Enacting socio-technical responsibility through Challenge Based Learning in an Ethics and Data Analytics course

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Abstract—**This Research Full Paper reports on a study conducted at a Dutch technological university, which examined how students engage with societal aspects in a Challenge-Based Learning course on Ethics and Data Analytics. Responsibility is a core concept for engineering ethics, yet there is still little known about how to best foster responsibility and the impact of different pedagogical approaches on engineering students' development of professional responsibility. In the E3Challenge2 course offered by TU Eindhoven in 2021, students worked in groups to develop solutions for smart-grid, smart-health or smart-mobility challenges. These challenges were put forward by real stakeholders from the university's ecosystem, taking on the role of a client. The study aims to explore how students understand their professional responsibility when having to develop a socio-technical solution to a real case brought by a real client. Our analysis is based on interviews with 19 students enrolled in this course in the spring of 2021. The study's preliminary findings show that the CBL format fostered a broad understanding of professional responsibility in the course's deliverables, which included micro and macroethical understandings. Supporting learning activities include stakeholder mapping, participatory practices, foresight exercises or value sensitive design.**

Keywords—engineering ethics, responsibility, socio-technical engineering education, experiential education, challenge based learning, data analytics, interviews

I. INTRODUCTION

Responsibility is a core concept for engineering ethics [1], commonly understood as the "exercise of judgment and care to achieve or maintain a desirable state of affairs" [2]. Nevertheless, despite its importance, there is still little known about how to best foster responsibility and the impact of different pedagogical approaches on engineering students' development of professional responsibility.

The aim of this contribution is to explore how engineering students understand their professional responsibility when having to develop a socio-technical solution to a real case brought by a real stakeholder. The article reports on a study conducted at a Dutch technological university, which examined how students engage with societal aspects in a Challenge-Based Learning course on Ethics and Data Analytics. In the course offered in 2021, forty-five first-year engineering students from different specialisations worked in groups of four to develop solutions for smart-grid, smart-health or smart-mobility challenges. The analysis is based on interviews with 19 students enrolled in this course in the spring of 2021.

The pedagogical intervention as well as the accompanying study responds to calls for broadening and diversifying the scope of responsibilities fostered by the engineering curriculum [46]. This aim aligns with the 4th SDG goal on quality education and UNESCO's vision on education for 2030 [3], the vision of developing the ethics dimension in education set under the Horizon 2020 programme of the European Commission [4], as well as the recent statement on the role of ethics in human societies and their governing institutions by the European Group on Ethics in Science and New Technologies [5]. Despite the increasing number of voices advocating for the renewal of the engineering curriculum, there is still progress to be made, as existing initiatives are considered to fall short of their transformative ideals [6] and the uptake of this process has been slow [7]. The paper thus puts forward an example of how Challenge Based Learning can be used to promote engineering students' sense of professional responsibility.

II. BACKGROUND

A. *Responsibility in Engineering Education*

A central distinction in engineering ethics education is between microethics and macroethics approaches [8]. The distinction puts forward different understandings of professional responsibility (Table 1).

Table 1. Microethics vs Macroethics in engineering ethics education

FRAME	MICROETHICS	MACROETHICS
Responsibility	Individual and personal	Collective and societal
Aims	Focus on improving individual character and will power	Focus on correcting the context that gives rise to unethical practices
Stance towards values	Value neutrality	Value sensitivity

a) Microethical approaches: have a strong emphasis on the individual responsibility of engineers. As Basart and Serra point out, it is "usually focused on engineers' ethics, engineers acting as individuals" ([9], p. 179). In this case, an engineer's individual responsibility is guided by precepts stated in professional codes [10]. Mundane engineering situations that require the exercise of an engineer's responsibility include conflict of interest, quality testing,

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trade secrets, representation of test data [8]. Microethics typically emphasize the Kantian duty to do the right thing, sometimes at any cost. In such cases, the responsibility of engineers is framed in terms of a heroic or whistle-blower response [11]. This approach is seen to lead to a conception of engineering ethics as a "kind of behaviour internal control" [12].

Microethical responsibilities include, among others, enhancing one's ethical willpower, resisting immoral managers, preventing disasters and enhancing safety [13]. Empirical studies show that microethics is the most common way of teaching engineering ethics ([14,15]).

b) Macroethical approaches: move beyond analysing individual engineers' actions to a focus on the profession as a whole and the wider implications of technological developments ([12]; [16]). Herkert has emphasized the concern of macroethical approaches with "the collective responsibilities of the profession and societal decision-making about technology" ([8], p. 373). For macroethics, the focus of enquiry is on the relation between the ideal and the actual norms or structures that characterise group processes and social institutions. Such an approach marks a shift from the microethical emphasis on the tensions between the morality of the individual and the priorities of those in power positions [17].

