A Pragmatic Approach for Teaching Ethics to Engineers and Computer Scientists

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***Abstract*—In this Innovative Practice Full Paper, we present a novel approach and a framework for teaching ethics to engineering and computer science students. The paper starts off by describing the background and context for the development process. The framework is sequential and consists of the following stages: Awareness, responsibility, critical thinking and action. It is described and related to earlier literature on engineering ethics, and we have tried to reflect our educational approach also in our description of the framework. The framework can contribute to research about engineering ethics education by re-stating the importance of responsibility, and by providing a sequential, interdependent heuristic that can make students and teachers aware of how different learning outcomes are related. The reconstructed, underlying reason for the pedagogical development is claimed to be an understanding of the human being from a post-phenomenological, virtue-based, and post-heroic standpoint.**

***Index Terms*—Curriculum development, STEM, Engineering education, Computer science education, Ethical aspects, Ethics**

I. Introduction

At some point we realized that we had a problem. For years, we had suspected that something was not right about our ethics teaching for engineers. Until five years ago, the courses that we had taught were electives, which had meant a certain degree of freedom when it came to the creation of content and structure of the courses (in addition to the fact that students who were not interested in the course could refrain from applying for it or, if they realized this too late, easily just drop out of it). The format was simple and, dare we claim, classical: we combined established ethical theories, such as consequentialism – maximizing good outcomes – and deontology – performing the right actions – with more modern theories; we discussed professional ethics, and paradigmatic cases, such as the Challenger accident; we assigned students to interview practitioners to learn something about how ethics could relate to the real world, and although each part seemed good in itself, we lacked a clear idea about how it all was supposed to form a coherent whole. Interestingly, this did not lead to any particular problems when it came to student evaluations, and neither students nor other faculty put any pressure on us to change anything.

Rather, some of the engineering students – those with prior interests in humanities, social sciences, and who had perhaps even studied philosophy – thought that the courses were amongst the best they had ever taken. Still, even though also most of the more stereotypical engineering students signalled that they were satisfied, we felt that they were not really given what they needed. Needless to say, we did not know at the time what they needed, and as we have come to learn, there is some debate about what a course, or an across-the-curriculum module, in ethics should aim at and contain. We will return to this particular lesson in the discussion section, but perhaps the best way to put it in hindsight, is that we taught courses *about* engineering ethics, rather than courses *for* engineering ethics.

In 2015, it was decided that the course would be obligatory within a certain technical Master's program at the Faculty of Science and Technology. Following a larger evaluation project (2010–2013) there were also indications that most of the engineering programs in Sweden failed to fulfil the degree criteria in the Sweden Higher Education Ordinance related to ethics.

The courses that we had taught until then were developed based on academic discussions about ethics, rather than in relation to any degree criteria or external institutional obligations. However, since the course was going to be obligatory and an instrument for an educational program to fulfil its degree criteria, we had to start from these. The criterion that inspired us the most was the one that states that students should have the ability to make judgments, taking ethics into account:

> [For a Degree of Master (120 credits) the student shall] demonstrate the ability to make assessments in the main field of study informed by relevant disciplinary, social and ethical issues and also to

demonstrate awareness of ethical aspects of research and development work" [1]

This was also the philosophy of one of our colleagues, Iordanis Kavathatzopoulos, in his ethics teaching in other courses, and in a research ethics course he co-taught with the first author. There, the students were trained to solve problems, applying various practical tools that Iordanis had developed. In the convergence between this approach *for* engineering ethics, and our previous approach *about* engineering ethics, we believe that we have reached a framework that is essentially for engineering ethics, but with a clear theoretical and descriptive component that was, in hindsight, the hallmark of our previous pedagogy.

When developing our alternative framework, there was a large degree of serendipity that came from thinking very deeply about how to make sense of the material, and what material we should teach, and how it connected to the goal of educating for engineering ethics. Although we are told, as faculty, that our measures to improve our teaching should be grounded in state-of-the-art international pedagogical research, for some reason (Lack of resources! Lack of time! None of the other teachers are drawing on pedagogical research to improve their courses!), we did not pay much attention to such research, but were more attentive to the local context, to students, to us as teachers, to educational programs and policies.

