained in not just ethics, because that's sort of a more philosophical stance on the issue, but really thinking about this composite of ethics and philosophical knowledge, the pragmatist piece and then actually connecting it to the work of design and engineering, and that actually being a valued skillset for people to have."

Unfortunately, most faculty are unprepared to engage and integrate ethical issues into engineering curriculum with this level of expertise (Fleischmann, 2004; Leydens, 2013; Plumb & Reis, 2007; Walczak et al., 2010), a finding confirmed by participants. In an ideal world, one Dean of Engineering put it, "the professors, and all my professors, buy in and engage this" topic because they "understand [its] importance"; unfortunately, however, "that's not the case right now"; because there is no consensus on its deployment, ethical instruction in engineering requires a broad set of interconnecting skills and interests that can sometimes supersede the aptitudes of any one instructor (Wells). For instance, Rottman described how a course on equity was retitled business ethics to make it more marketable to students, but this retitling left the teacher feeling incapable of teaching the subject it advertised.

Given the specialized nature of ethics training, and the perception that there is too much to know, institutions need to provide greater training supports to faculty. For instance, Gray is working on "train the trainer" modules. Support for engineering faculty to develop and deliver ethical curricula can also include assigning assessment specialists for participating organizations (Plumb & Reis, 2007).

Most importantly, research supports the need to value and validate ethical training at all levels in academia, up to and including tenure decision (Cech, 2013). If faculty are more willing to devote time and resources if they are assured that the work will count towards their academic research and not be treated as a timesink. Upper-level administrative support is critical in this regard (Mitcham & Englehardt, 2019). Importantly, institutional support for these types of initiatives needs to foster longevity. Describing summer ethics modules offered at an institute, Alex explained that "once the money went away, there was no clear basis by which to support these faculty." These factors lead engineers to see ethical considerations as extraneous and outside the domain of engineering.

An additional challenge to scaling engagement is the issue of burnout, which can occur for several reasons. First and foremost is the sense of fatigue and futility that professors experience from a lack of momentum in addressing these issues at an institutional level. Participants noted that interventions in engineering ethical education typically comes from dedicated professors pursuing "passion projects"—but passion is not endless, and change takes time and dedication. Yet each semester presents the same challenges of trying to squeeze ethical content into already overpacked curricula and working within the general paradigm of engineering that sees itself as removed from these sorts of ethical implications. As some participants pointed out, there is limited incentive for faculty to commit too deeply to these topics, and without a clear mandate from their institution, professors can soon find their commitments overstretched and overwhelmed.

Burnout can also afflict students, who may see the lack of institutional engagement as a red flag, amplified by a lack of industry uptake about these topics. Overpacked curricula that typically pays marginal attention to ethics also means these passionate students must also pursue these topics as electives or co-curricular activities. This lack of academic support, coupled with a lack of industry recognition, can lead some to wonder if they are harming their career prospects, especially if, as some participants noted, they get a job where they are expected to do the opposite of the ethical training they received.

Engage (with) Students

Most participants suggested that a small percentage of students are already deeply invested in engineering ethics. Those students are interested for a variety of reasons, including a sense that it is professionally and/or personally relevant, or even morally necessary. Even lacking these motivations, students can be engaged simply if the content is engaging and provokes critical thinking.

Many participants acknowledged that opportunities *do* often exist for students to pursue questions and topics related to ethical thinking in the tech sector, but that they don't often reach far enough since students need to actively seek them out. On the plus side, this argument suggests that these topics already *are* present in many programs; on the negative side, it indicates the limited reach of those initiatives and the fact that they don't always (or even often) lead to more widespread uptake. The question becomes, as Eggermont put it, "how do we catch the big chunk [of students] in the middle?"

There's a large swath of engineering students that are not invested in ethical implications. Flipse, for example, noted that "a lot of researchers PhD level master postdoc couldn't care less. They're not trained [in ethics], and they're also not trained to take these kinds of things seriously. So they have to take an obligatory ethics course, but that's it." For those students who need to be engaged, it will be important to stress the competitive and professionally relevant qualities of this training.

Despite a prevailing paradigm in engineering that ethics is "boring" and tangential, there are nonetheless engineering students already engaged in these issues, often because they are personally relevant to them (for instance, as an engineering student from a marginalized background), or deemed professionally relevant and aligns with their concept of an engineering identity.

Some participants stressed that this student engagement can provide an easy way for engineering departments to mobilize support for grassroots engineering ethics initiatives. "Students have a lot of power," explains Eggermont, "so I think just really mobilizing the students to make this push. It's what's going to make it happen." This support can function as a value-add for departments and schools, providing unique and engaging opportunities for students that can support professional development. Eggermont notes that self-motivated students will seek out co-curricular activities, especially when engineering ethics is absent in their already overpacked curricula: they will join clubs and teams and "find avenues", including "joining [Engineers Without Borders] EWB" (Indeed, one of the participants traced their early engagement in engineering ethics to their involvement with EWB).

In a related sense, participants emphasise a need to empower students: "so you need to bring in that other expertise, but we need to provide for students opportunities for them to understand the language, [and] the approaches; so that they can speak together and appreciate and understand what the other person is saying" (Wells). They also stressed the importance of listening to students:

> When our students say 'I have felt excluded in the following seven places', listen and figure out what's going on there. Don't try to defend the organization. Don't try to get human resources to say what was actually fine. Don't strike another ethics [committee] or another EDI committee and let that be your action… take what students have to say to heart and start your change there. (Rottman)

To do so, institutions must provide student forums for discussion and problem definition.

Engineering also needs to engage beyond students already invested in these topics. While some participants encouraged institutions to focus efforts on those students, others cautioned against the tendency to focus on those already invested because it inhibits growth of investment from students, faculty, and institutions more broadly. Given the overpacked curriculum and the prevailing attitudes in engineering, there are few opportunities and incentives for most student cohorts to engage in these ethical considerations.