Macroethics thus aims to cast light on what Devon calls "mutable social arrangements" for the decision-making related to the development and use of technology [17], which is considered a joint responsibility of engineers and the different stakeholders involved or affected by it. Vanderburg notes that a responsible intervention by the profession is possible when "the long causal linkages between the engineering activities and some of the major social issues are clearly understood" [18]. In this case, the concept of responsibility is no longer divorced from the context of engineering practice itself. As such, macroethics education considers the need to address and remove structural obstacles that come in the way of acting right [19].

Macroethical responsibilities include, to name a few, taking a stance in regard to the "kind of world they want to engineer" [20], combating the unequal distribution of risks generated by technology [21], counteracting technological colonialism and cultivating indigenous technological capability [22], ensuring a balance of power in opinion formation, negotiation and decision making in regard to technological development and adoption [23] or making sense of existential risks [24].

B. *Responsibility in the Context of Challenge Based Learning*

The rapid pace of technological advances confronts engineers and universities with challenges that call for a broadened and diverse set of responsibilities [25,42,44]. Whether by addressing climate change, the advent of artificial intelligence, ensuring the privacy and security of technological systems or developing fair algorithms, many of the challenges that engineers tackle are at the nexus between complexity and interdisciplinarity and include various problem statements, decision makers and stakeholders. Complex challenges, such as sustainable development or artificial intelligence, require an interdisciplinary approach comprising science, technology and social systems [26].

To address these challenges and encourage engineers to take their responsibilities to heart, engineering programmes need to familiarise students early with the features of a VUCA (Volatile, Uncertain, Complex and Ambiguous) problem, that requires a mix of socio-technical skills. Such ill-structured learning activities [43,45] can offer students a deeper exposure to ethics and enhance their motivation to engage with ethical topics ([27, 28, 32, 39-41]). They can also contribute to students' awareness of the varied ethical situations they might encounter in their practice or the type of responsibilities they can take on in their profession [29].

Challenge Based Learning (CBL) is an experiential teaching method that brings to the engineering classroom real-life problems put forward by real-life stakeholders [30]. These are presented to students as socio-technical challenges embedded in a learning context. A recent survey of CBL pedagogy found that it promotes content areas with a strong societal focus, which are presented as challenges of global importance that students address through proposal solutions with a localised focus and applicability [31].

III. CBL COURSE SETUP

In 2020-21 the course "E3Challenge2" (where E3 stands for Eindhoven Engineering Education) was offered for 10 weeks to 43 students from different engineering departments. Students were asked to apply and contextualise the data analysis skills they developed during a previous dedicated course to a real-life challenge. The "E3Challenge2" course built on the technical knowledge developed in a previous quartal for the "E3Challenge1" course, in order to further develop students' technical understanding of how and why data is generated and enhance their awareness about the constraints inherent to the data analysis process that are rooted in ethical considerations related to users, society and enterprise [32].

The course is inspired by the precepts of Value Sensitive Design, a theoretically grounded approach which seeks to foster the professional responsibility of engineers from the design stage of an artefact. Value Sensitive Design considers the prospective mediating role of technology development and instils it with moral values [33]. The values prioritised by Value Sensitive Design target the societal good [34], and often relate to safety, sustainability or inequality [35]. The focus is on encouraging students to design value driven artefacts or solutions that contribute to societal welfare or diminish the negative societal effects of existing technologies.

For the "E3Challenge2" course, students were grouped in teams of four and asked to develop a socio-technical solution for smart-grid, smart-health or smart-mobility challenges (Table 2). The course consisted of an interdisciplinary team of fourteen members (one ethics lecturer, one data analytics lecturer, three coaches, five expert generalists and nine teaching assistants - master students in ethics and/or data-analytics or students preparing a master thesis in one of the cases), three researchers observing the course (collecting data about ethics education, self-regulated learning and teacher training) and three groups of clients. There were five types of learning activities in a weekly cycle, in addition to weekly peer-to-peer meetings for the teaching staff. The Ethics workshops brought in ethics materials and evoked ethics discussions. The teaching assistants supported feedback among student groups. In the expert and stakeholder meetings, students could ask remaining questions. An assigned coach met weekly with each student team of 4 students for 30 minutes to support reflection on the learning process and gains. The three client groups participated voluntarily and had four contact moments with students throughout the ten weeks of the course.