However, in this paper, we have connected the framework that is the backbone of our course, which is described in our course literature [2], to research within engineering and computer ethics education, and to some degree ethics education in general. In this encounter between our approach and existing research, we have also come to understand more about what we have been doing, and how our framework and approach to engineering ethics education is similar but also differs from existing approaches. Given that it has materialised as a solution to our concrete practical problems of teaching engineering ethics, we do not have one clear gap to fill within the engineering ethics education literature, but rather we contribute to a variety of discussions. For those who prefer a traditional paper structure, perhaps it is recommended to read the paper backwards. We have tried to adopt a post-heroic, in other words, a vulnerable, fragile, hesitant, and honest writing style, which is a part of our framework, a point we will return to in the discussion.

Finally, to avoid complicating the message unnecessarily, we will in the paper refer to both engineers and computer scientists simply as engineers. We acknowledge that there has been debate over whether computer science, due to the features of computing, is facing unique ethical issues (cf. [3]–[5]), but as computing is now ubiquitous in engineering practice, these potentially unique ethical issues have come to permeate all engineering practice. While acknowledging the need for domain expertise for understanding what issues can arise, we question the idea that ethics education is about teaching domain-specific canons of ethical problems. Ethical problem solving, which is our focus, is a skill that transcends disciplinary boundaries.

In the following parts we describe our framework, which consists of awareness (identifying ethical issues), responsibility (internalizing these ethical issues), critical thinking (finding a way to solve the ethical issues), and action (acting in line with the conclusions drawn from the preceding stage). See figure 1 for an overview.

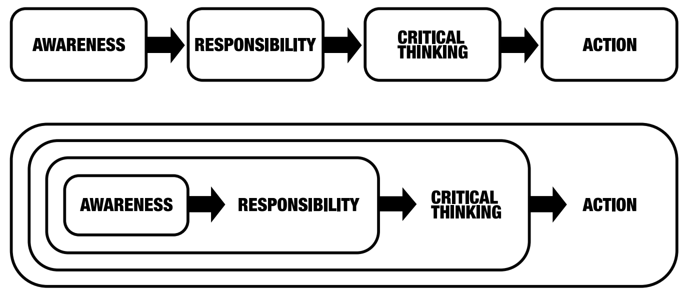

Fig. 1. Two illustrations of the process model. The top version stresses the sequence in which the aspects are learned, whereas the bottom version stresses progression and incorporation of prior stages: action should be based on critical thinking, which is triggered by the realization of one's own responsibility, which in turn requires awareness.

II. Awareness

Our first stage is awareness – to become aware of the ethical issues that exist in engineering practice. Without awareness of ethical issues, ethics makes little sense, and one cannot do anything about the things that one does not know about. We cannot assume that all students are thinking about ethics all the time, but rather explain how ethics can be hidden from the view until we try to look for it in our everyday lives. Rather than taking specific ethical issues as points of departure, for example whistle blowing, assessing technological risk, or engaging in ethical product design, we focus on three broad areas of engineering practice: working with technology, working with others, and private life.

Working with technology concerns the ethical issues that have to do with the development, refinement, implementation, or use of technology (physical or non-physical artefacts, including knowledge and skills to use the artefacts). Drawing on the work of Ihde, Latour, and Verbeek [6], it is argued that technology affects people's perceptions and actions (through scripts, i.e., norms that are embedded in artefacts [7]), and it is therefore important that the engineer thinks about this influence. We hold that this is a good argument for the relevance of teaching engineering ethics; better even than referring to the demands from laws (such as the Swedish Higher Education Ordinance), or from systems of accreditation such as the ABET operative within the U.S. context [8].

Working with others concerns the interpersonal relationships that the engineer has to employees, customers, suppliers and other stakeholders. Here, various ethical issues may arise such as injustice in the remuneration of men and women, sexual harassment, corruption, etc. Working with technology relates to "the product", while Working with others relates to "the process". We have met many students who believe that since they will be engineers within an unproblematically "good" technological area – for example renewable energy – they believe that there will be no ethical issues in their work lives. Although this is doubtful, since all new technology has both positive and negative impacts on different stakeholders, such students would still need to think about issues in interpersonal relationships.

Furthermore, while engineering ethics is often seen as a professional ethics [9], we include *private life* into engineering practice. Private life contains many issues with ethical aspects and these also affect the work performance as an engineer. For example, the question of where to draw the line between work and private life is a pertinent question for most engineers. With the possibility to work all the time and from anywhere, private and work realms are increasingly intertwined. Furthermore, we think that much interesting ethical reflection can be found in our private life, and that such reflection is conducive to thinking about ethics in one's professional role as well. Failing to address private life would strip the relevance of the course to students' current lives and aim only for the issues that might occur in a possible future work role.