One of the ways to establish relevance for students is to turn to actions recommended by international organizations. For instance, many participants described the utility of the UN Sustainable Development Goals in orienting and focusing the attention of all stakeholders towards sustainability concerns. These common frameworks help set goals and targets for practitioners and educators, and are typically included in assignment designs and rubrics. For instance, one study to cultivate sustainability teaching created a modified assessment rubric from several international Well-Being Indices including "Well-Being indices such as the Gallup-Healthways Well-Being Index, WHO Five Well-Being Index, Canadian Index of Wellbeing and important existing methodologies such as the Social Return On Investment (SROI) and the Capabilities Approach (CA)" (Castro-Sitiriche et al., 2012).

Ultimately, institutions must attend to what Millar called "professional socialization" and instill a sense that these ethical considerations are bound up with the profession from academic into industrial contexts. Scaling this engagement is vital because if students are primed with language and critical thinking faculties to understand and describe these situations according to critical paradigms, then it can lead to consensus about what socio-cultural problems exist and ultimately help to determine what work can be done to address them.

Engage (with) the Community

To cultivate ethical thinking, focus on issues related to caring and that are local and specific. Several participants described the importance of "listening" to community needs. "If you care about this thing and then you come together and you have to listen to other people and other disciplines and they care about this thing too… it makes a social difference" (Rottman). Research emphasizes the importance of strong community building for sustaining ethical programs (Plumb & Reis, 2007).

Several participants described the positive pressure a social movement like Black Lives Matter exerted on technology makers to better anticipate and mitigate the impacts of technological innovation. Turning to culture change theory helps clarify the importance of these social movements. Changing culture typically requires clear, urgent and external pressure or difficulty (Schein, 2016). "Only when external pressures arise—e.g., the new ABET 2000 accreditation criteria or the NSF 2010 requirements for research ethics education—and administrators recognize a need, does real action take place. Yet even then, once any specific urgency has been met, initiatives readily falter" (Mitcham & Englehardt, 2019, p. 1748). Maintaining a culture of ethical concern in engineering will require more than single interventions, and will require cultivating a new paradigm in engineering (see section "Engineering Identity").

Engage (with) Industry

Our literature review identified relatively few interventions that engaged with industry, but that should not be taken to mean that industry professionals not interested in this topic. In fact, there has been an increasing call from within organizations to engage with ethical concerns (Flipse). In 2018, for instance, technology futurist Shara Evans proposed the role of the Chief Ethics Officer (Masige, 2018). That same year Microsoft appointed its first AI policy and ethics officer, directing the development of ethical policies related to the use of technologies like facial recognition (Davenport, 2019), and the past year has seen an industry trend towards the appointment of Chief Ethics officers (Bannister et al., 2020). Data from Deloitte's global AI study found that a third of respondents who are executives rated "ethics" one of the top general areas of concern (Loucks et al., 2018), and Deloitte advocates organizations adopt an "ethical tech mindset" that positions ethical tech as central to a "holistic, tech-savvy approach" (Bannister et al., 2020). Similar research confirms that "organizational ethics matter significantly to most employees and managers, and that people want to work for employers whose values and principles are aligned with their own" (Bailey & Shantz, 2018).

Various models for engaging ethically in innovation have been proposed, including linking Corporate Social Responsibility with Responsible Innovation (Valdivia & Guston, 2015), and corporate citizenship with Responsible Innovation (Hemphill, 2016). This human-centred approach matches calls made by the World Economic Forum to rethink technological development with ethics at the centre (Philbeck et al., 2018). In *Bridging the Values Gap*, Edward Freeman and Ellen Auster (2015) propose a process for organizations to articulate values and structure operations around them, while acknowledging that outcomes will depend on the structure of the organization and its values.

The challenge, however, is to encourage industry and academia to work together to resolve what Karwat refers to as the "research/practice gap"—the "huge disconnect" between academic research and practitioner knowledge. Gray provides an illustrative example:

> You have people who've done really important critical work, like Batya Friedman with the value sensitive design framework [VSD]. But you talk to practitioners and they've never heard of VSD. And even if they've heard of it, they don't really know how to use it to pragmatically engage with their everyday work. And it's not because Batya's work is bad, it's actually very thoughtful. But it's not resonant in the ways that practitioners need in the moment. … It's great if there's an ethics-focused method that helps you think about things. But if it doesn't fit into your work practices, then it might as well not exist. And that's the state that we're at right now with industry and tech ethics.

Flipse similarly describes a "a misalignment in these kinds of mutual responsibility" between academia and industry, and feels that research going forward should attend to "aligning those [issues] where there are possibilities and opportunities for responsible design or responsible innovation."

We need to develop more robust and nuanced assessment mechanisms

While accreditation criteria call on engineering educators to ensure students can think critically about the impact of technological innovation, there is limited understanding of what should be done in education about these topics (Hess & Fore, 2018). Exploring this question with a focus on assessment methods, Knight et al. (2018) surveyed 1448 instructors found that few instructors use standardized assessment tools for ESI topics. They suggested this may be due to instructors' unfamiliarity or a desire to customize their teaching, but that this may limit the quality of their assessment, especially for novice instructors.

Some measures our review identified for assessing ethical development include:

- Defining Issues Test 2 (DIT-2), a verified measure for assessing moral schemas.
- Engineering and Science Issues Test (ESIT), examines moral judgement and reasoning within the space of technical issues found in engineering and science (Borenstein et al., 2010).
- Engineering Ethical Reasoning Instrument (EERI), a verified instrument for "assessing individual ethical decision-making in a project-based design context" specifically within engineering (Zhu et al., 2014), developed in collaboration with Illinois Institute of Technology (IIT), Lehigh University, and Michigan Technological University (MTU) (Zoltowski et al., 2014)

Beyond a need for better awareness about the types of assessment tools available, there is a need to better understand their efficacy for topics like ethics, sustainability and EDI. Few assessment measures exist to determine the efficacy of different pedagogical interventions for getting students to think about sustainability, EDI, and ethics in the space of engineering, in part because multiple tools and methods are used in interventions, which can confound their impact.

In instances where assessment methods were detailed in the studies reviewed in this report, assessment typically often amounted to brief student satisfaction surveys, or asked students to report on self-assessed gains in their understanding of these topics, often with little or no indication of how student development was measured related to these topics.