Table 2. Socio-technical VUCA Challenges offered in the E3Challenge2 Course

Client	Challenge description
5G-Mobix	5G-Mobix is a student team based at TUe which is part of a European Large-Scale Pilot project investigating the added value and potential benefits of adding (autonomous) vehicles to a worldwide 5G network. The team works on enabling the control of a car from a remote station using an internet connection and feedback from various sensors on the car. The challenge is that some of the sensors in the car that are necessary for autonomous control cease working and a user then must take control of the car from a remote location. (https://www.5g-mobix.com/)
Diagame	The DiaGame project applies the sciences of data learning and biomedical simulations to an existing serious diabetes gaming platform (SugarVita). The challenge is to make SugarVita a data-driven, personalized serious game (SugarVita-P4) that empowers individuals with diabetes to manage their disease. SugarVita is a collaboration between BLINDUNIVERSITY, Maxima Medisch Centrum, and HRH Diabetes Games.
Red	The student team RED collaborates with TUe on providing insights into how the campus can be more sustainable. The challenge is to develop a model that can simulate the physical environment (the main campus buildings), which will allow users to add and configure various technologies such as solar panels, wind turbines, charging points. (https://teamred.nl/)

IV. METHODOLOGY

The findings reported in the paper are part of a broader mixed methods study conducted at TU Eindhoven to examine the ethical and self-regulation learning of students in the "E3Challenge2" course. The study has been approved by the Ethics Review Board of the university (ERB2021ESOE6). At the beginning of the course, all students enrolled (n=43) were invited to participate in the broader study, and 41 consented. Students did not receive course credit or any incentive for consenting to data collection, and there was no penalty for declining to participate in the study.

The first author is the engineering ethics researcher who conducted the study and was not involved in the teaching or grading of the course. The second author coordinates a 20 ECTS program offered by TU Eindhoven, which aims to raise engineering students' awareness on user, society and entrepreneurship aspects of technological innovation. He was involved in the course as coordinator and coach, but did not have access to any of the data until the completion of the course.

In the article, we report on the qualitative approach we undertook to explore students' view on responsibility upon following the course. The research question explored in the paper is: (RQ) How do students understand their professional responsibility when having to develop a socio-technical solution to a real case brought by a real stakeholder?

Nineteen of the 41 students who took part in the broader course study agreed to be interviewed for research purposes their ethical learning and their views on ethics and responsibility. The interviews were conducted at the end of the academic quartal, upon completing and submitting all the course work and assignments related to the course.

The interviews had a semi-structured format which included a set of open-ended and probing questions [36]. The open-ended questions explored their enjoyment of the ethical aspects of the course, how they view the relevance of ethics for their profession and their own future responsibilities, how they addressed the challenge they received from an ethical point, how they developed a joint socio-technical solution to the challenge and the ethical criteria and values they considered. Based on the responses received, probing questions were asked to help participants offer a more detailed response. Such questions invited participants to reflect about why specific ethics aspects, criteria and values were pursued and if they could say more about the role ethics played in addressing their challenge.

The interviews were conducted by the first author based on a protocol agreed with the second author. The protocol respected the guidelines provided by Jacob and Furgerson [37]. All interviews were conducted online and recorded. The institutional procedures in relation to consent, confidentiality and data storage were adhered to, in line with the expectations and requirements of the institutional ERB.

The interview analysis was guided by Lofland's recommendation to group the data into meaningful categories [38]. The first coding iteration inspected the interview transcript line by line, identifying examples and trying to understand their deeper meaning. The second coding iteration organised the meanings and examples identified previously into themes, guided by the literature on engineering ethics. To understand the interviews in relation to our research questions, the data was coded against the distinction between microethical and macroethical aspects and the description of responsibilities described in section II. All the data gathered and analysed is part of a carefully audited trail of written documents and video recordings.

V. RESULTS

In what follows, we report on the findings of our study purporting to how students articulate their responsibilities, the course factor that were considered by students to influence their views and the main take-aways at the end of the course when it comes to considering their responsibility as engineering professionals for their future activities.

a) Students' reported view on responsibility

The study finds that students exhibit an understanding of their professional responsibilities both at the micro and macro level.

Microethical responsibilities focus on compliance with legislation and the standards of conduct, foreseeing and avoiding negative consequences of engineer's decisions and designs, opposing amoral managers as individuals and fostering character traits (Table 3).