In our approach, we do not distinguish between awareness of issues on different "analytical levels", for example the ongoing debates around whether to focus on micro-ethics (decision-making) or macro-ethics (social science, STS approaches) [8]. The idea of different levels has been problematised by STS scholars [10], and even for those who believe in ontologically separated levels, decision-making at the micro-level – for example whether to work with promoting genetically modified salmon in Sweden – inevitably leads to macro-level questions about genetic modification, vegetarianism, or environmental consequences, as well as debates about various countries' roles in promoting new technologies.

In addition, we try to create awareness not just around "engineering disasters" [11], but more importantly, around ethical problems in the everyday life of an engineer [12]. Engineering disasters can make engineering ethics seem distant and irrelevant to the students [13]. Morrison [14], who argues for a post-phenomenological approach, similar to Ihde and Verbeek, suggests that we should aim for expanding "the field of personal ethical significance to include the many small day-to-day decisions that frame the ethical conflicts that we may have to grapple with in the future".

Furthermore, we focus on both the positive and the negative, where the "positive" is the good that can follow from competence and skill, whereas the "negative" is the harm that should be avoided. The positive often tends to be forgotten within engineering ethics education [15], [16], while the negative framing is more common. A teacher in [17] represents this well:

> I'm still struggling to find a better way, rather than threatening them, to get them to appreciate the importance, but I just can't come up with a better solution, other than just sort of describing the worst case scenario and sort of motivating them to be honest. [17, p. 178]

The negative framing could even be seen as representing an attitude of distrust towards technology, which is apparent in literature that focuses on risks rather than also focusing on the positive (for such an argument see [18]).

In our teaching, we do use negative cases, but also positive examples such as Mentzer Pehlivan – a construction engineer dedicated to building earthquake safe buildings in developing countries. In this way, we help students diversify their experience and reflect on both types of motivation.

To create awareness, we encourage the students to identify ethical issues in the three domains of engineering practice, focusing on working with technology. They are expected to be able to identify scripts, for example how a bench has several armrests which would indicate the script "sit on me, but don't lie down". The collective capacity of the class is used to generate examples revealing the ubiquity of engineering ethics. Students also interview practicing engineers about everyday ethics, and then role play the dilemma as a performance in class.

III. Responsibility

Even if you are aware of ethical issues, you may still think that it is someone else's responsibility to deal with them. For example, an engineer who contributes to the development of a healthcare robot may suspect that there are ethical issues in its design, but still shift the responsibility to the implementers, arguing that the customer should decide whether it is ethical or not. Or, an engineer may have witnessed sexual harassment at work, but thinks that the manager is responsible for doing something about it, not the engineer. It is important to make clear that we do not interpret responsibility as something that is delegated to actors but as something that is assumed by them. Therefore, in the second stage of the framework, responsibility is discussed as a person's internalisation of a certain ethical issue, asking oneself: is this an issue that I should do something about?

Our concept of responsibility encompasses both forward-looking (related to the future) and backward-looking responsibility (related to the past) [19], [20]. Our responsibility concept is thus about the conditions for action, rather than accountability – the need to justify actions to others – and liability – the backward-looking responsibility according to the law [19].

In this stage, the main goal is not to discuss what is the right thing to do, but rather what are the conditions for taking responsibility. Building further on van de Poel and Royakkers' [19] discussion about responsibility, we have developed three concepts to capture this concept, namely *freedom to*, *freedom from*, and *impact*. *Freedom to* (actor-specific aspects) seeks to describe whether a person can be said to be capable and knowledgeable of making his or her own informed decisions. *Freedom from* (context-specific aspects) attempts to describe the degree to which the actor is free from structures, external pressure, and coercion. *Impact* is whether the actor can make a difference if they decide to deal with the ethical issue, or if she could have made a difference had she tried to do something about it. For example, as an individual, you may be able to do something about a specific case of sexual harassment at work, but it may be more difficult to immediately do something about global injustice. Following a discussion of these components of responsibility, various forms of rationalisation (neutralisation techniques such as denial of responsibility, denial of harm, blaming the victim, condemnation of condemners, appeal to higher loyalties, etc.) and avoidance (conformism, obedience, lack of time, etc.) are presented; in other words, how we usually avoid our responsibility. We have realized that many students (and faculty, including ourselves) recognize how they are using rationalisations, all the time. We, of course, do not recommend the use of rationalisations, but rather consider them as alarm bells – every time we use a rationalisation we should be self-reflexive.