These observations raise questions about the limits and obstacles that instructors experience as they develop these initiatives, and the ways that rubrics, or more formalized and standardized assessment mechanisms could support teaching these topics to become more common. For instance, to guide the development of engineers ethical becoming, Hess and Fore (2018) propose the Integrated Community-Engaged Learning and Ethical Reflection (I-CELER) framework for engineering ethics instruction, and other studies have described novel curricular interventions including internships (Patel et al., 2015), and capstone design courses (Favaloro et al., 2018; MacDougall et al., 2012) that have sought to cultivate holistic approaches to engineering practice.

Summary: putting it all together to cultivate culture change in engineering

A major obstacle to the widespread adoption of ethical thinking within the engineering discipline is a lack of investment from faculty, students and professionals—the perception that this topic is simply not interesting, or that it is merely an obligatory "check-box" element of engineering practice. Flipse confesses that "you still see a lot of researchers (PhD level, master, postdoc) who couldn't care less." Part of the disinterest is related to group dynamics. As Gray points out, "even if you have the best ethics training ever and you know all the right words, if you're on a team that doesn't care about it, then you're not going to get any traction. And that's the space where ethics education is just very poorly executed right now, in my opinion." This difficulty extends into the professional arena as well. Looking to strategies for mitigating this "misalignment" and instead fostering "mutual responsibility," Flipse encourages both academics and practitioners to seek out shared "possibilities and opportunities for responsible design or responsible innovation."

In many instances, Gray suggests, the biggest problem is "just a lack of awareness" of technology's broader implications. Karwat explains this challenge in terms of problem definition: "if you talk to engineers … they'll just sort of frame climate change is a carbon problem. Get rid of the carbon, we're fine. And, you know that maybe addresses the issues to a certain extent, but really [there are] other political, social ethical questions that can help frame the climate crisis differently, and therefore change the engineering interventions we bring to it." The challenge, however, is to encourage those implementing change on the ground and academia to work together to resolve the "research/practice gap" between academic research and applications to address problems in the world (Karwat).

Millar puts these challenges into a broader context by reminding us that when it comes to fostering ethical thinking in the engineering profession, we need to think carefully about how we define our goals: "I think one of the main barriers is just understanding the nature of the work. … It's about change. The job is change management." From this perspective, a key element of any successful initiative to encourage engineers to prioritize ethical considerations is cultivating **buy-in**. Crucially, buy-in needs to happen on multiple levels at once for the impact to be felt: we need buy-in from industry and institutions, just as we need buy in from faculty and students to create **alignment** across the varied contexts and ensure the **scalability** of these ideas.

Implications

The insights from our analysis, including the literature review and the interviews with tech-ethics leaders, hold several implications for *policymakers* in government and academia, *practitioners* who work as engineering educators and industry professionals, and *researchers* who study the ethical dimensions of engineering. Below are several recommendations for future actions that will assist these various communities of stakeholders in propelling broader engineering culture change.

Policy

Government:

- Consult with professional engineering organizations who are developing new standards and guidelines focused on the ethical dimensions and societal/environmental impacts of technology (e.g., the IEEE Standards Association) to develop legislation that aligns with these broader initiatives to promote responsible innovation practices.
- Develop funding opportunities that specifically promote interdisciplinarity projects and ethics training (e.g. NSERC's recently launched "Equity, Diversity and Inclusion Institutional Capacity-Building Grant"); these types of funding should target both academic research and broader industry/community initiatives.
- Embed a section on ethical implications as required information in funding applications, similar to the way Gender Based Analysis plus (GBA+) and Equity, Diversity, and Inclusion (EDI) sections are now integrated in various Tri-Agency grant forms.

Academia:

Accreditation Bodies

- Advocate for and support academic institutions' efforts (at the program, department, and individual faculty member levels) to develop more robust criteria for teaching, training, and assessing the graduate attributes/student outcomes related to ethical awareness.

Academic Administrators

- Create funding, research, and teaching opportunities for faculty to engage with these topics (either individually or as part of interdisciplinary groups) in ways that are rewarded equally to technical projects.
- Create systems and support structures in which the decision to pursue this area of research/teaching does not to lead to faculty burnout.
- Accept that pursuing these large-scale culture changes will take time and sustained commitment.

Practice

Education/Training:

- Build ethical interventions out from what engineers already do. Build from where students are already invested and interested rather than trying to engage them from the vantage of a separate disciplinary focus.
- Make connections across contexts, clarify relevance between training and professional practice (i.e., don't assume or demand buy-in from students and faculty).
- Actively look for ways to engage with stakeholders and contributors from different disciplinary backgrounds; i.e., be open to (and seek out) cross-discipline and cross-sector collaboration/consultation.
- Move beyond one-off modules/workshops and towards more integrated and embedded approaches for cultivating ethical thinking in the profession.
- Look to fields like sustainability for models to initiate and scale ethical education.

Industry:

- Engage with academic organizations to research ethical implications in your own organization, and especially to research the value of these topics to industry.
- Create C-suite level positions focused on ethics, EDI, and sustainability.
- Initiate more industry-led training interventions that are designed to cultivate ethical thinking and promote responsible innovation approaches, and disseminate these interventions more broadly (at conferences, in journals, etc.).
- Work with co-op offices to create training opportunities for students in which they are encouraged to adopt and prioritize ethical and societal awareness.

Research

- Develop research strategies for:
  - **assessing efficacy** of pedagogical interventions
  - enabling increased **buy-in** to these ideas (from students, educators, and professionals)
  - connecting various bottom-up, top-down, inside-outside initiatives in ways that enhance **alignment** between engineers and various stakeholders' perceived priorities and values
  - improve **scaling** of these ideas (to ensure they are in place in the long term, and also that they permeate all levels of the tech sector)
  - targeting the study/development of **industry**-focused training and professional development initiatives

Conclusions and Future Research

Returning to the questions that guided this overall report, we found hundreds of pedagogical and training initiatives have attempted to cultivate ethical thinking in academia around the world over the past decade. While the literature presents a great deal of exemplary efforts to grow and embed ethics training, the status of these efforts in engineering disciplines remain sporadic, transitory, and idiosyncratic. These efforts are often initiated by a professor who is passionate about the topic and who recognizes a need to go beyond the requirements set by accreditation bodies and their own institutions. As such, the pedagogy is often set by the professors who initiate these interventions, who are typically venturing outside of their expected duties and knowledge area to teach this content, and who contend with numerous barriers including student and institutional disinterest and a pervasive culture of engineering that focuses overwhelmingly on technical and mechanical considerations in engineering.