Table 3. Microethical responsibilities fostered in the CBL course E3Challenge2

MICROETHICAL RESPONSIBILITIES	EXAMPLES
Uphold ethical standards	"To create the product while upholding the highest standard of ethics. And if ethics and values are being breached, then there needs to be a solution around it so that you protect the

	values that all the stakeholders involved respect and follow." (S9) "Follow the things that the ethics code stands on. More than anything for an engineer, it is completely important to use the golden rule of ethics." (S7) "I think as a future engineer I realized there was much more considerations that need to be taken into account when I'm building something. All the golden rules relating to the public and relating to safety and everything, basically." (S18)
Comply with legislation	"Not go against the law, but with the law." (S3)
Foresee and account for consequences, such as to avoid harmful or unsafe consequences	"As a future engineer, one needs to look out for different problems that one might encounter when deploying a certain product or launching a certain product, problems that you previously didn't think about, but that could have implications that are far beyond just what you thought it would imply. […] Look out for problems that are related to what you are doing, also that wouldn't be too easy for yourself so, that you do not skip these things that you thought "that will not happen, that's very unlikely" because sometime it will happen and then you're responsible." (S12) "It's not about your intention behind creating something. It's about considering how others might use it as well so. You need to consider more than just your own personal preferences and also understand that there's a whole network of people that have their own motives and their own agendas." (S15) "To run over the consequences of what you could do." (S8) "It's really good to identify the risks or things that could go wrong and to really make sure that they don't go wrong if they are dangerous." (S14) "When I have the task to make something, I should think about the consequences this could have" (S10) "To see: is it a product that has long term negative consequences? Is it maybe targeting some group of people, or old people, and how is it targeting them in the meaning? Is it actually physically harming? Is that a moral harm and how to minimize it as much as possible?" (S3)
Develop and implement solutions that are not harmful	"To find a solution for some problem that is designed in such a way that it is not harmful for society." (S13)
Responsibility on behalf of the client	"If you have a client, you're responsible if you would suggest something that's wrong, you are responsible for that mistake." (S14)
Develop and enact specific character traits and attitudes	"Just be super careful." (S12) "The main responsibility an engineer should have, ethically speaking, should be respecting everyone's work and ensuring that there's cooperation, by not starting conflicts, for example. […] Always have the integrity to be clear and open about the issues that might appear." (S7)
Individual responsibility in face of power and to resist amoral managers	"It's the engineers against the management. The management may want to go in a certain direction and you really have to see, if that direction is ethically not in your line, you really have to put the foot in front of door and say "no, sorry, I'm not doing this, you might make more money but it's not the right way to handle this." I think the engineer does really have a strong position there, it's.. under their control." (S11) "If a certain actor has a lot of power over another actor, then for instance, the engineer could drop their standards related to safety or privacy in order to keep their job, for instance, or to keep their status, since the company, if that's the more powerful actor, wants to make more money by saving costs on product testing and they force that upon their engineers. Then what kind of choice do you have as an engineer, if you want to keep your job?" (S12)

In terms of responsibilities framed in a macroethical way, students expressed an acknowledgement of the responsibility to reflect on the future of technological developments for the public good, the collective responsibility of the profession in face of power, promoting human rights and fostering appropriate structural conditions for ethical practice in the workplace (Table 4).

Table 4. Macroethical responsibilities fostered in the CBL course E3Challenge2

MACROETHICAL RESPONSIBILITIES	EXAMPLES
Reflecting on the future of technological development and its societal impact, as well as develop technology for the public good	"I think technology is growing really fast and ethics isn't really keeping up with that, in thinking about whether a product has a good influence on society or maybe a bad one." (S10) "I'm thinking about all the work and knowledge and energy that right now goes into trying to get fusion energy to work. You can think like *we shouldn't be doing that. We should focus on different things, we should focus just on improving solar panels*. But if you think like *OK in the long run, if this works, it is very valuable*, then definitely I think those are decisions that you think *OK, I should just still work on it*. but if you see no real worth, I think you should never do it." (S11) "I think our responsibility, as maybe the super highly educated, so from a Technical University, I think our responsibility is very big, because the world is now so complex […] If we are specialized in technology, then we should do the best we can in ethics terms, because there's nobody that can check on us if we're doing the right thing. […] I think technology can solve a lot of problems there are in the world or maybe contribute to do that in the coming years. I think we have a great responsibility." (S9) "Pinpoint what could go wrong, what is ethically justified, especially in human trials" (S19) "Really change things on the long term […] by creating new products, changing society." (S2)
Collective responsibility of the profession in face of power	"I think you have quite little power. But I think as a collective you always have power. So if engineers are well educated, then is really tough to find people that will do the wrong things. I think you have as a group some power. I think individually, you can always make decisions that you are not really able to work them out, it is always a lose-lose scenario. If you don't do it, you will just get fired then." (S11) "Power needs to be held accountable. […] I think there is a very strong, more moral imperative for the engineers and scientists who are part of those large