The responsibility stage concludes with a discussion about the professional responsibility of the engineer. Sometimes professional ethics take as a point of departure the fact that engineers belong to a professional society, with its own code of conduct. However, at least amongst Swedish engineering students, many do not know of the existence of a code of conduct for engineers, and when they are told that it exists, they wonder about the validity and relevance of that code – why should we follow it? Perhaps this is similar to the experience that teachers have in many countries, but we get the feeling that engineers do not identify themselves as professionals in Sweden to the extent that engineers do for example in the U.S. We therefore, based on our components of responsibility, provide them with arguments for why engineers are expected to take more responsibility than others in their professional role. For example, engineers can be considered to have a greater responsibility than non-engineers since their knowledge about technology gives freedom to act, their alleged autonomy gives freedom from external pressure, and their power and involvement in technology development, refinement, and implementation impacts other people.

Connecting our responsibility stage back to the literature, we have realised that we can nuance scapegoating. For Vaughan [21], scapegoating of individuals leads to a situation where we do not consider the structural causes of engineering disasters. Those structural causes (context-specific) are related to freedom from, and thus responds to calls for including structural factors into engineering ethics education [22]. Furthermore, our discussion about responsibility directly addresses the agency of the individual, and we hold that a middle ground is taken between the treatment of agency in the micro vs. macro level debate, where the former exaggerates this agency and the latter downplays it [23].

In line with the discussion in the awareness section about the 'positive' and the 'negative', we differ from Roeser [24] who argues that backward-looking responsibility is only about finding blame for something that went wrong (for example, who was responsible for the Challenger space shuttle exploding?) but could also concern how we should attribute responsibility for something good that happened – who was to praise? Forward-looking responsibility, can of course be driven by positive emotions like Roeser [24] argues, but also by negative ones, such as shame, guilt, and anxiety.

In our course, we start with an example taken from the lyrics of the song "Who killed Carlos?" which is about a youngster who, when being denied entry to a bar, hits a guard, is apprehended by policemen using excessive violence, followed by Carlos' death in custody. After his death, a process of cover-up ensues, where the system works against Carlos and acquits the policemen from any blame. The lyrics of the song problematise the simple attribution of responsibility for the death of Carlos and rather points to collective responsibility, and we discuss the case of backward-looking responsibility by means of our prescribed components of responsibility (freedom to, freedom from, impact). However, we also imagine ourselves into the head of Christina, who is a person witnessing the crime scene and the violence of the policemen, and who decides to rally support for truly investigating and exposing what really happened to Carlos. Here we take the perspective of forward-looking responsibility to analyse the actions of Christina, and whether the ethical issue that she was made aware of was also something that she should act on.

Rationalisations are studied by using the case of Volkswagen's Dieselgate, and in class we let the students try to rationalise "cycling against red light" using all forms of rationalisations. The module ends with an exercise to discuss who was responsible for a construction accident in Kista, Sweden, and if the actions of the involved individuals adhered to the honour code for engineers. With this particular example, we also note that there are different forms of responsibility. We implicitly try to avoid the all too easy "collective responsibility" view, and point out that by assessing professional, as well as personal, responsibilities at every critical decision point, we can understand the nuances of a situation in much greater detail, and thereby move towards judgement. For many students, this can be quite surprising.

IV. Critical Thinking

After having identified a problem (awareness) and having reached the conclusion that I need to do something (responsibility), this third stage is about finding the right course of action by means of critical thinking.

We focus on problem-solving tools; essentially describing the problem, finding information, formulating alternatives, evaluating the alternatives from an ethical point of view and deciding which alternative to choose. This appears similar to how any problem is solved, and it also coheres with how engineering students solve problems in other domains. We present a range of problem-solving / decision-making models: Collste's decision making framework [2], the ethical cycle [19], Kavathatzopoulos' autonomy matrix [25], the ethical technology development process [2], and EVIL (exit, voice, insubordination, loyalty) [2], and merge them into a synthetic model which can be used in a structured, recursive and visual way for ethical problem solving. We support this problem-solving tool with other approaches such as casuistry and dialogue-based methods.

We explain that the fundamental aim of critical thinking is to see the "wicked" problems [26] of ethics from various standpoints, to think creatively and openly about issues, and to challenge existing opinions. However, we also say that ethical problem solving differs from problem solving in other domains, since we have a rich history of ethical thinking that the students are encouraged to draw on to facilitate thinking in a more critical way about a problem at hand. We present consequentialism (egoism, altruism, particularism, utilitarianism) and discuss what should be maximised. Deontology is presented, from traditional systems through Kant to prima facie duties, as well as rights. We also discuss virtue ethics, with some additional insights from Buddhist philosophy. Then follows a discussion about freedom, which is based on theories by Kierkegaard and Nietzsche, but also some voices from libertarianism. Furthermore, relational ethics is discussed with ideas from Confucianism (five relationships) to the ethics of care. After that, theories of fairness and justice are presented, from basic concepts such as distributive justice, strict egalitarianism, to brief introductions to Rawls and Nozick. Following this, there is a discussion on environmental ethics. These different theories are aimed at functioning as scaffolds [27] to help the student develop critical thinking about ethics.

