Chapter 10

# Three European Experiences of Cocreating Ethical Solutions to Real-World Problems Through Challenge Based Learning

*Diana Adela Martin, Christian Herzog, Kyriaki Papageorgiou and Gunter Bombaerts*



## Abstract

The chapter presents the implementation of ethics education via challenge-based learning (CBL) in three European settings. At TU Eindhoven (the Netherlands), a mandatory first-year User, Society, and Enterprise course on the ethics and history of technology offers a CBL alternative on ethics and data analytics in collaboration with internal student and research teams. The University of Lübeck (Germany) initiated the project CREATE – Challenge-based Learning for Robotics Students by Engaging Start-Ups in Technology Ethics, which enables 60 students in Robotics and Autonomous Systems to integrate ethical and societal considerations into technological development processes, in cooperation with start-ups from a local accelerator. In Spain, CBI-Fusion Point brings together 40 students from business and law (ESADE), engineering and technology (Polytechnic University of Catalonia), and design (IED Barcelona Design University) for an innovation course focused on the application of CERN-developed technologies to real-world problems. The chapter documents the process of setting up three CBL courses that engage students with grand societal topics which require the integration of ethical concerns from the design stage of technological development. The authors also reflect on the challenges of teaching ethics via CBL and the lessons they learned by delivering experiential learning activities rooted in real-life challenges and contexts marked by high epistemic uncertainty. The contribution reflects the transition to

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remote teaching and presents strategies employed to enhance online communication and collaboration. The chapter thus provides guidance for instructors interested in teaching ethics via CBL and recommends further lines for action and research.

*Keywords*: Ethics; societal responsibility; sustainable development goals; education for responsible innovation; student engagement; stakeholders; online education; engineering education

## Introduction

Our contribution presents the implementation of Challenge-based Learning (CBL) in three courses of engineering ethics, set in three different European settings.[1] At TU Eindhoven (the Netherlands), a first-year User, Society, and Enterprise course on the ethics and history of technology offers a CBL alternative dedicated to ethics and data analytics. Students work in groups on real-life cases provided by external stakeholders, having to analyze the ethical aspects of a technological innovation and recommend technical and ethical solutions. The University of Lübeck (Germany) initiated the project CREATE – Challenge-based Learning for Robotics Students by Engaging Start-Ups in Technology Ethics, which enables 60 students in Robotics and Autonomous Systems to integrate ethical and societal considerations into technological development processes, in cooperation with start-ups from a local accelerator. In Spain, CBI-Fusion Point brings together 40 students from business and law (ESADE), engineering and technology (Polytechnic University of Catalonia), and design (IED Barcelona Design University) for a CBL innovation course focused on the application of CERN-developed technologies to real-world problems.

In structuring our contribution, we are guided by Goodlad's (1979) model, according to which the main curricular components pertain to learning goals, content, and experiences. As such, the chapter opens with a background overview of recent calls in engineering ethics education to foster societal engagement through experiential involvement in real-world challenges, highlighting the rationale for adopting a CBL teaching approach. The chapter proceeds with a description of how ethics has been implemented via CBL in the offline and online format in the three university settings that are the subject of the present contribution. The focus lies on presenting the setup of each course, including the main challenges brought to students, the learning goals and structure of the course, as well as the role of the stakeholder. The final sections reflect on the challenges encountered and the lessons learned, before tracing further directions for research at the institutional, teacher, student, and stakeholder level explores the effectiveness of teaching ethics via CBL.

The chapter responds to the "paucity of clear documentation regarding what and how ethics is taught" (Fore & Hess, 2020, p. 1357) and to recommendations about the development of immersive learning activities that rely on real-life scenarios and the input of external stakeholders (Martin, Conlon, & Bowe, 2021). The aim is to provide insights into the rationale and goals for teaching ethics via CBL, how CBL elements can be adopted in ethics instruction, the challenges such efforts may face, as well as the benefits that instructors and students who participate in CBL ethics activities can expect. Overall, the contribution puts forward recommendations for instructors or program chairs interested in adopting CBL activities emphasizing ethics, as well for researchers aiming to further the pedagogy of CBL.