	companies to actually hold that power accountable." (S15)
Consider and contribute to the enforcement of human rights and stakeholder needs and preferences	"It's about not doing only things you feel is good regarding the data, but also consider the human rights. […] I think it's my responsibility to respect the data of the customers, because that's the biggest problem now" (S16) "I think the wellbeing of our stakeholders is a top priority. […] make sure that no stakeholder is forgotten." (S17)
Creating the conditions for a professional environment that fosters ethical discussions and actions	"We had a discussion as to whether we should include this value and we had a debate about it. But basically, what it comes down to, is creating an environment in the company that stimulates asking these questions, where people are encouraged to do that and the process of doing that." (S9)

We note that compared to macroethical responsibilities, microethical responsibilities place an emphasis on compliance (versus change), localized interventions given existing features of the workplace (rather than creating organizational structures that are ethics friendly) and negative formulations focused on avoidance (rather than positive formulations focused on added contributions).

b) Course factors facilitating students' view on responsibility

Real-life socio-technical challenges were included in the course, for which students had to propose a solution that has both technical and ethical components. Students mentioned the realness of the case as a factor that encouraged them to emulate the responsibilities they will take on as professionals. They also appreciated having to provide a solution that is both technically and ethically sound, which prompted them to consider the responsibilities they have towards the users they design for and the society:

"I think having a real client also gives you some responsibility, you just want to help them. So that adds something extra to the course and I do appreciate that." (S14)

"I see now that every technical problem always comes hand in hand with an ethical problem." (S19)

"having to think about ethics and data analysis. You need to combine them. In previous projects the focus was only on one part, for example only on data analysis. This makes it more complex." (S16)

TA sessions were held weekly, supervised by three teaching assistants overseeing the ethics, data analytics and relevance to the case. Students found the activities useful for digging in more into the ethics aspects and seeing their ethical solution in a broader manner. This meant considering how the solution may affect a diverse range of stakeholders and how to argue in favor of a more ethical solution (but less technical or more complex to implement) to the client when delivering their solution.

"I think for the client short term ethical considerations were much more important, and that's understandable, right? They want to know how to conduct the user tests in an ethical way, and so forth. But as a student, I found the long-term ethics far more interesting […] and these were explored in the TA sessions." (S15)

Client sessions took place three times during the course. In the first week, client groups introduced the challenge and answered any questions students might have. An intermediary meeting took place in the middle of the course, for which students prepared a presentation of their preliminary strategy, for which they received feedback from the client. The final meeting was scheduled for the last week of the course, when students delivered their solution to the challenge posed by the client, comprising both a technical and ethical dimension. These sessions proved useful in making students aware that what they, as engineers, might consider to be a good solution from an ethical perspective, might not be of so much interest to the stakeholder, who either prioritizes the technical implementation or might have different criteria for what counts as a successful solution. This is linked with a diminished familiarity of stakeholders with ethics, which can be more representative of how ethics is prioritized by a potential future manager, as opposed to an ethics teacher with expertise and interest in the topic.

Pointing to the client's reception of the ethical component of the solution to the challenge, some students pointed out a lack of engagement and lower importance given to ethics:

"I think, to be honest, it [n.m. ethics] was more important for me than it was for my client. […] I do not think we got much feedback from the client in regard to the ethical dimension. I think most of it was technical or it was questions about the user test itself and what data would be collected from it. I think that's again kind of a testament to, I guess, the relevance that they give it." (S15)

"I don't think that the clients were that into ethics, they were more into the data analysis part." (S8)

"We haven't really had feedback on our ethics part or not really much feedback at all from the client." (S2)

"We didn't have much interactions with them [n.m. the stakeholders] in regards to the ethical parts of the solution." (S4)

"For the ethics part, I don't think it [n.m. the feedback] was that elaborated, because maybe they were not sure themselves of what core values they want to consider" (S18)

"The clients, their feedback was that they mainly lacked in ethics, so we didn't really have a direction to go out." (S19)

c) Student take-aways related to enacting their responsibility

Students identified several practices that they consider will help them towards enacting their professional responsibility, which they will rely on in the future. These include:

Stakeholder mapping which considers the direct and indirect stakeholders that may be affected by engineering designs or decisions.

