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Learning to Reframe Problems Through Moral Sensitivity and Critical Thinking in Environmental Ethics for Engineers

Andrea R. Gammon[1] and Lavinia Marin[2]
TU Delft

ABSTRACT: As attention to the pervasiveness and severity of environmental challenges grows, technical universities are responding to the need to include environmental topics in engineering curricula and to equip engineering students, without training in ethics, to understand and respond to the complex social and normative demands of these issues. But as compared to other areas of engineering ethics education, environmental ethics has received very little attention. This article aims to address this lack and raises the question: How should we teach environmental ethics to engineering students? We argue that one key aspect such teaching should address is the tendency of engineers towards technical framing of (social) problems. Drawing then on engineering ethics pedagogy we propose that the competencies of moral sensitivity and critical thinking can be developed to help engineering students with problem (re)framing. We conclude with an example from our teaching that operationalizes these competencies.

KEYWORDS: Moral sensitivity; engineering ethics education; environmental ethics education; problem framing; critical thinking

Introduction[3]

AS ATTENTION TO THE PERVASIVENESS AND SEVERITY OF ENVIRONMENTAL CHALLENGES grows, technical universities are responding to the need to include environmental topics in engineering curricula (Byrne et al. 2010) and to equip engineering students, without training in ethics, to understand and respond to the complex social and normative demands of these issues (Kirkman 2020). But as compared to other areas of engineering ethics education, environmental ethics has received very little attention. This article aims to address this lack and raises the question: How should we teach environmental ethics to engineering students? To answer this, we work from the awareness that environmental problems—like responding to climate change—will require societal transitions "unprecedented in terms of scale" (IPCC 2018: 17). We argue that engineering students are and will be uniquely positioned—as builders and rebuilders of our physical, social, and ecological worlds—to contribute to these transitions.

However, their education does not equip them to think about this influence and the ethical, environmental, and social dimensions of their work, its impacts, and their corresponding responsibilities. In their training, engineers hone a technical mindset where problems are often presented as idealized, apolitical, and free of social dimensions, history, and context. Such technical framings of problems are inadequate to understanding environmental issues rife with political impacts, that have important implications for justice, and that concern a range of present and future stakeholders, both human and nonhuman. We focus on this issue of technical problem framing as specific aspect that environmental ethics education should address and draw on arguments made by environmental ethicists and others to substantiate why these problems cannot be understood only as technical problems, hence *solvable* by technical solutions.

To make possible a disposition towards problem re-framing, we then propose two distinctive competencies that need to be cultivated in the environmental ethics classroom for engineers: moral sensitivity and critical thinking. Our contribution lies not only in identifying two key competencies that lead to problem re-framing, but in explaining how these competencies should be cultivated and operationalized in the classroom. In the final section, we present an example from our teaching that draws on these competencies to help students examine possible problem framings of socio-technical-ecological problems.

Environmental Ethics for Engineers?

Meso-level Influence of Engineers

As climate change[4] increases in urgency and severity, and with little resolution in sight, it's now common for people in the West, including our students in the Netherlands, to wonder and often fret over what they can, or should, do to respond to such a crisis. Should they go vegan and refuse the use of single-use plastics? Stop flying? Offset flights? Replace fossil-based cars with electric vehicles? Do these actions add up to anything? Or should we as individuals even feel responsible for this problem when we know that only a small number of companies accounts for the majority of emissions?[5]

Much environmental literature, in environmental ethics but also more popularly, is oriented around these kinds of questions, and tends to be focused on the level of the individual.[6] While this level—as the immediate realm of daily life, behavior—is easy to conceptualize and take responsibility for, there are important challenges to this level of analysis: individual actions are not likely to be sufficient on their own to address the scale of environmental problems we face in the twenty-first century.[7] On the other hand, the macro-level—where global populations, policies, trade, supply chains, and waste flows are concerned—is not a level many people, especially engineering students, feel empowered to affect. While decisive changes might be made at this level in the way of environmental protections and climate action, change is gradual if it happens at all, and in the case of climate change, if there's any movement, it's at a pace that's dangerously slow.[8]