## Background

### *Ethics Instruction: From Hypothetical to Real-Life Contexts*

The education of engineering ethics has traditionally emphasized hypothetical dilemmas which an engineer might encounter in her practice (Bielefeldt, Canney, Swan, & Knight, 2016; Martin, Conlon, & Bowe, 2019; Verbeek, 2006; Verrax, 2017). The resolution of these dilemmas is typically cast as the outcome of a straightforward heuristics that appeals to the provision of professional codes or ethical theories and principles (Harris, Pritchard, & Rabins, 2009). Basart and Serra (2013, p. 179) capture the spirit of this approach by noting that it "is usually focused on engineers' ethics, engineers acting as individuals." The goal of ethics instruction is in this case strongly focused on enhancing students' knowledge of professional codes and their moral reasoning and character development, as to enable identifying the right course of individual action. There is a high emphasis on preventing disasters and enhancing safety, which require the exercise of professional responsibility (Davis, 2006; Harris et al., 2009). Popular topics featured in hypothetical dilemmas include conflict of interest, integrity of test data, trade secrets, gift giving, and opposing immoral managers (Dempsey, Stamets, & Eggleson, 2017; Watkins, 2017).

It has been argued that this approach puts forward a narrow conception of engineering ethics as a "kind of behavior internal control" (Ladd, 1982). It is deemed insufficient for making agents understand their moral responsibility or take a proactive stance in ensuring that technological developments promote human welfare (Hansson, 2017; van der Burg & van Gorp, 2005). This is also due to the neglect in the engineering curricula of key societal themes revolving around participation, citizenship, politics, and policy (Pritchard & Baillie, 2006, p. 564). There is thus a need to broaden the education of ethics to include issues such as future directions in technological development, sustainability, poverty and underdevelopment, security and peace, social justice, bioethics, nanoscience, responsible innovation, and social responsibility (Bielefeldt et al., 2016; Guerra & Rodriguez, 2021; Martin & Schinzinger, 2013; Morrison, 2020; Rottmann & Reeve, 2020). This requires reflection not only about *what* ethical topics should be the subject of instruction but also on *how* to teach ethics. As such, a growing number of voices call for shifting the focus from hypothetical teaching approaches to more creative, affective, reflexive, critical, situated, community-oriented, and experiential instruction (Bissett-Johnson & Radcliffe, 2019; Martin, Conlon, & Bowe, 2021; Pedretti & Nazir, 2011; Stransky, Bodnar, Cooper, Anastasio, & Burkey, 2020). Such a shift is especially important given that engineering students were found to express significantly lower concern for society than students from other disciplines (Sax, 2000), consider it is unrealistic to expect engineers to have an ethical behavior (Stappenbelt, 2013), hold declining beliefs about the importance of public welfare (Cech, 2014), and fail to recognize subtle ethical dilemmas (Shuman, Besterfield-Sacre, & McGourty, 2005).

### *Rationale and Goals for Teaching Ethics via CBL*

Students can get a more complete exposure to engineering ethics in ill-structured learning environments that contain real-life scenarios with external stakeholders (Bairaktarova & Woodcock, 2017; Martin, Conlon, & Bowe, 2021; Valentine, Lowenhoff, Marinelli, Male, & Mubashar Hassan, 2020). Ill-structured learning environments tolerate conflicting goals, multiple forms of problem representation and solution paths, as well as nonengineering success standards and constraints (Gutiérrez Ortiz, Fitzpatrick, & Byrne, 2021; Jonassen, Strobel, & Lee, 2006). They also make use of distributed knowledge and collaborative activity systems, placing a high importance on experience (Jonassen et al., 2006). Thus, the epistemic features of engineering practice can be more adequately rendered (Martin et al., 2019). Real-life scenarios can also correct the "problem of professional distance" arising when student activities emphasize individualism and are divorced from features of current practice (Perlman & Varma, 2001, pp. 6–7). Such scenarios contain authentic professional problems, thus raising students' awareness of the type of ethical situations they might encounter in the workplace or would have to consider at the design stage of a technological artifact (Davis & Yadav, 2014). Building such deep understanding of practice into the curriculum has the potential to strengthen ethics education (Trevelyan, 2010).

CBL responds to the need for a change in the way ethics is taught, toward the inclusion of real problems of societal significance. A literature review of CBL pedagogy found that it favors content areas rooted in societal themes of global importance, to which solutions with a local focus and applicability are proposed by students (Gallagher & Savage, 2020). Furthermore, it sets to contain real-world challenges that students have to address, oftentimes in cooperation with external stakeholders (Gallagher & Savage, 2020). CBL approaches are thus more supportive of the societal responsibilities to be pursued by engineers, related to enhancing the quality of human life, the well-being of the community, or the vitality of the ecosystem (Bowen, 2009; Doulougeri et al. this volume).