Regarding the larger paradigm in which these interventions occur, engineers in academia and industry describe concepts like ethics, tech ethics, and responsible innovation using a broad spectrum of terminology that encompasses a wide range of social, cultural, environmental, and technical concerns. Inconsistencies and overlap in terminology were identified as a challenge to overcome, since they reduce the discursive impact of words like ethics, sustainability, equity (and related terms) within the engineering community and profession. This ambiguity therefore constrains the potential for ethical and social implications of technology to be widely adopted by the engineering community because it frames these ideas as topics external to engineering. Perhaps the most succinct summation of how the engineering profession can move towards a greater integration of ethical and social implications of technology is by reframing ethical instruction as "*fundamental*" rather than "*supplemental*" (Cech, 2013, p. 78).

In this report we have identified more than 35 opportunities for cultivating ethical interventions in academia and industry teaching and training (for a complete list, see "Appendix F: Strategies for overcoming barriers to scaling ethical training"). We hope that this synthesis will empower engineers, engineering educators, administrators, industry professionals, policymakers, and even members of the public to develop new ways to prioritize and embed robust frameworks for ethical thinking in tech sector and engineering culture more broadly.

Gaps in our Knowledge Synthesis

Since our analysis relied on interviewees who spoke English, and articles published in English, the interventions and issues described in this report over-represent North American concerns, and particularly US-based research—indeed, nearly half of our interview participants worked at US-based institutions, and about 60% of studies in our literature review focused on efforts at universities in the United States.

Due to limited time and resources, and the overwhelming number of articles our team reviewed, we were unable to complete data extraction on articles ranked 2 or above (see "Appendix C: Ranking Criteria"), which would have provided additional nuance to the scope of ethics interventions. We look forward to continuing and completing this work in the future.

While we sought to gain additional insight into industry practices through our interviews and search in grey literature, neither yielded significant findings for us to review.

Future Areas of Research

The literature and interviews revealed little to no description of interventions and training directed at industry. This may be because such efforts are not published in academic journals, if at all, perhaps owing to industry IP. However, when considered in the context of one of the key SSHRC themes, education and training for lifelong learning (which asks how we can develop a skilled workforce able to respond and adapt to evolving labour demands), this absence begs several questions:

1. When and how do practitioners and professionals get re/up-skilled and/or trained in socio-ethical issues of engineering impact?
2. How do individuals and institutions who provide training and consultation for industry establish, verify, and ensure best practices?
3. What institutions or agencies verify that this training takes place after post-secondary education?

Part of our knowledge mobilization activities, especially those involving workshops with Engineering Change Labs Canada are directed towards exploring these questions.

Given the association between ethics and topics like sustainability and equity, diversity, and inclusion (EDI) stated in both the interviews and the literature, future research could attend to the state of training aimed at teaching students about the importance of sustainability and EDI in engineering, and develop ways to ensure these considerations are factored into design and development of technology.

Our research found a wealth of resources generated by organizations and educators on these topics that can support the development of ethical training initiatives, but which were beyond our timeline and resources to explore more fully in this study.

Returning to one the gaps we identified about our research, we acknowledge a need to further explore the geographic distribution of initiatives and how those contextual factors make them possible in some places more than others. As Clancy (2020) points out, “Since engineering and technology are increasingly cross cultural and international, it is important to expand empirical research on engineering ethics beyond these narrow samples.”

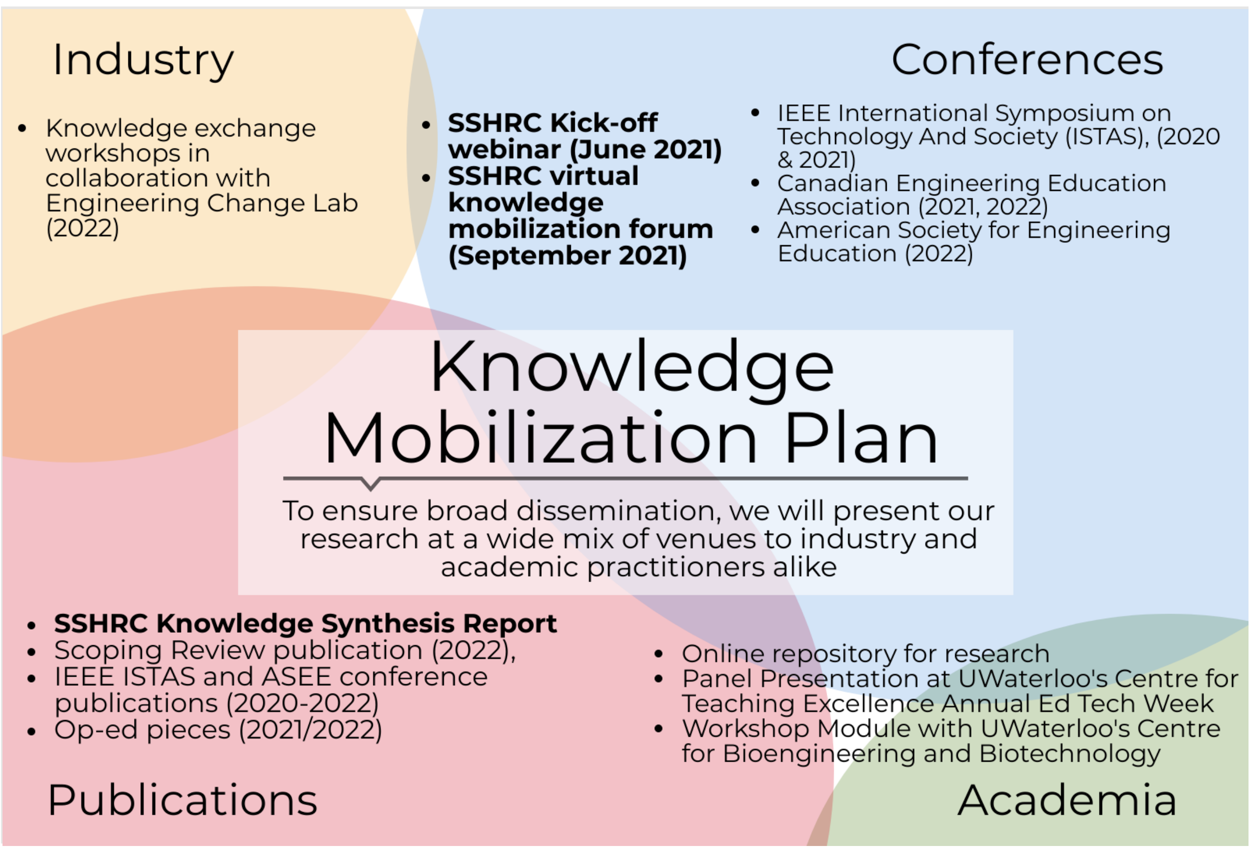
Additional research could also explore ways to settle on and consistently deploy contextually relevant terminology across engineering contexts. For instance, some participations recommended the using terms like “Grand Challenges” over “ethical implications”, and “engineering for global development” instead of “environmental ethics,” but the question remains: would this help or hinder uptake of ethical education in engineering?