Especially in the context of engineering education, however, we suggest that neither of these levels is ideal, as neither level engages the capacities or positionality unique to engineers. Engineers, through their professional role, will ultimately occupy a different position, what we consider a *meso-level*, where they can build and rebuild the physical and social systems that comprise our world. Engineers, in the eyes of Langdon Winner, are "the unacknowledged legislators of our technological age" (1990: 59). He writes: "They are intimately involved in maintaining key social patterns and in inventing new ones as well," and as such, are "charged with the work of building basic structures of our social and political future" (ibid.). The position of engineers involves, crucially, the designing, construction, and maintenance of the world around us. Engineers possess unique access to the infrastructures, buildings, networks, and systems that order our world, that use and supply energy, that constrain or connect, that close a loop or create waste, that pollute, that provide. Engineers influence how these systems are made, which stakeholders are considered, what values are prioritized, what legacy we as societies will leave. To prevent the worst impacts of climate change, engineers have a critical role to play, given the radical and widespread transitions called for "in energy, land, urban and infrastructure (including transport and buildings), and industrial systems" (IPCC 2018, 17). These systems impact the lives of populations now and in the future, as much of what is designed and built now will outlive us and will be inherited by those after us. This is to say that the meso-level connects the actions of individuals to the larger physical systems we find ourselves part of, but it also connects the lives of those in the present with those in the future.

While engineers may be aware that the structures and systems that they help design and build have an influence on how we live our lives and, hence, on what environmental values get expressed, they are somewhat wary about taking this as entailing moral responsibilities. In shying away from the moral dimension of their influence, engineers often invoke the argument that they are merely solving technical problems. We identify thus the technical mindset as a specific difficulty in dealing with environmental issues as ethical issues in a pedagogical setting.

Technical Attitude to Problems

In their training, engineering students hone a prevailingly technical mindset. Engineers are routinely asked to scale back, or abstract away the non-technical aspects of problems so they can get to work on the "real" problem, which is decontextualized, apolitical, ethically neutral. For many engineers, this is not a liability, this is the point. Vesilind and Gunn, in one of the few textbooks for engineers about environmental ethics, recognize that this is how engineers often see themselves, and indeed what they enjoy about their work. For many engineers ". . . the freedom to concentrate on their job, unfettered by monetary and social concerns" (1998: 27) is what draws them to the profession. The common perception is that "Engineers do not make the decision to build a dam . . . but are simply asked to design and construct it" (ibid.) Engineers are thus "freed" from having to think about all of the messy problems they've bracketed off—the political, social, ethical issues that form the context of the dam—and can "perform the technical task for which they were trained and which they find most pleasurable" (1998: 28). This is an ideology of depolitization, as Erin Cech argues, which engrains in students (and later, engineering professionals) an understanding that "engineering work, by definition, should disconnect itself from social and cultural realms" (2013: 71). Any considerations involving issues of social justice, inequality, and power are excluded from, and viewed as "culturally irrelevant to engineering practice" (2013: 68).

Others have observed this technical/social problem distinction operating in engineering. Based on his ethnographic work studying engineering practice, Bucciarelli observes that engineers are "trained not to see" (107), that is, they're trained to home in on a problem by abstracting away all of the seemingly superfluous information. He writes that to be successful, the engineering student

> must learn to perceive the world of mechanisms and machinery as embodying mathematical and physical principle alone, *must in effect learn to not see what is there but irrelevant.* (1994: 147 emphasis added)

Part of the training is this bracketing off of the non-mechanical and non-mathematic—the irrelevant—so that the technical aspects alone are the focus. Sarah Kuhn's work (1998) notes that when engineering students do recognize these socially-oriented aspects, they see them as additional to, or in conflict with the core aims of engineering. Wendy Faulkner has argued that this separation constitutes a technical/social dualism: the engineer is trained that the technical explicitly excludes the social, but that moreover, a hierarchy emerges where the technical—the abstract, mathematical, mechanical—is prioritized and the social is neglected. This of course raises immediate problems, as "in practice, most engineers know well—engineering practice is heterogenous. If artefacts are to 'work' and meet a 'real' need, engineering practice has to integrate technical and non-technical elements" (2000: 763).

From the side of environmental ethics, there are other reasons to worry about this technical/social dualism. First, we can think of the critiques that environmental philosophers and others have made of the idea of the technological fix, or technofix. This idea was originally coined—and promoted—by Alvin

Weinberg, who saw technology and 'big science' as offering up the answers to intractable social issues:

> Social problems are much more complex than are technological problems, and much harder to identify. . . . How do we know when our cities are renewed, or our air clean enough, or our transportation convenient enough? By contrast the availability of a crisp and beautiful technological solution often helps focus on the problem to which the new technology is the solution. (1966: 4)

But soon thereafter, Weinberg's idea was critiqued by environmental thinkers (among others) viewing technological fixes as wanting solutions for social and especially environmental problems. Max Oeschlanger argued that the technofix idea rests on a series of mistaken assumptions about human behavior, the neutrality of technology, and the reducibility of complex social problems to simpler, technical ones that "can be worked out in the relative calm and quiet of the laboratory" (1979: 46). To Eric Katz, technological fixes are irredeemably hubristic: the "presumption that we are capable of this technological fix demonstrates (once again) the arrogance with which humanity surveys the natural world. Whatever the problem may be, there will be a technological, mechanical, or scientific solution" (1991: 91–92).