### *Learning Goals of CBL Ethics Instruction*

Teaching ethics via CBL can make students aware of the "mutable social arrangements" for decision-making about the development and use of technology, which is considered a joint responsibility of engineers and the different stakeholders involved or affected by it (Devon, 1999). Thus, CBL contributes to learning goals set for improving the *moral situatedness of* students, by allowing students to see their work through the eyes of the community (Haws, 2001) and to understand the social relations of expertise in connection with technology management and decision-making (Devon, 1999; Gorman, 2001).

With students proposing and developing solutions to real-life challenges, CBL also favors learning goals related to *moral design*. Teaching ethics via CBL prompts students to consider how values, as well as modes of use and interaction, can be implicitly or explicitly inscribed into engineering artifacts at the design stage (van de Poel & Verbeek, 2006; Verbeek, 2008). Moral design fosters reflection about the ethical considerations that may emerge when formulating requirements, specifications, and criteria during the design of an artifact, assessing trade-offs between the different emerging criteria and taking a stance on what would constitute an acceptable trade-off (van Gorp & van de Poel, 2001).

As CBL is focused on tackling real issues, another significant learning goal supported by this approach targets *moral agency and action*, by seeking to empower students to reshape the social, economic, and legal context of practice (Martin, Bombaerts, & Johri, 2021) or encouraging students to take an activist stance "for what is right, good and just" as responsible innovators or entrepreneurs (Hodson, 1999; Karwat, 2020; Karwat, Eagle, Wooldridge, & Princen, 2015).

The learning goals of developing moral situatedness, moral agency, and moral design have been overlooked or not explicitly mentioned in popular handbooks used in engineering ethics education (Harris et al., 2009; Martin & Schinzinger, 2013; van de Poel & Royakkers, 2011), highlighting the potential of CBL to broaden traditional ethics instruction.

## Teaching Engineering Ethics via CBL

The deficits associated with teaching engineering ethics via hypothetical or disaster-oriented scenarios resonated with the three course leaders, who found that ethics is oftentimes too theoretical in nature to the detriment of familiarizing students with the features of day-to-day engineering practice and the ethical implications of their work. The authors believe that exposure to real-life ethical dilemmas arising in the design, development, operation, or use of engineering artifacts can provide a meaningful educational experience. This can be achieved by implementing CBL approaches in the education of ethics.

All three experiences recounted below share three main CBL characteristics purporting to the content of their course, the role of the student, and the course design (Table 10.1).

### *The CBL Experience of University of Lübeck*

At University of Lübeck (Germany), the second author initiated the CBL project CREATE – Challenge-based Learning for Robotics Students by Engaging Start-Ups in Technology Ethics in the winter term of 2020/2021. The project affords to teach a maximum of 60 students how to integrate ethical and societal considerations into technological development processes, in cooperation with

Table 10.1. Main CBL Components of Engineering Ethics Educational Initiatives.

| Categories | Features |
|---|---|
| Course content | (1) Addresses grand societal challenges from an ethical and technical perspective (energy transition; sustainability; technological revolution)<br>(2) Based on input provided by real stakeholders |
| Student role | (3) Confronts students with real-life challenges<br>(4) Definition of working problem |
| Course design | (5) Encourages contextual and real-life perspective-taking, instead of relying on hypothetical scenarios or historical disaster cases<br>(6) Fosters the development of sociotechnical skills and knowledge<br>(7) Groups students to work on collaboratively designed solutions |

start-ups from a local accelerator. This takes place in a mandatory course offered in the third semester of the study program in Robotics and Autonomous Systems.

**Course Setup**

Since 2016, the University of Lübeck gradually established a dedicated research group and educational activities addressing the ethical and societal implications of (mostly AI-based) technology. The amendment of both the curriculum and course regulations of the study program Robotics and Autonomous Systems opened the possibility to transform an immensely popular elective seminar entitled "Ethics of Innovative Technologies," cf. (Herzog, 2018), into a mandatory course called "Ethics of Technology." This change meant that the number of students that needed to be accommodated increased from about 15 to 60. This called for a semi-scalable course structure that can facilitate a hybrid of plenary and smaller group discussions and working phases. The aim of setting up the course in the CBL format was to make its contents more immediately relevant to engineering practice, while maintaining free and open-minded discussions. CBL was also seen to equip future engineers with the skills to identify and systematically deliberate on the ethical implications stemming from concrete system designs and technological solutions.

To support his vision about the goals of the new course, the second author aimed to establish collaborations with external partners with experience in technology development. For this, he reached to the Gateway49 start-up accelerator, which is offering entrepreneurs a structured program toward minimal viable products and can be considered an important asset in the thriving technology ecosystem comprised of the University of Lübeck, its surrounding partners and collaborating institutions and companies. Gateway49 is an example of how different stakeholders from a university's ecosystem interconnect to support novel technology and business ideas with a focus on value-based change.