Knowledge Mobilization Activities

We will use the findings from this project to produce a series of knowledge mobilization activities, including several strategically targeted presentations, publications, and workshops in academic and industry venues. These activities will (a) propose strategic educational and training-based interventions to increase the capacity for and valorization of ethical thinking within the tech sector; and (b) identify areas for future research to address.

As the graphic below illustrates, our KMB activities will engage with four main audience/venue "areas of influence": Industry/Academia and Conferences/Publications. The size of each sphere represents the anticipated impact that the "Ethical Tech Innovation" project will have on each. Conferences and publications represent the greatest focus for outreach venues, and the audiences of our project outputs are divided equally between industry practitioners and academic researchers/educators.

Additionally, the results of the scoping review data extraction will be presented in a publicly accessible database (link TBA), and will continue to be updated as extraction proceeds over the duration of the grant. This archive is intended as a comprehensive repository of material published on the research topic between 2011 to 2021, and the link will be widely circulated through various academic networks to support additional research on ethics education.



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Appendices

Appendix A: Scoping Review Protocol

Title of the review	Ethical Tech Innovation: Uniting Educational Initiatives and Professional Practice
First Reviewer	N/A
Team of reviewers	Jin Sol Kim Kem Lauren Lubin Jason Lajoie Jen Boger
Supervisor/Project PI	Heather Love
Co-Apps	Jen Boger, Jason Lajoie
Collaborators	Marcel O'Gorman, Neil Randall

1. Background to review Brief introduction to the subject of the review, including rationale for undertaking the review and overall aim
Workers at the forefront of technological innovation play a central role in shaping the future of our digital economy, and the COVID-19 pandemic has revealed with stark clarity the urgent need for ethical expertise to guide the development of technologies and its integration into society. The ability to engage in ethical thinking is becoming an increasingly crucial skill for workers in the tech sector who seek to mobilize technological innovation in response to global challenges. Propelled by calls for increased attention to ethics from within the tech-industry and a growing body of academic work on ethics and technological innovation, this Knowledge Synthesis project investigates the state of existing knowledge related to the question: How can we ensure that ethics and ethical thinking are integrated as core elements of training and professional practice within Canada's tech sector? This project has two central objectives: (1) to conduct a thorough review of existing literature from the past ten years to identify recent knowledge and gaps on effective approaches to embedding ethics in the tech industry; and (2) to disseminate these findings to multiple audiences from academia, industry, professional organizations, and the public through presentations, workshops, publications, and a Knowledge Synthesis report. Our methodology for achieving these objectives begins by reviewing and synthesizing published research studies about the status of ethics in engineering education curriculum, since engineering programs are key sites of influence for shaping the values and perspectives of the incoming generation of leaders within the "digital workforce." We will learn from what's been done around the world to complement Canada's ecosystem's needs. Then we can propose strategic interventions to increase the capacity for and valorization of ethical thinking within the tech sector, and identify gaps in our knowledge that future research can address. The project engages with the following themes: • Education and training: Skills, competencies and lifelong learning (how can we develop a skilled workforce able to respond and adapt to evolving labour demands?)

- Work and the worker: Innovation and engagement (how can we enable employees to find meaning in their work and drive ethical change in the tech sector?)
- Society: Changing social dynamics (how do we leverage technology towards more inclusive, accessible ends that provide security to vulnerable individuals and marginalized communities?)
- Governance: Regulation and ethics (how might we use policy to prioritize ethical thinking and consideration for social impacts in tech development?)

2. Specific Objectives
1. To identify teaching interventions in engineering instruction to embed critical thinking about tech ethics 2. To summarize these teaching interventions across the engineering education literature and discuss the gaps, challenges and opportunities for cultivating tech ethics.

3. a) Criteria for including studies in the review	
i. Population, or participants and conditions of interest	Postsecondary institutions, industry reskilling Engineering educators Engineering students
ii. Interventions or exposures	All education interventions and enhancements, including, but not limited to: 1. Lecture 2. Case study 3. Flipped classroom 4. Problem based learning
iii. Comparisons or control groups	N/A
iv. Outcomes of interest	Discussions of enhancement and interventions, and their efficacy/effectiveness at embedding ethics
v. Setting	Any postsecondary institution or workplace
vi. Study designs	Any study design, provided they describe specifics of intervention or teaching enhancement

3. b) Criteria for excluding studies not covered in inclusion criteria Any specific populations excluded, date range, language, whether abstracts or full text available, etc
1. Studies published prior to the year 2011 (years 2012-2021 included) 2. Studies that do not focus on tech ethics, tech literacy or tech innovation 3. Descriptions of existing ethics courses without assessment of their efficacy 4. Studies conducted in secondary education

5. Studies for which a full-text report is unavailable. We will exclude conference abstracts for which a full paper has not been published.