We take the most significant and relevant critique of the technological fix made by environmental thinkers to be the argument that a technological fix, as such, fails to address the underlying issues driving the problem's creation, and so ultimately will fail as a solution. The way problems are framed, or reframed is important here: it's worth noticing that even in Weinberg's introduction of the term, invoking the possibility of a technological fix already requires reframing the problem, and that this often happens neatly around the proffered technology. This form of the technofix critique is often made against the suggestion of climate engineering, or geoengineering, as a way of managing climate change.[9] Strategies that fail to address the underlying issue of greenhouse gas concentrations, or perhaps more fundamentally, societies producing too much carbon dioxide, are not true solutions, and they misrepresent the problem. Corner and Pidgeon write: "For groups and individuals who see climate change as a symptom of a social and economic order that is inherently unsustainable, geoengineering represents the worst kind of 'techno-fix'" (2010: 31).

However, even without entertaining thoughts of climate engineering, climate change risks being framed technically, in terms of "global mean surface temperatures," carbon budgets, or greenhouse gas reduction targets.[10] But these framings obscure both the social and economic arrangements that have led to climate change, as well as the particular, localized impacts climate change brings. These factors are crucial to a complete understanding of the problem of climate change, and should inform all efforts to address it. Climate change is a paradigmatic example of structural injustice, where those who have created and contribute to the problem to the greatest degree are the last to be affected by it. Szerszynski writes: "it is the dominant technological framing of climate change that ultimately constitutes a more radical evasion of responsibility" (2010: 22). Any problem framing that abstracts away these social contexts and histories is in no position to address them, and is probably more likely to be perpetuating them, whether we realize it or not.

Our final remark on the limitations of the technical/social problem framing is to suggest that engineers' tendency towards technical framings of problems *obscures from themselves their own position of influence*—the meso-level, world-building potential they can command. We observe that our students struggle to realize or take up the responsibility for this privileged position: when they reason about environmental problems as engineers, they're prone to technical framings of social problems (e.g., conceptualizing climate change primarily in terms of technologies to reduce or monitor emissions, or to remove carbon).[11] This enables them to forget, or fail to attend to, the normative issues, which they feel are not called to address as engineers. And when they are reminded of these issues, they drop the engineering mindset and revert to thinking of what they should do at the individual level (e.g., consumption-based pro-environmental behaviors). This either/or situation strikes us as the particular difficulty of teaching environmental ethics to engineers. We suggest that a key part of what we should do in teaching engineers environmental ethics is to help them learn to reframe problems with the social and political conditions, historical contexts, and normative and ethical considerations in mind. A systematic way of approaching this challenge is to look to the existing competencies for engineering ethics education for those that would train students to recognize and reason about the normative as well as technical dimensions of the problems they face. In the following sections, we put forward moral sensitivity and critical thinking as the primary competencies needed for this, and argue that by developing these in engineering students, environmental ethics education can help better attune engineers to the multidimensionality of environmental problems.

Engineering Ethics competencies—Moral Sensitivity and Critical Thinking

In engineering ethics education, moral sensitivity is a core competency, usually defined as "the ability to recognize social and ethical issues in engineering" (van de Poel and Royakkers 2011). However, we contend that recognition alone might not be enough for the purposes of ethics education because students may be content with the first solution, or framing, that they find and stop searching further. This might be because students have trouble imagining alternatives, that they assume their worldview or perspective to be universal or standard, or that simply they often have these social and ethical issues identified for them already in ethics teaching, and rarely practice identifying alternatives or thinking beyond those already scoped out by a teacher or a case study.

In the following section, we consider a more expansive conception of moral sensitivity in professional contexts, which, when paired with critical thinking, gives rise to a new way of seeing a problem, hence of overcoming the problem of framing as a limiting rationality. Moral sensitivity and critical thinking are two ways of being sensitive to the salient features of the problem at hand, entailing a sensitivity for both the normative dimensions as for the epistemic context in which the problem is stated. We think that, when taken together, these two competencies have the potential to foster a new way of seeing problems that, uncoupled from the limiting assumptions given in the problem framing, can yield interesting and morally relevant solutions.