Students get to engage with start-ups active in ethically rich fields, but they can also reflect beyond the start-ups' remits as to identify considerations and lines of actions that would strengthen their ethical mission. Consequently, the course's focus rests on the ethical dimensions of daily engineering practice and problem-solving.

**Stakeholder Role**

The role of the participating start-ups is to offer the opportunity to identify ethical challenges rooted in one of their value-based innovation projects and to commit their time *pro bono* to interact with students as they address the challenge. Given that the course does not yet benefit from a dedicated learning space, the partnering start-up accelerator can offer their space based on agreement.

For the first CBL run of the novel course on the "Ethics of Technology," five start-ups committed to support student groups by providing real-life challenges (Table 10.2).[2] To ensure the feasibility of the voluntary commitment of the start-ups, there were seven 45-minute meetings with two student groups. The meetings followed the format of a Q&A session, with students preparing questions and representatives of the start-ups answering to the best of their knowledge and considerate toward limitations brought by sensitive areas such as intellectual property.

Table 10.2. Participating Start-Ups in Winter Term 2020/2021

| Start-Up | Brief Description |
|---|---|
| food21 | Predictive analytics for food sales and production to minimize food waste. (https://food21.de) |
| mobOx | Deep learning-based, mobile blood analysis for emergency medical services with lab-grade accuracy. (https://mob-ox.de/) |
| ReHero | A deep learning-based multisensor fusion arm band for recognizing and visualizing minimal and intended hand motions to provide positive feedback in rehabilitation. (https://www.gateway49.com/startup_rehero.php) |
| Bareways | Off-highway navigation fusing big data to provide safe navigation of potentially hazardous roads. (https://bareways.com) |
| Natix | Edge AI for urban camera-based surveillance, such as parking lots, crowd density estimation, etc. (https://www.natix.io) |

**Learning Goals and Deliverables**

The course aims to achieve the following learning goals:

(1) Students understand the fundamentals of the ethics of technology and AI. They know the most common ethical and societal issues in relation with current and emerging technologies.
(2) Students can relate conceptual ethical implications to practical, applied examples.
(3) Students understand the complexity of processes of technological innovation within an ethical and societal context. They are able to communicate and debate socioethical questions in technology in interdisciplinary groups.
(4) Students can analyze complex interdisciplinary issues in technological innovation with regards to their ethical/societal implications.
(5) Students can conceive of and evaluate innovative (non-)technological solutions with respect to ethical and societal implications.
(6) Students embrace and commit to the ethical and societal relevance and responsibility of their chosen career path.

Students are asked to provide a portfolio of deliverables, for each of which feedback is provided in terms of a comment and a grade. The individual grade for each deliverable contributes to the overall grade obtained for the course: (i) Fortnightly throughout the course, each student group is asked to reflect on the course's current topic in relation to their stakeholder project and document their thoughts on a single slide, which may consist of a mind map, a structured list of bullet points or even a creative drawing. (ii) The major deliverable consists in a project report to be handed in by each group at the end of the term. The report should strike a balance between being a collaborative effort as well as showcasing individual work. It should document the analysis of a specific ethical challenge as well as well-argued proposed options for acting upon this. Extensive feedback is provided with an explicit request to incorporate this for an updated version of the report. (iii) This updated report should then be condensed into a poster for public exhibition as a final deliverable.

In terms of grading the deliverables, different approaches were pursued for deliverables (i) to (iii). For the reflection slides (i), assessment criteria were communicated to strongly rely on the level of detail endorsed when problematizing. At this point, no solutions were sought, but rather a clear and comprehensible line of thought in investigating potential ethical pitfalls. The report (ii) was required to consist of both an introduction and conclusion (~500 words each, written collaboratively) as well as individual chapters (~1,250 words) that link together in a coherent narrative. Students were given the opportunity to hand in exercise chapters before Christmas and receive a test grading on these. Assessment was split in three different domains (clarity and structure, understanding and use of literature as well as independence, critical analysis and relevance). Grade ranges were communicated in terms of the qualitative criteria to be met. For instance, in order to achieve a very good grade, in the assessment domain corresponding to clarity and structure, students were required to formulate precise statements and present clear lines of argumentation in connection with an unambiguously highlighted main thesis.