Our view of critical thinking is rooted in problem-solving, which is well connected to how engineers and computer scientists are portrayed in the literature [2], [28]. We find that our approach to critical thinking is similar to Zhu and Jesiek [29], who propose a pragmatic approach, where moral deliberation (i.e. critical thinking in our framework) requires "our use of moral imagination to rehearse every possible course of action and anticipate the consequences of executing each" [29, p. 667].

This means that we do not see value in merely "applying" ethical theory or codes of conduct – claimed to be the "most popular method" [30], because this probably leads the student to consider the exercise as purely cognitive and intellectual. Rather, we see ethical theory or codes of conduct as important tools, values, enablers, and constraints to take into account when thinking about how to solve the problem.

When it comes to how the various alternatives should be evaluated, we adopt a broader and more pragmatic approach than other authors, in line with Haws [31] suggestion that ethical behavior requires divergent thinking. In many courses, the ethical theory presented often singles out certain "mainstream" ethical theories as the fundamental tools for ethical reasoning, overlooking other Western (e.g., ethics of care, feminist ethics, pragmatism) and non-Western (e.g., Confucian ethics) ethical theories [29], [31], [32]. We present theories that are not male-centric and that are intercultural, which is related to the claims of Lohman et al. [33] and Murphy et al. [34] that engineering is becoming increasingly complicated with increased global interdependence, i.e. globalisation and diversity (cf. [35]).

By keeping an open approach, we go beyond the application of utilitarianism and deontology, for example, but also differ from the recent suggestion to draw on the biomedical ethics canon to apply reflective principlism to engineering ethics, based on beneficence, non-maleficence, respect for autonomy, and justice [36]. Although we fully agree with their approach of reflectively and iteratively specifying, balancing, and justifying, within a structured learning framework [27], we do not commit ourselves to their four core ethical principles. Rather, we believe that a more open framework can also bring in codes of conduct and other ethical theory, which can assist our critical thinking about ethics. We also engage in role-playing, which can increase empathy and to understand the position of others [31], [37], as well as drama which is held to contribute to the formation of empathy [38].

This part of the course is the longest, and we present two case studies in which students try to find the best solutions to the problems presented, using different problem-solving models and increasing amounts of ethical theory: 1) designing an algorithm for handling accident scenarios for self-driving cars and 2) choosing a system for the storage of spent nuclear fuel. Furthermore, dialogue-based approaches, such as the Constructive Technology Assessment (CTA), are practiced in a role play. We have also tried to do a CTA both on sex robots and on an active learning monitoring/surveillance system to be implemented in a university setting.

V. Action

As outlined in Figure 1, the necessity to act, and the responsibility to act in accordance with what seems right, is the reason for critical thinking. The fourth and final stage of the process is, consequently, action. In the short term, this means to act in the way that one has concluded. Here we discuss weakness of will, acrasia, where we do something else than what we identified, through our critical thinking process, as the right thing to do.

We also present a model for long-term ethical conduct – the ethical roadmap. This consists of giving a person a description of the current situation in terms of ethical conduct, thinking about his or her normative ideals, and making a plan for how to achieve these ideals. The normative ideals are formulated by each individual, and not something given by the teacher.

In relation to previous reviewed literature, we believe that action is downplayed in engineering ethics teaching [39], and that given the practical nature of engineering we should never forget about ethical action [40]. We also believe that it is possible to promote ethical action without running into indoctrination [41], if we connect action to the critical thinking process of each student. Our ethical map is normative in the sense that it posits that one should have normative ideals but is open to different well-reasoned, critically thought-out ideals.

Haws [31] points out the importance of service learning for engineering ethics, and we believe that this directly relates to ethical action. Another important work is done by Walling [39], who lets students experiment on themselves and then reflect on it: they first read Dalai Lama's *Ethics for the New Millennium*, and then test a statement in that book using their own experience. Concretely, this means to attend to ethical dilemmas that they face in their own life, engaging their emotions in ethical decision making, to develop moral imagination and produce ethical behaviour.