Moral Sensitivity, Engineering, and Vulnerable Others

A key definition of moral sensitivity in professional contexts comes from Weaver, Morse, and Mitcham (2008): moral sensitivity is “that which enables professionals to recognize, interpret and respond appropriately to the concerns of those receiving professional services” (2008: 607). This definition is based on their review of the use of the term[12] in professional ethics literature. They elaborate that moral sensitivity has three key attributes: (1) **moral perception**, which is an alertness or receptivity to the needs of clients, (or, we might add, to the ethical dimensions of the broader situation); (2) **affectivity**, or responsiveness to the Other in a moral situation, and according to Weaver et al., takes the form of a “spontaneous, embodied” (609) relational reaction to the Other and their situation; and (3) **dividing loyalties**, which requires an appropriate response through interpretation, justification, and reflexivity to the moral considerations that arise once an ethical issue has been recognized. On their conception, moral sensitivity involves the moving back and forth between the aspects of moral perception, affectivity, and dividing loyalties to overcome the respective limitations of each aspect.

We see moral sensitivity, then, as a competency engineers will need to cultivate to be able to recognize technical problems as having integral social and ethical dimensions, and respond appropriately to these. However, we’d like to respond to a general point about the relevance of this conception of moral sensitivity for engineers, before combining moral sensitivity with critical thinking. The first is a point made by van Grunsven et al. in a forthcoming chapter “Caring from a distance: Moral sensitivity, universalized care, and engineering ethics education” (2021). They argue that the working contexts of engineers are fundamentally different from the professional contexts on which work on moral sensitivity had been developed, namely from the profession of nursing (Weaver et al. 2008; and Weaver and Mitcham 2016), where moral sensitivity takes the form of close attention and responsiveness to the individualized patient-Other. Engineers, van Grunsven et al. point out, have no such *individualized* Other around which a capacity for moral sensitivity can—or should—be focused. Rather, they argue that Weaver and Mitcham, in attempting to extend moral sensitivity as developed in a nursing context to an engineering context, have missed an important distinction in the context of care and moral sensitivity for engineers. Engineers, by virtue of their profession, must administer to a *generalized* Other. Unlike nurses, engineers are not attentive to specific patients who they meet face to face and whose needs and situations they must respond to individually; this is not the kind of care we expect engineers to provide. Instead, engineering contexts requires a different *kind* of moral sensitivity, one that recognizes the position of engineers as distant from those they care for through their professional role, as a matter of definition.

We are in agreement with van Grunsven et al. on this point, as well as their suggestion of a substantive view of moral sensitivity for engineers. They argue that *universalized care*, "performed by maintaining, preserving, and rehabilitating physical structures, is care for the engineer's Other in her universally shared standing as a vulnerable technology-dependent being" (sec. 4, p. 17). This is what is required by engineers. Cultivating an attitude of care towards the generalized Other requires broadening the scope beyond technical framings. Specifically, understanding the role of engineering as caring for people though the maintenance, preservation, and rehabilitation of the shared world, aligns with the important meso-level of influence engineers have the potential to affect. Universalized care thus rejects what we have been problematizing so far: a technocratic view of the engineer only attending to, and responsible for, technical problems where social and ethical issues are bracketed off and abstracted away.

However, as we think about moral sensitivity in the context of climate change, we would like to go beyond van Grunsven et al.'s suggestion of universalized care to further specify this in reponse to the morally relevant aspects of climate change. In the next section we put forward one main aspect of climate change that should inform how engineers are asked to conceptualize and frame problems related to climate change. These specifications build on van Grunsven et al.'s concept of a generalized other, but with climate change, this generalized other is also distant in time.

Future Generations, Climate Change, and Moral Sensitivity

One of the dimensions that makes climate change such a complex and challenging problem is its intergenerational dimension. This is largely due to the fact that greenhouse gases remain in and act on the atmosphere for long periods—generations—after they are emitted.[13] Climate change is a "*substantially deferred phenomenon,*" explains Stephen Gardiner (2006: 403, original emphasis): "The climate change that the earth is currently experiencing is primarily the result of emissions from some time in the past, rather than current emissions" (ibid.). According to Gardiner, this temporal dispersion between cause and effects is one of the factors that makes climate change "a perfect moral storm." Just as generations alive today live in a climate made by the emissions of past generations, and a world built by fossil fuels, future generations will inherit our action (or inaction) on climate change and live the climate and the world we've made.[14] Generations following us are connected to us through time: they have no choice but to receive our carbon legacy and the technical, political, and social possibilities we cultivated or stunted. That they remain to us anonymous and generalized does not negate the obligation we have towards them. John Nolt explains: "We cannot know future people as individuals, but that is what they are. . . . And just so, our predecessors could not know us as individuals, although that is what we are" (2017: 345). Nevertheless, we still have ethical obligations to take future people seriously (Nolt 2017; Caney 2018.) That engineers contribute in very direct ways to the lives and livelihoods future generations will have is a strong reason engineers should imagine these future generalized others in their present-day work.