4. Search Methods	
Electronic databases Please list all databases that are to be searched and include the interface (eg NHS, EBSCO, etc) and date ranges searched for each	*See Appendix B*
Other methods used for identifying relevant research ie contacting experts and reference checking	We will check the references of high-impact included papers for additional papers not identified by the primary database searches.
Journals hand searched If any are to be hand searched, please list which journals and date searched from, including a rationale.	MIT Technology Review

5. Methods of review	
Details of methods Number of reviewers, how agreements to be reached and disagreements dealt with, etc.	Research question: **In the past ten years, what approaches have been implemented in the field of engineering training and education that explicitly aim to cultivate ethical understanding and practice?** Search terms (example for Scopus): (ethic*) AND (engineer*) AND (design OR pedagog* OR curricul* OR teach* OR accredit* OR educat* OR learn*) After searches are completed, duplicate results will be removed. Titles and abstracts will be reviewed in duplicate. Full-text articles will be retrieved for all citations deemed to merit consideration by at least one reviewer. Inclusion and exclusion criteria will be reviewed for each full-text article retrieved by two reviewers, with disagreements to be resolved by a third reviewer. Searches will be conducted Feb 9, 2021.
Quality assessment Tools or checklists used with references or URLs	N/A
Data extraction What information is to be collected on each included	For each study, we will extract: ○ Article ○ Author

study. If databases or forms on Word or Excel are used and how this is recorded and by how many reviewers	○ Year ○ article type (lit review, practice, essay, manifesto, commentary, report) ○ Geographic location of study ○ Institution ○ Primary engineering discipline involved ○ Additional engineering discipline(s) involved (if applicable) ○ Non-eng discipline(s) involved (if applicable) ○ Type of Intervention (course, workshop, pedagogy, etc)- single choice ○ Pedagogy design (lecture, case study, other- single choice) ○ Duration (<= 1 day, <=1 week, <=1 month, <=1 semester, <=1 year, single choice) Single event or recurring? (choice) ○ Target audience of educational intervention (Academia, Policy makers, industry) ○ Target Academic level (lower-year undergrad, upper-year undergrad, master's, PhD)- single choice, include "multiple" ○ Enrollment (# of students/ sample size) ○ Purpose (what were they seeking to achieve with intervention?) (measurement, proposal, etc) Outputs (curricula, teaching tool, etc) ○ Assessment (How did they measure the intervention? How are they measuring efficacy? survey, quantitative, qualitative, focus group, etc) ○ Main result (e.g. 70% of students reported knowing more about tech ethics at course completion) ○ Do authors consider this a success or failure? (single choice) ○ Barriers (e.g. lack of faculty buy-in, teacher skill, student interest, infrastructure, etc.) ○ Catalysts to success (e.g. faculty buy-in? student buy-in? infrastructure in place? etc.) ○ Engineering Definition (if present, write quote; if not, write "NO") ○ Ethics Definition (if present, write quote; if not, write "NO") ○ Synonymous or Alternative concepts/terms (implying "ethical thinking") ○ Theme Definition (if present, write quote; if not, write "NO") ○ Key Themes (sustainability, equity, diversity, etc) A piloted Google Sheets tool will be used to record extracted data. Extraction will be performed by a single reviewer.
Narrative synthesis Details of what and how synthesis will be done	Narrative analysis will describe the types of interventions, assess relationships between them, and develop a preliminary synthesis of findings of included studies.
Meta-analysis Details of what and how analysis and	N/A

testing will be done. If no meta-analysis is to be conducted, please give reason.	
Grading evidence System used, if any, such as GRADE	N/A

6. Presentation of Results	
Additional material Summary tables, flowcharts, etc, to be included in the final paper	
Outputs from review Papers and target journals, conference presentations, reports, etc	Upon completion of the review, we will submit a full manuscript for publication, and aim to present at several conferences.

7. Timeline for review – when do you aim to complete each stage of the review	
Protocol	February 2021
Literature searching	February 2021
Title and abstract screening	February 2021
Quality appraisal, Review of inclusion criteria	February 2021
Data extraction	February-March 2021
Synthesis	March-May 2021
Writing up	June 2021

Appendix B: Keyword Searches

ERIC

Search included title and abstract and keywords. The "peer reviewed only" option was not selected. Note that the ERIC database does not allow the use of wildcards. Also, “Pubyear” was included because ERIC's "last ten years" option starts at 2012 (excludes 2011)

Search term	Results
(ethic OR ethical) AND (engineer OR engineering) AND (design OR pedagogy OR pedagogical OR curriculum OR curricula OR curricular OR teach OR teacher OR teaching OR accredited OR accreditation OR education OR educate OR educator OR educational OR learn OR learner OR learning) AND pubyear:(2011 OR 2012 OR 2013 OR 2014 OR 2015 OR 2016 OR 2017 OR 2018 OR 2019 OR 2020 OR 2021)	253

CEEA published after Jan 1 2011

Search terms	Results
(ethic*) AND (engineer*) AND (design OR pedagog* OR curricul* OR teach* OR accredit* OR educat* OR learn*)	246

MDPI open access journals; 2011-2021

Search terms	Results
(ethic*) AND (engineer*) AND (design OR pedagog* OR curricul* OR teach* OR accredit* OR educat* OR learn*)	26

Scopus 2011-2021

Search terms	Results
(ethic*) AND (engineer*) AND (design OR pedagog* OR curricul* OR teach* OR accredit* OR educat* OR learn*)	3355

Web Of Science Core collection

Search terms	Results
(ethic*) AND (engineer*) AND (design OR pedagog* OR curricul* OR teach* OR accredit* OR educat* OR learn*)	1553

MIT Technology Review

Search terms	Results
(ethic*) AND (engineer*) AND (design OR pedagog* OR curricul* OR teach* OR accredit* OR educat* OR learn*)	34

Appendix C: Ranking Criteria

Ranking 1 (Specific, already-completed interventions that directly and primarily address the topic of tech-ethics in the engineering field)

- Discussion of a direct intervention in teaching/growing "tech ethics" to engineering--that is, making engineering students (postsecondary), faculty, and professionals aware of and/or able to engage with social, cultural, environmental implications of tech innovation, development, and/or deployment.
- Tech ethics must be the primary focus of the intervention, and engineering discipline (STEM broadly conceived is okay) must be the recipient.