VI. Discussion

We have now discussed the different stages of our framework, and also related them to earlier research related to each of the stages. We now shift to the broader perspective to discuss what learning outcomes are inherent in our framework, and how these are related to the learning outcomes in existing research.

Harris, Davis, Pritchard, and Rabins [9], in their central and foundational paper in engineering ethics education, discuss a comprehensive set of learning outcomes of engineering ethics education, namely, that it should:

- stimulate the ethical imagination of students,
- help students recognize ethical issues,
- help students analyze key ethical concepts and principles,
- help students deal with ambiguity,
- encourage students to take ethics seriously,
- *increase student sensitivity to ethical issues,*
- *increase student knowledge of relevant standards,*
- *improve ethical judgment,*
- *increase ethical will-power.*

Although comprehensive, later research has condensed and narrowed down to a smaller set of learning outcomes. Herkert [42] argues that there is general agreement about the importance of the last four ones. Davis [43] revised the final one to concern ethical commitment rather than will-power, but otherwise, there seems to be a general consensus that these are reasonable.

Finelli et al. [44], who participated in a large-scale study of the effectiveness of engineering ethics education in the U.S., discuss engineering ethics education in terms of its impact on three constructs: knowledge of ethics, ethical reasoning, and ethical behaviour. For some reason, they do not connect these to the earlier debates about learning outcomes in engineering ethics education, but derive them from literature on moral development, moral reasoning, and pro-social behaviour. Given that these are the constructs that are measured in the paper, they should likely be interpreted as constituting the central learning outcomes.

Pfatteicher [41], who is also a prominent voice within engineering ethics literature, takes a different position, and argues that we should provide students with an understanding of the nature of engineering ethics, an understanding of the value of engineering ethics (why should one be an ethical engineer?), and to train students in the resolution of problems. Her first two learning outcomes are related to Davis' ethical sensitivity, while her third learning outcome is similar to ethical judgment.

If one centers on Davis's [43] learning outcomes, we can see that they cover important dimensions of the approach that we are suggesting. Our framework points to the importance for students to learn how to be aware of ethical issues, how to internalize them (responsibility), how to critically think about them, and how to act. Implicit in our framework are, thus, four learning outcomes. The first of these is well connected to ethical sensitivity, the third is connected to moral reasoning, and the fourth to ethical will-power in Davis' framework and to action in Finelli et al. [44]. The one learning outcome that we have and others seem to be lacking, or at least do not mention explicitly, is responsibility. This has led us to frenetic literature study to understand if we have simply made a mistake by including responsibility or whether this could indeed be a contribution.

A. Responsibility as a learning outcome

After re-reading the above mentioned papers on learning outcomes for engineering ethics, Harris et al. [9] became particularly interesting to focus on. We became curious about how nine learning outcomes were boiled down to four (in Davis [43]), and could not find an explanation for it in the literature. The five learning outcomes that were either neglected or treated superficially in the subsequent engineering ethics canon, are claimed to derive from Callahan [45], but according to our reading of Callahan's chapter, the depiction of them in Harris et al. [9] could be improved. Callahan discusses five learning outcomes. First, moral imagination, often by invoking the emotional side of students through plays, novels, and films. Second, to recognize ethical issues, in other words to reach awareness. Third, to elicit a sense of moral responsibility. Fourth, to develop analytical skills, and fifth, to tolerate and reduce disagreement and ambiguity.

While most of the learning outcomes in Callahan [45] are present in the four learning outcomes from Davis [43], we hold that "eliciting a sense of responsibility" is not captured fully by "ethical will-power". Rather, Callahan argues that one needs to create a connection between reasoning, willing, and acting, and that this is the core of this learning outcome. Callahan asks whether it is acceptable to stimulate an intention to do good without this leading to indoctrination?

> The answer to the question lies, I think, in the necessity of making clear in any course in ethics the centrality of freedom and personal responsibility. [...] [F]or all practical purposes, it makes no sense to talk of ethics unless it is presupposed that individuals are free to make moral choices, and that they are responsible for the choices they make. [45, p. 66]

Our learning outcome of responsibility addresses this, which could be seen as a contribution to the engineering ethics education literature.

B. The framework as a heuristic

One of the aims of the framework was to set a structure and make students understand the linkages between the different concepts in the framework. Our heuristic framework does not accurately represent the iterative and reflective nature of ethical awareness, thinking and action, but despite this, we argue that it is a pedagogically innovative and sound approach to learning the interconnected aspects of ethics in a tangible way, especially for engineers.

If the framework indeed serves as a heuristic – that ethics is about all of these four stages in a particular order – then it is possible to resolve some of the issues that have been pointed out in the engineering ethics education literature.