Our suggestion here is that climate change involves a specific kind of moral sensitivity, namely a sensitivity to others distant in time. The climate ethics literature supplies the reasons that we should take responsibility for these distant others.[15] What this looks like for engineers relates to the meso-level of influence we've discussed previously: engineers have a crucial and impactful role to play building new or transforming old infrastructures, systems, and environments that lead us out of the current fossil era. This entails learning to pose questions about power structures and arrangements, of who has the power to change and who bears responsibility, of how historic inequalities persist through built systems and what just infrastructure might look like. Given that social critique—as a discipline—has relied on the disclosure of power relations as a systematic approach (McGuirk 2021), we think that the methods of social critique would help students have a more systematic way of approaching the normative aspects of environmental problems. One such method employed in social critique is critical thinking as a skill systematically deployed to deal with complex, intractable, or wicked problems.

Critical Thinking and Epistemic Context-sensitivity

Critical thinking is an overarching goal of university education, fostered in various courses through various methods. Critical thinking (CT) has received many definitions throughout its history and while there is no single overarching perspective on how CT should be defined, there are points of convergence among the multiple definitions (Hitchcock 2018). CT is usually seen as a process, a particular way of engaging in thinking, namely in a "careful and deliberate" (ibid.) manner with the ultimate goal to arrive at a decision about what to believe or do. CT has been discussed increasingly as an educational goal for higher education starting with the early twentieth century, and one can identify two phases in the historical development of this concept. In the beginning, CT was seen mostly as appraisal of information or of other's conclusions and hence was focused on logical evaluation of arguments and on assessing evidence.[16] This phase has been surpassed and critiqued by several authors who stressed that critical thinking is a constructive process that arrives at new conclusions by means other than simply logical deduction, inference or induction; these means include creative thinking, intuition, and sensitivity to context.[17] We side with this latter view which sees CT as a well-rounded process of thinking involving more than learning logical reasoning and avoiding fallacies.

While CT is a stated goal for most higher education programs, it has different flavors according to the disciplines in which it is taught. In the engineering education, CT is usually understood as a range of reasoning skills such as "considering and articulating assumptions in problem solving; selecting appropriate hypotheses/methods for experiments; considering multiple perspectives in an ethics case study; assessing social impacts of technology; and structuring open-ended design problems" (Claris and Riley 2012: 102). These skills are taught across the curriculum, in most of the engineering courses, and so they appear as part and parcel of the technical knowledge (since most courses that engineers take are technical). Meanwhile, a more humanities inspired understanding of CT entails learning to question the very discipline in which students are initiated, by learning to think about and question "problem framing, power relations within the profession, hegemonic epistemologies of the discipline, or reproductive practices of engineering education" (ibid.). This approach to CT as a disposition to question dominant epistemologies of the engineering profession is not typically done in technical courses.[18] It remains a challenge in the ethics and science and technology studies courses that students take to instill these kinds of critical dispositions as well.

In environmental ethics for engineers, this approach of instilling CT alongside the other ethical competencies would entail that our students should get used to actively questioning the terms in which the problem is phrased, the values underlying these terms, and the realm that the problem is confined to, through exercises and class activities. In other words, that CT is taught as a disposition for context sensitivity in an epistemic sense. What does it mean concretely for CT? Context sensitivity was introduced by Matthew Lipman in his influential discussion of CT, and it was carried forth into successive definitions of CT. Lipman defined CT as being "skillful, responsible thinking that facilitates good judgment because it 1) relies upon criteria, 2) is self-correcting, and 3) is sensitive to context" (1987: 39). Lipman understood context sensitivity as an appropriateness of the judgement to the context of application: "The context determines the relevance of plausibility of the criteria employed, and furnishes particular circumstances that may require specific alterations of the criteria when applied to the case at hand" (Weinstein 1991: 17). Briefly put, it is not an exercise of CT to apply the apparatus of legal reasoning when analyzing the wording of a literature text—although it can be an imaginative exercise to do it, it is in no way critical of the author's words. If we employ criteria for judging information that are not appropriate to the time, space, and culture when the piece was written, we are not doing justice to the intended meaning and we are failing to pay attention to context or willfully ignoring it.