Ranking 2 (Specific, already-completed interventions that include tech-ethics in their scope but not as a primary goal - i.e. tech-ethics outcomes are a side-benefit)

- Discussion of a direct intervention in teaching/growing ethics among engineering students (postsecondary), faculty, and professionals, but where issues of tech ethics are secondary E.g. “Cultivating ABET Criterion 3, which includes professionalism, communication, ethics” or “Growing sustainability/EDI thinking” and where ethical thinking specifically includes tech ethics described above; studies in this regard may intersect with sustainability and EDI issues--related terms: holistic engineering, Ethical Social Issues (ESI), global(ly engaged) engineering, micro/macro ethical concerns

Ranking 3 (Ideas about potential/planned future interventions that will cultivate tech-ethics but have not yet been implemented)

- Proposal (e.g. guidelines, framework, manifesto) for an intervention in tech ethics training for engineering students (postsecondary) and professionals, either pedagogical or conceptual (e.g. tech ethos for engineering profession), but either not applied or article does not describe its application

Ranking 4 (Theoretical papers that address the theme of tech-ethics and or the problems associated with a lack of tech-ethics expertise/awareness - things that set out the context for this project that we will want to talk about in the report Intro/Conclusion)

- Theoretical interventions in/discussions of tech ethics training--e.g. “a survey was conducted and here are some implications/considerations for cultivating tech ethics in the future” or “these tools/discussions/ideas/results/theories may be useful to future intervention for tech ethics” but no clear application
- Note: these sources will likely be useful for the KSR introduction/discussion

Appendix D: Interview Protocol

Preamble:

(to be read by interviewer to interviewee at the start)

"As a reminder, the purpose of this project is to better understand current knowledge about how we can ensure that ethics and ethical thinking can be are integrated as core elements of training and professional practice within Canada's tech sector. As part of this project we are conducting one-on-one interviews with expert professionals in academia, government or industry involved in cultivating ethics about the social, cultural and environmental implications of tech innovation and to gather grey literature about this topic. If there are any questions you do not feel comfortable answering, simply ask me to move on, and you are free to stop the interview at any time. And lastly, I will be recording this interview for transcription purposes."

Questions:

Intro/Icebreaker question:

- Tell me a bit about yourself, what's your background and how did you become interested in the areas of technology and ethics?

Topic: Overview of the field

- What do you think of when you hear words like "tech ethics" or "responsible innovation"?
- How do these ideas apply to your domain?
    - What do you think are some of the most significant ethical concerns related to tech innovation in your field?
    - What role should engineers play in addressing the various impacts of a new technology or innovation?
- In the work that you have done to increase ethical thinking about the impacts of tech innovation, what have been your most successful and your most challenging experiences?
    - What were the reasons for this success?
    - What barriers/obstacles created the challenges?
- What can you tell me about the state of ethical training in your field? How does this relate to your own training?

Topic: Interventions

- What shifts, developments, or notable interventions have you seen in [your domain, e.g. the Faculty of Engineering; tech sector workplace training] over the last 10 years to increase awareness about the ethical implications of technology? And more recently?
    - What makes those examples the most exciting/promising?
    - What are some factors that have contributed to their success?
    - What obstacles or challenges have come up with implementation/roll-out of these ideas?
    - Have specific attempts to implement ethics training in the field of engineering at your university failed? Why do you think they failed?
- What do you see as the greatest barriers to embedding critical thinking about the implications of technology in engineering?
- At what levels of your organization [e.g. university/institution/company/etc.] do you most see an effort to increase ethics training and awareness in engineering?
- Optional question (if interdisciplinarity doesn't come up - or to integrate if/when they bring up interdisciplinarity): What are some existing ways non-STEM disciplines are involved with ethics training in engineering?

Topic: Next steps

- Here is our "big picture vision" question: It's ten years in the future, and [name of their institution] is the premiere institution for tech ethics in Canada. What does this look like?
  - What are the key/distinguishing features of the program?
  - What kinds of infrastructure and networks are in place?
  - What approaches to learning are prioritized?
- What had to happen to get you there?
  - What can be done right now to better prepare engineering students, faculty and professionals to understand the impacts of the technologies they use, design and deploy?
  - How could other disciplines or sectors (academic, industry, government) contribute to these developments?

Topic: "Grey Literature" Suggestions

- The other main part of this knowledge synthesis project is a scoping review of published academic literature. Do you have suggestions for non-academic or unpublished resources we should check out?
  - Projects that cultivate tech ethics
  - Resources you rely on to learn about these kinds of interventions
  - Notable reports or you've come across

Concluding Questions:

- Are there any questions you wish I had asked that you would like to discuss?
- Do you have any questions for me?

"Thank you very much for your time and for your responses."

Appendix E: Interview Thematic Coding Overview

Last updated July 14, 2021

1. Terminology
2. What's happening in pedagogy?
    a. Why is ethics currently being instructed?
        i. Accreditation
        ii. University mandate
        iii. Social change
        iv. Equity (participant 10)
        v. Etc.
    b. How is ethics currently being instructed?
        i. Types of content/ area of ethics?
        ii. Pedagogical methods (and, if possible, what's effective/ineffective?)
    c. How has ethics interventions changed in the last 10 years?
    d. How are interventions initiated?
        i. passion projects
        ii. Funding
        iii. Etc.
    e. How is training/ efficacy of programs assessed?
    f. What are student responses to/interest in these types of topics
3. What are barriers to pedagogical changes, and reasons for them?
    a. student response
    b. faculty buy-in
    c. Difficulties in communication (inter/multi/transdisciplinary collaboration)
    d. Engineering requirements/ program overload
    e. Issues in pedagogical methods
    f. Etc.
4. What are the forms of external pressure? who are the main stakeholders and how do these actors think about these issues? and how do they influence intervention?
    a. academia: student, faculty, admin levels
    b. private sector, industry
    c. government
    d. Public
5. Importance of inter/multi/transdisciplinarity, approaches to…
    a. Breaking down silos
    b. Cultivating buy-in