For example, engineering ethics education has been criticised for failing to fulfil its own learning outcomes, and merely becoming an intellectual exercise in moral reasoning [46]. By using our framework, where moral reasoning corresponds to the stage "critical thinking", students and teachers can remember that there are three other stages that also need to be studied.

Furthermore, it has been argued by Holsapple et al. [17] that students perceive engineering ethics to be about the dogmatic learning of codes and rules, and by Sunderland [23] that we need to shift away "from the mindset that ethics is nothing more than a list of rules, laws, and codes to be memorized" [23, p. 1784]. By using our framework, students and teachers are reminded that codes and rules can be one part of the critical thinking process – one is encouraged to pay attention to codes of honour when critically thinking about an ethical issue – but that there is more to critical thinking than just codes and rules.

Since action is included in our framework, we emphasise that ethics can never just be about moral reasoning, at the same time as we distance ourselves from arguments such as, for example, Pfatteicher's that including ethical action in the learning goals would amount to preaching [41]. This is only the case if action is seen as a separate learning outcome from moral reasoning. Rather, in our process, the role of the person's own critical thinking is central for formulating how to act, and neither teachers nor teaching materials dictate what action, if any, should be taken.

There are many processual approaches to problem-solving and decision making in the literature, but few authors link the learning outcomes in a processual way. An important exception within the engineering ethics literature is the one developed by van de Poel and Royakkers [19]. They relate their six learning goals – moral sensibility, moral analysis skill, moral creativity, moral judgment skill, moral decision-making skills, and moral argumentation skills – to different parts of their problem solving framework "the ethical cycle". The basic idea of their framework and ours is similar, but there are some slight differences, which we will explain. First, their framework starts with "case", while our framework starts with training awareness of ethical problems from an undifferentiated reality – in other words training the students to identify what is a case in the first place. Second, phase 1 in their model discusses the moral problem statement and asks who has to act, while in our model we always take the point of departure of the actor who is making the analysis, and what this actor should do (it could of course entail that the actor seeks support from other people or indeed artefacts). Our framework is thus more centered on the person/group doing the analysis, which brings the problem closer to that person/group. This is the reason why our model includes the stage of *responsibility* which is focused on determining to what extent the person/group doing the analysis could/should act. Third, the final stage *action* in the ethical cycle is not explicitly discussed, and is not a learning outcome, which it is in our model. This could indicate that the ethical cycle runs the risk of being focused on the cognitive part of engineering ethics. Fourth, reflection is the final step before action in the ethical cycle, while it is an integral component of all stages in our model.

If one broadens the scope and takes discussions about teaching computer ethics into account, there is an interesting paper by Maner [47] that synthesises various procedural decision-making frameworks into a generic model that consists of twelve sequential stages: preparing, inspecting, elucidating, ascribing, optioning, predicting, focusing, calculating, applying, selecting, acting, and reflecting. While Maner's procedural model is arguably more complete than ours, we focus explicitly on the important stages for learning to handle ethical issues in engineering. Our ambition is not to create a complete routine for ethical engineering but to scaffold the learning of how to realize and handle ethical problems. This necessitates some simplification in order to leave room for interpretation and creativity. In the following part, we will try to reconstruct the theoretical underpinnings for limiting the process to these four stages, rather than others.

C. Theoretical bases of the framework

Throughout the paper, we have implicitly presented some pedagogical ideas that permeate the approach. First, we frame ethics as awareness, responsibility-taking, critical thinking, and action in relation to problems. The reason for doing this is predominantly to engage students in doing engineering ethics, rather than reading about engineering ethics. By focusing on awareness of problems, taking responsibility for solving such problems, solving problems, and acting on the solution, the approach is something that could be readily applied to the student's own problems.

Second, we wanted to create an open approach regarding critical thinking, in other words to draw inspiration not only from engineering and moral theory, but also from sociology, economics, criminology and psychology, to bring in theories and perspectives from both men and women, and from different parts of the world. The reasons for this are on the one hand theoretical: ethics as it is studied academically is done by scholars who identify themselves as belonging to a certain field (e.g. philosophy, theology) and who have a clear focus on Western philosophy. However, there are no good reasons for neglecting to take into account what is discussed in other fields and geographical contexts. On the other hand, this choice is related to the pragmatic nature of the framework. Students are not and do not aim to become scholars in philosophy, but rather (hopefully) want to think as critically as possible about a problem. We see no clear arguments for not using all resources possible to better understand problems.