Context-sensitivity in CT means having some knowledge about the domain of application and its concepts (Hitchcock 2018). For this reason, it is primarily a form of epistemic sensitivity: this includes understanding what concepts fit which problems and also an understanding of the mode of reasoning demanded by the particular kind of knowledge. How CT will look will vary according to domain. A critical thinker in legal domain will know how to look at evidence, how to discard formal procedural arguments in favour of substantive ones, and will, through thinking critically, be able to get to the root of the issue at stake. A critical thinker in environmental issues will know how to evaluate evidence about climate impacts, will not be fooled by greenwashing, will compare effects in terms of scales and long-term vs. short-term effects of climate mitigation actions. This is to say that, while CT relies on some general epistemic virtues, the ways in which it is exercised in a specific domain need some solid knowledge as background and some practice in that domain. A form of context-less, generic CT is hard to imagine because CT always serves as a means to achieve some domain-related values: CT for citizenship, CT for sustainability, CT for epistemic goods (elucidation, consensus). As Hitchcock put it, "Critical thinking abilities are not a magic elixir that can be applied to any issue whatever by somebody who has no knowledge of the facts relevant to exploring that issue" (Hitchcock 2018).

For critical thinking as applied to environmental ethics, this means that the students need first some knowledge of the environmental debates (epistemic context) and of the social debates around climate (social and normative context) before they can attempt any kind of critical intervention in this debate. Knowledge here refers to knowledge of the topic at hand, its history, and the terms used and existing debates. But having this knowledge alone will not be enough to tackle the ethical problems at stake, it is merely a precondition for engaging critically with the topic. Therefore, as discussed previously, we also propose emphasizing moral sensitivity in the mix of competencies.

Our model is not merely summative: we are not only saying that engineering students need critical thinking and moral sensitivity. Rather, we contend that these two competencies complete one another in ways that enable students to re-frame the problem(s) at stake and provide some novel solutions while, at the same time, to assume the perspective of the engineering profession. Concretely, our model construes problem re-framing as a goal for engineering ethics education in environmental issues. To reframe a problem, one needs two intertwined competencies: CT, which allows for a deep knowledge of the epistemic domain and comes with a critical attitude about reconsidering the argumentative steps or even the terms in which the problem is posed; and moral sensitivity which makes students attentive and careful about the normative context in which the problem unfolds (which, as we stressed in the beginning, cannot be eluded in the case of environmental issues—there is always a normative component at stake). We can see, then, that domain-contextual critical thinking will then require moral sensitivity to get off the ground, and that critical thinking can move students into the realm of ethical reflection and reasoning.

One might object that these two competencies should be cultivated anyway in an ethics classroom for engineers—or for any other professional ethics classroom for that matter. While generally speaking we don't disagree, we think that the challenge of teaching lies in precisely the ways in which these competencies are instilled. With engineering ethics, the challenge lies in learning to frame, or re-frame environmental problems in ways responsive to their ethical and social dimensions, not see these as merely technical problems. When these kinds of problems are recognized as engineering problems, students will be better positioned to realize the influence they have as engineers and then, we hope, be ready to take on the responsibility for solving such problems.[19]

In order for students to remain attuned to the normative challenges of the situation—to stay in the engineering responsibility mindset—they need to be able to engage at the same time in critical thinking, moral sensitivity and ethical reflection. This is the pedagogical challenge. In the next section we will provide an example of how this could be pursued in a concrete classroom situation.

Operationalising CT and Moral Sensitivity in the Classroom

To develop any kind of sensitivity, one needs to practice it repeatedly by being exposed to situations calling for it. In a pedagogical context, this means that one cannot learn moral sensitivity by merely reading about it, one needs to experience it, such as through debates with colleagues, bringing in external stakeholders, going out into the world and seeing the effects of one's imagined innovation, any other ways in which one's own worldview is dislocated by a confrontation with other points of view. To understand how our proposal might fare in an environmental ethics classroom, we propose the following exercise which is adapted from our own pedagogical practice (the modified exercise was used in the course Environmental Ethics, TU Delft).