Appendix F: Strategies for overcoming barriers to scaling ethical training

Student

- Encouraging student buy-in
- Aligning interventions with student's engineering identity

Faculty

- Encouraging faculty and upper admin buy-in
- Resolving incompatible approaches in teaching and assessment
- Avoiding overconfidence about scaling buy-in, and the speed at which buy-in will scale
- Overcoming political polarization (personal and political differences/disagreements among cohorts and within institutions)
- Resolving interdisciplinary "turf wars"
- Preventing and/or mitigating burnout

Curricular

- Solving implementation challenges
- Overcoming the "research/practice gap"
- Determining what specifically needs to be added to the curricula, and how to even do that
- Working within overpacked curricula
- Resolving issues in pedagogical methods and measurability (what works, what doesn't work, how do you know, who's to say, and who's asking for this pedagogy?)
- Devising clear, specific, and compatible measures of success, which will vary based on institution

Institutional

- Developing accreditation criteria that require academic programs to move beyond a "check-box" mentality to engaging with ethical thinking
- Accepting "belated gratification" (Eggermont); recognize that change is slow, takes time, can be hard to track
- Overcoming the need (perceived or real) to scale quickly, and to maximize Return on Investment quickly
- Determining what is feasible for a program to achieve and how soon
- Navigating entrenched systems, getting people and systems/institutions to change
- Overcoming perverse (dis)incentive structures
- Developing funding models that reward/recognize ethical training
- Countering norms and accepted practices within the "corporatized" university system
- Understanding the scope of the problems and the actors involved
- Avoiding too many cooks, and taking too much time
- Resolving academic Silo-ing—dealing with perception that ethics occurs in Philosophy and Humanities

Professional

- Recognizing the ways ethical debates fall within one's professional obligations
- Determining what is feasible for an engineer to master
- Resolving contradictory demands within an engineer's professional context and balancing all these competing "factors" (Wells)
- Working within the way industry (or at least the perception of what industry wants) functions as a selective pressure on pedagogy, curricula and focus

Appendix G: Evidence Brief

The following Evidence Brief was prepared to accompany this Knowledge Synthesis Report.

About the Project

Despite the increasing attention paid to the impact of technological innovation and the role played by engineers, there remains an inadequate understanding about what is being done to address these implications. Part of the reason for this, in North America at least, is the limited impetus from engineering departments to engage in, let alone document, ethical teaching interventions. This neglect is matched by a general perception in engineering that ethical implications are either tangential or outside its scope. This lack of knowledge poses significant challenges for the entire engineering profession, particularly since it makes it difficult for educators to effectively deliver and assess ethical training. To better understand the scope of ethical training and education in engineering, and how to embed these interventions, we convened an interdisciplinary group of scholars to achieve the following three specific objectives:

1. Conduct a scoping review of existing literature from the past ten years to identify recent knowledge and gaps on effective approaches to embedding ethics in the tech industry;
2. Conduct semi-structured interviews with key industry leaders and experts about the need for ethics training in engineering; and
3. Disseminate these findings to multiple audiences from academia, industry, professional organizations, and the public.

Key Findings

Literature Review Overview:

- Our literature review of 337 sources revealed that direct interventions have occurred in over 40 countries, and at least 16 articles describe interventions involving multi-national collaborations.
- While the trend in publication numbers appears somewhat flat over the first 8 years of study, a marked increase appears in the two most recent years, with almost 60% more publications in 2020 compared to 2018.
- Most published interventions focused exclusively on academia (87%). Of these, 85% focus on students, with 82% of student-focused interventions targeting undergraduates.

Combined Analysis: Literature + Expert Interviews:

- This project analyzed the literature alongside data from 10 expert interviews (representing both Canadian and international perspectives).
- We first provide an overview of key *barriers* preventing uptake in tech-ethics training, covering both the "intangible" contexts of engineering *identity* and the *terminology* we use to discuss engineering ethics, and the more "concrete" issues related to engineering education *institutions* and their surrounding *infrastructure*.
- We then outline a suite of *priority areas* that can be mobilized to *cultivate buy-in and alignment* from across the diverse stakeholders that comprise the engineering community.

Identity & Terminology:

- A narrow definition of "engineering" presents one of the primary impediments to cultivating buy-in for ethical training in engineering.
- A lack of consistent terminology and definitions about the role of ethical thinking in engineering prevents us from achieving widespread consensus about how these ideas align with engineers' core work and values.

Institutions & Infrastructure:

- Accreditation bodies, professional organizations, and industry are all powerful forces of influence on the ways in which ethics instruction *can* be integrated into engineering programs and *is perceived* as a priority within those systems.

- Current institutional pressures related to funding (for research and for programs), faculty promotion requirements, and timeline expectations often *impede* or *disincentivize* efforts to develop robust ethics-focused curriculum initiatives within engineering programs.

Priority Areas for Cultivating Buy-In & Alignment:

- Engineering should embrace the current reality that technological work benefits from (and often *requires*) input and expertise from a range of disciplinarity perspectives.
- To produce large-scale, meaningful, lasting change in the engineering profession that centres the values associated with ethical thinking and responsible innovation, we need to undertake multiple, simultaneous initiatives across academia, industry, and even government.
- Ethics education research in engineering needs to develop more robust assessment methods for evaluating the efficacy of current and new pedagogical interventions.

Policy Implications

- Governing bodies, professional engineering organizations, industry practitioners, and academic institutions should collaborate on new standards and guidelines that prioritize the ethical dimensions and societal/environmental impacts of technology; the resulting legislation will then align with broader cross-sector initiatives to promote a cohesive approach to responsible innovation practices.
- Academia and government alike should develop funding opportunities that specifically promote the development of interdisciplinary ethics training; these types of funding should target both academic research and broader industry/community initiatives to help foster collaborations that can resolve the current research/practice gap.
- Academic institutions should prioritize creating research and teaching opportunities for faculty to engage with projects related to tech ethics in ways that are rewarded equally to technical work; these initiatives should support the development of robust criteria for teaching, training, and assessing engineering programs' graduate attributes/student outcomes related to ethical awareness.

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Read full report:

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