"I think the stakeholder view on things was quite new to me. […] So I think the course has convinced me that it's the right way of looking at things. So that's definitely something that I can apply to future projects. I would say that's the main thing I like in terms of ethical theory that we've learned." (S15)

"I think the stakeholder part is very important. So, thinking from the point of view from any of the stakeholders, first coming up with all the stakeholders and then thinking of their relations in between each other and more consciously considering their views. I think that's something I can definitely take away. I think that's the biggest part." (S17)

> "The next time I do a project, I will think about how the particular product we are designing affects the customer or other people or the stakeholders." (S9).

Participatory and open-ended practices that allows engineers to gauge the different perspectives, values and desired aims, rather than infer them directly considering their own individual perspective.

> "I think communication, especially listening to other people's opinions and perspectives, can give you larger insight on whatever valuable information you will get" (S19)

> "There are always a lot of people involved and everyone has an opinion, and I see it as really important to try to find a way that you satisfy the most people or consider the most people." (S5)

Value sensitive design that encourages engineers to consider which and whose values are integrated at the design stage of an artefact.

> "It also comes back to value sensitive design, where we consider the values of everyone that uses the product and how does it affect humans as a whole, the humans that use the product and the humans that don't use the product, the indirect stakeholders." (S9)

> "If you design something, you can't ignore the values. Ethics should be included, as they have a real significance on the user you design for." (S5)

Focusing on the long-term and broad impact, to account for the non-immediate effects of the engineering decisions and design.

> "I also discovered some long-term consequences. This project brought me that experience of thinking about it. […] About the ethics question that I was working on, what was important was the long term of result of the test, as the results could maybe present a general profile of the driver that can be employed. Maybe older drivers are more preferable. When you have those results and when you want to use them, are you using them as a job requirement, but are those actually requirements, or are you discriminating against some people?" (S3)

> "I found the long-term ethics far more interesting, considering how this technology might influence different demographics or different groups, kind of like a very long-term projection." (S15)

> "Thinking about the long-term impact […] You're doing something that would make a long-term difference […] which is what real-world situations are." (S7)

VI. DISCUSSION

Students enrolled in the CBL course exhibited an awareness of a broad range of responsibilities. As expected, given this is an early year course for students with little previous exposure to ethics, the microethical responsibilities prevail. Nevertheless, the study reports that students are moving towards a macro understanding of their responsibilities, that takes into account the need for collective actions and global impact.

The findings lead us to suggest that course instructors may support students' awareness of macroethical responsibilities by introducing real-life case studies or challenges, where students get to interact with stakeholders external to the course, such as companies, student start-ups, community groups or research units. In addition, learning activities may include stakeholder mapping, participatory practices, foresight activities or value sensitive design.

As the paper is based on a study conducted in a European setting, with a fairly homogenous make-up of participants (preponderantly male, white, European engineering students), further research is needed to explore how students' articulate their professional responsibilities in CBL courses set in other geographic settings or with more diverse student groups. Similarly, research is needed into the influence of the different types of clients (large companies, SMEs, young start-ups, NGOs, community groups, policy groups, research units a.o.) offering the challenge on students' understanding of their professional responsibility, and the benefits and learning gains of including each type of client.

Given that students reported that clients showed a lack or low interest in ethics, further research may elucidate how to involve external partners in engineering ethics education, and towards which aims. Such aims can be directed both at students' learning through interactions with the client, but also to the wider role of engineering higher education institutions in "educating" members of their local ecosystem as to enhance their awareness and behaviors of socially responsible practice. Students' dissatisfied comments about the clients' reception of the ethical dimension of their projects leaves open the question about the role that universities have in contributing to societal growth and developing the societal responsibility of their non-academic partners.

VII. CONCLUSION

The study's findings show that the CBL format that incorporates a real-life socio-technical problem in an engineering course fostered a broad and diverse understanding of professional responsibility. Further research will be conducted in the academic year 2021/2022 to follow-up on the findings of this first course iteration. The study will explore in more depth how the emphasis on ethics and responsibility coming from the student teams influences in turn the stakeholders bringing such challenges, and how to navigate the process of developing a socio-technical solution for stakeholders that have varying degrees of knowledge and interest in the ethical dimension of their products and processes.

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