We introduce a case-based problem concerning low traffic neighbourhoods (LTNs) to our students:

> *Low-traffic neighborhoods are a somewhat recent experimental approach some neighborhoods are trying to make streets safer for pedestrians, cyclists, children, and to encourage alternative modes of transportation. Especially in recent years, as people spent more time at home because of the Covid-19 pandemic, many cities have started to reconsider the primacy their road infrastructure gives to the car. This activity is about LTN-related controversy in London, England.*

We then ask them to read a long-form article[20] that presents the sides taken on this issue and problematizes it.

A standard exercise in engineering ethics education might have the students debate and take sides on this issue, ultimately asking them to argue if LTNs are a good policy or not. This might be done in a classroom setting that involves either splitting the students into smaller groups and asking them to debate inside the group and then present their results to the class, or in a plenary debate with students assigned to a pro- or a con-side. This might also be done as a role-play, whereby students take on the role of a particular class of stakeholders and argue for their position in a kind of a "ethics tribunal" enacted in classroom. While these exercises are useful for moral deliberation and stimulating ethical reflection, we think that these side-step the issue of moral sensitivity and problem framing and, in a way, short-cut the student's path towards reflection. Students already know this is an ethical issue (they are being presented with the case in an ethics classroom), and they can pick up the relevant normative terms from the McIntyre article. The article, a nuanced piece, already frames the problem for our students by dividing the classes of stakeholders into groups with opposing interests which cannot be reconciled.

Our pedagogical operationalisation aims at arriving at ethical reflection by cultivating critical thinking and moral sensitivity through rethinking the framing of the problem. In this case, what would this look like?

1. First, we ask the students to make a list of all direct and indirect stakeholders in the LTNs case. Then, we ask each of the students to place themselves in a group of stakeholders that closest resembles their own interests. If there is no such group, they should create a new one. Thus, we aim to show the students that they are not reasoning from a detached perspective, analysing the problem from above, but that their perspective is situated and that they also have some interests and inclinations. Next, we ask the students to make a map of power relations among the stakeholder groups with arrows from the most powerful to the least (we call this the power map). We ask them to identify the most powerful actor in their power map and the most powerless. These steps were intended to stimulate critical thinking about power relations and to highlight the student's own situated perspective on the matter.
2. The second step targets moral sensitivity. While some values and ethical concerns are already given in the article by McIntyre, we want to encourage students to come up with their own framing of the problem. In this step, we ask the students a series of questions:
    - is this an environmental problem? If yes, what is the environmental aspect of it?
    - Is this a moral problem? If yes, what is the moral aspect of it?
    - Is this a political problem? If yes, what is the political aspect of it?

- What are the technical aspects of this problem? Can this problem be solved with technical (i.e., engineering) solutions with out involving any policymakers or other stakeholders?

We expect students to come up with a list of normative terms that highlight the moral, environmental, technical and political aspects of the LTNs, neatly separated. After this step is concluded, the instructor will ask the students to what extent is the distinction between environmental/moral/political/technical an artificial one. Can we actually separate these aspects and deal with them in a different way? Some student may still think that the aspects are totally separate while others may start to see that there is an overlap.

3. The third step asks students to solve the problem by reframing it. If, as seen in the previous step, the normative aspects of a problem are hard to disentangle from the technical ones, we ask the students to imagine an alternate universe where they can modify any aspects of the physical universe such that the problem of the LTNs ceases to be a problem. We divide the students into four groups and task each group with one aspect of the problem: technical, environmental, moral, and political. We then ask them to redesign their alternate world in such a way as to solve their particular aspect of the LTNs. We then discuss the solutions in a plenary.

   The goal of the exercise is not for students to 'solve' the problem, but to arrive at an understanding of the particular way in which the problem is framed when presented to them and then to empower them to reframe it in their own terms. Following this exercise, the problem of LTNs has been reframed first by asking students to analytically recognise the environmental, moral, political and technical aspects of the problem (thus employing domain-specific knowledge and CT), and secondly by asking them to imagine some alternate universe where this would not be a problem in quite the same way.

Conclusion

In this article, we raised the question of how we should teach environmental ethics to engineers. Without claiming to be a complete or exhaustive answer to this question, we hope to have contributed to the very limited literature on environmental ethics education for engineers. These students, in our view, are poised to contribute in unique and impactful ways to addressing climate change (and other environmental issues), because of the meso-level of influence they'll have professionally, in charge of the making, remaking, and maintaining of our shared world. We've shown how their tendency of framing problems as technical problems distorts engineers' understanding of these problems and obscures from them their own potential impact and responsibility. Environmental ethics for engineers, in our view, should work to counter this tendency and train engineers to recognize and understand the normative and ethical questions around climate change and other environmental issues. We've proposed two key competencies—moral sensitivity and critical thinking—that, together, can help students challenge technical problem framing and approach complex problems in their complexity.