Third, to focus on both the positive and the negative, rather than to focus only on the negative, which engineering ethics education has been criticised for. As Kiran and Verbeek [18] argue, there has been a dominance of scholars who view technology as negative, perhaps even embracing a romantic view of life before modern technology. Students, and particularly engineering students, do not see this clear negative impact of technology (perhaps rather the opposite), and we believe that a message that only focuses on the risks of technology would not be amenable to our student population.

Fourth, our approach is related to appreciating mundane ethical issues, rather than only spectacular dilemmas. This is yet another strategy in order to connect ethics to the students', and later professionals', own lives, rather than externalising it and discussing events that are unlikely to happen.

Fifth, our approach is to play on both cognitive and emotional registers to stimulate the attention and motivation of students. This was a central part of Callahan [45] so the idea is of course not new. By drawing on the emotions of the students, we aim to connect the subject to the students, rather than making ethics "just another course". One should also not underestimate the importance of "having fun" in a course, particularly since ethics is considered boring or unimportant by many students and educators.

Based on the above, a view of the human being, underlying our approach, emerges. We take our point of departure from the perspective and experiences of the individual student. In this sense, our approach is similar to post-phenomenological approaches, where "post-" means that they take a view that human experiences and the world are mediated by technology. [6]. Thus we need to connect the course to the student as she experiences the world today, and not in some fictive future role (only). An interesting contribution to phenomenological perspectives on teaching engineering ethics is Troesch [48], who builds her teaching around the question "what is an ethical engineer?" In her course, students interview an engineer about ethics, and reflect on the students' own work during the semester to answer that question.

Furthermore, our approach is built on the fact that ethics is an ongoing process and that a student can evolve over time. This is a more long-term, agentic, processual approach, that coheres with virtue ethics.

Moreover, we use a post-heroic approach, inspired by management studies [49], in which the student that we address in our teaching is not a morally fulfilled subject ("the brave whistleblower"), but rather one who is using rationalisations, who is avoiding responsibility, who is not sure about what ethics means in her private life, who does not think that engineers have any particular responsibilities, who is not interested in moral improvement and self-development, and who is generally not so interested in the subject.

How does such a theoretical foundation relate to other teaching approaches documented in research? In some papers within engineering ethics education, the theoretical view of ethics is spelled out, while it is lacking in many others. There seems to be a general understanding that Kohlbergian approaches, focusing on moral reasoning, are dominating the view of the individual [50], [51]. If this is correct, it might explain the critique of engineering ethics education as being strictly a cognitive exercise. For example Walling [39] claims that the dominant approach in engineering ethics teaching emphasises cognitive competence (for similar arguments, see [24], [37], [46]). She argues that this leads to students just applying a variety of frameworks as an intellectual exercise, which rarely translates into action and commitment.

Huff and Frey [50] draw on moral psychology to propose a different set of learning outcomes for engineering ethics teaching. In their view, a new framework for teaching engineering ethics based on moral psychology will "treat moral action as the interaction of situational pressures, personal moral commitments (of various kinds), and the social moral-support system" [50, p. 394]. Frey [51] argues for a virtue-based, psychologically informed approach, based on personality traits of the students, and explicit attempts to connect moral value in the self-system. In future research it would be interesting to deepen the discussion between our approach and that of Frey [51], particularly what the differences could be between a psychological approach and a post-phenomenological approach.

VII. Conclusion

We have presented and argued for a processual framework for engineering ethics education, and that although it was constructed to solve particular problems that we were facing in our own teaching, it could contribute to the literature in engineering ethics education in a variety of ways, as explained throughout the paper.

We have already mentioned that a process never fully captures the complexities of ethics. Furthermore, in similar processes that are proposed in relation to other problems, there is often a component of reflection, added after action. However, in our approach, reflection is a core component of each stage. Furthermore, the process is iterative. Even though you have managed to create positive ethical patterns of action, it is still necessary to be aware of new moral values that you might need to think about, or new information that you need to process. Such triggers should not be neglected, and should spur a continuous development.

To sum up, from the point of view of our framework, one could say that we identified that there was an issue – that something was not right with our previous courses. Then we took responsibility for internalising the problem and making it indeed our task to do something about it (Yes, we could have an impact! Yes, we could make a reasoned decision! Yes, we were under pressure to do other things, and it would have been possible to just keep going and do nothing, but we still dedicated time to improve the course!). We then critically thought about what to do, chose this framework as the best way to solve the problem (as for now), and then acted and reformed our course. As soon as we become aware of new problems with our approach, we will need to re-iterate the cycle.

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