The transitions we need and hope to see "in energy, land, urban and infrastructure (including transport and buildings), and industrial systems" (IPCC) are engineering transitions but so too are they societal transitions. They will affect our ways of living; they will be far reaching, political, messy, controversial, and undeniably value-laden. This is not a moment when our engineers can recuse themselves to work on purely technical matters. Instead, we see the work of environmental ethics for engineers as helping to equip them to respond to the ways in which the technical is interwoven with larger questions of value, responsibility, and justice.

Notes

1. Corresponding author: a.r.gammon@tudelft.nl.

2. L. Marin has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 707404. The opinions expressed in this document reflect only the author's view. The European Commission is not responsible for any use that may be made of the information it contains. orcid.org/0000-0002-8283-947X.

3. An earlier version of this paper was presented at the Seventh Annual Conference of the Society for Ethics Across the Curriculum, Colorado School of Mines, 9 October 2021. We thank the participants in this session for their points of feedback, and an anonymous reviewer for their helpful comments.

4. In this paper, we focus on climate change as a central environmental problem, though our claims could be applied to environmental contexts and issues more generally.

5. Riley, T. (10 July 2021). "Just 100 companies responsible for 71% of global emissions, study says" *The Guardian*. https://www.theguardian.com/sustainable-business/2017/jul/10/100-fossil-fuel-companies-investors-responsible-71-global-emissions-cdp-study-climate-change.

6. Perhaps the best example of this is the idea of the carbon footprint. Environmental ethics literature on climate change it should be said, is not exclusively focused on the individual, but also asks much larger questions of intergenerational

justice, responsibilities for mitigation and adaptation; how to conceptualize the Anthropocene, etc. Nevertheless, questions about individual responsibility or response remain a key theme.

7. Writing about the context of climate change specifically, environmental ethicist Chris Cuomo identifies this as the insufficiency problem (2011). Others have also questioned whether individuals are the best or appropriate level for effecting environmental change (see for instance Sinnott-Armstrong (2005); Godoy (2017); and Fragnière (2016) for a review.

8. This has inspired other movements, especially from young people and climate activists like the Fridays for Future school strikes, the Sunrise Movement in the US, Extinction Rebellion, and various protests of pipelines and other fossil fuel expansion projects around the world.

9. See especially Scott (2012) and Preston (2013).

10. See Buck et al. (2014) for discussion.

11. It is also worth considering whether this tendency runs deeper than engineers' technical training. Nolan (2021) argues that the narrative of engineering as socially captive (cf, Goldman), that is, a practice steered by and subordinate to political, technological, and corporate power structures and dynamics, fundamentally stymies the active role engineers could play in their work, towards environmental or other ends. Following Nolan's argument, it is not only the problems and social contexts of engineering that require reframing but the practice itself. Here we focus on the framing of problems, though we recognize that the interrelations between problem framing, engineers' self-conceptions, and degree of influence they hold professionally deserve greater attention.

12. Weaver, Morse, and Mitcham use the term ethical sensitivity and reviewed uses of the term "ethical sensitivity" and "moral sensitivity" in professional ethics contexts. We will use the term moral sensitivity for the same concept.

13. See Solomon et al. (2010).

14. Kimberly Nicholas makes this point poignantly, though focused on individual responsibility for emissions: "Everyone alive today is skywriting the most important legacy of their lives in atmospheric carbon. . .this carbon legacy will. . .literally define the terms of [our descendants'] lives: where they can live, how they can make a living, what kind of civilization and nature surround them" (2021:15).

15. These are far more extensive that we've sketched here. See for instance Shue (2014); Caney (2018).

16. See Ennis (1962); Fisher and Scriven (1997); and Johnson (1992).

17. See Bailin (1988); Lipman (1988); and Bailin and Battersby (2016).

18. Nor does it appear to be done successfully in some engineering ethics classes, where students are given cases that also bracket off larger ethical contexts. Langdon Winner again: "Indeed, it is a property of the case study approach to education in business, law, and engineering that the contexts that underlie particular cases are never themselves called into question. By failing to analyze and criticize these contexts, case studies tend to legitimate and reinforce the status quo" (1990: 54).

19. See Cech 2013 on expanding what counts as an engineering problem.
20. McIntyre (2021).

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