**Course Structure**

In order to meet the learning goals set for the course, the author set the following learning activities:

(1) *Stakeholder meetings,* whereby students identify challenges and potential solutions in conjunction with the business and technological case of the external partners. This activity is facilitated by the cooperation of the start-ups, through regular 45-minute meetings. The meetings are moderated by teaching assistants (TAs). Students come prepared with questions that are informed by course materials or that arise from group and plenary discussions held during topical meetings in the absence of start-up representatives (learning goals 1, 2, 3, and 6). The ongoing series of shorter stakeholder meetings clearly helped in gradually establishing a trustful atmosphere between students and representatives of the start-ups. This consequently uncovered the potential for students to contribute with a specific ethical analysis that can be of relevance to the participating start-ups.

(2) *Topical meetings,* taking place in between stakeholder meetings, whereby students discuss in plenary or groups how the topics studied link to the technological innovation or business challenge posed by their respective start-up. The second author uses a flipped classroom approach (Flaherty & Phillips, 2015) to guide students in their engagement with topics from the ethics of technology and AI. Three topical meetings precede the first stakeholder meeting to provide foundational knowledge in the ethics of technology. In the later weeks, students can choose between different topics to increase the relevance of their approach. Before each topical meeting, the student groups prepare a poster slide documenting their initial thoughts based on questions prepared by the TAs (learning goals 1, 2, 4, and 5).

(3) *A project report,* which reflects cumulative insights and results that have been developed into options for action recommended to the start-ups (learning goal 5).

(4) *A public exhibition of student projects*, which is designed to boost motivation (EDUCAUSE Learning Initiative, 2012) and facilitate exchange with other external actors (learning goal 3).

This course structure allows the instructor to alternate between activities advancing the student groups' progress on identifying and working toward solutions of a challenge in conjunction with their start-up, culminating in a project report, and activities that advance the students' general understanding of issues in the ethics of technology and AI. The latter can and should, of course, also contribute to the students' project work, elevating knowledge about existing issues, conceptual approaches, and potential technical and non-technical solutions.

Ideally, all learning activities would have been conducted in person, including the preparation of posters showcasing the groups' reflection on certain topics. However, due to the pandemic, the topical meetings had to be held via the open-source integration of BigBlueButton in the e-learning platform Moodle, while Webex was used for the meetings with external stakeholders. The use of the online meeting platforms made plenary discussions more difficult. However, even though frequently only a few students participated in these large group discussions, the quality of the contributions was not negatively affected by the online format.

## *The Experience of CBI – Fusion Point*

In Spain, Fusion Point (FP) is at its seven iteration of Challenge-Based Innovation (CBI-FP) a CBL innovation course that brings together approximately 40 students from business and law (MBA, ESADE), telecom engineering and computer science (BA, final year, Polytechnic University of Catalonia) and design (BA, final year, IED Barcelona Design University). This is a 12 ECTS course that runs from September to December. Students get to use the unique space of CERN and the cutting-edge technologies of the scientific institution to develop their own project focused on a theme of current importance. In addition, the course allows them to experience the innovation process from start to finish and the inherent high levels of uncertainty and frustration, and also facilitates their interaction with people with different backgrounds, actual users and various stakeholders in a real-life context (Papageorgiou et al., 2021). Since 2017, the course formulates challenges around the UN Sustainable Development Goals.

### Course Setup

A defining characteristic of CBI-FP is bringing together three schools with different disciplinary backgrounds. Since the beginning of the course in 2014, the students have worked in flexible spaces in the three different school campuses, but also off-campus, while field research is conducted. This flexible and unbounded learning space situates learning in the real world and integrates it with existing societal processes (Papageorgiou et al., 2021, p. 7). Except for the 2020 edition of the course executed during the pandemic, students also benefitted from working in the dedicated learning space that fosters collaboration and experimental innovation at CERN's IdeaSquare.

During the autumn of the academic year 2020–2021, students collaborated online with CERN scientists to address four current major social issues. The projects included proposals on urban mobility, remote work, counteracting fake news, and education and learning (Table 10.3). Each challenge was developed by two teams of students from different universities who defined them according to sustainable development goals. The students' innovation journey takes place over 16 weeks.

Table 10.3. Team Projects in Autumn Term 2020/2021

| **Challenge area** | **Student Team** | **Project Description** |
|---|---|---|
| Urban mobility | Myrmex | The *FUTO – Modular public transport* project aims to replace large metro or tram carriages with self-driving pods |
| Urban mobility | Nicola | Project *MobiNou* develops a semi-autonomous, micromobility solution for people over the age of 65, to transport them along a set route |
| Remote work | Feynman | *Preelio* is a system for assessing motivation during company presentations, classes and video conferences. |
| Remote work | Lamarr | *TeamBox* is an app designed to help employees bond with their company and help hybrid teams working from home remain motivated. |
| Education and learning | Dirac | *Savant* is a program that adds video to calls to facilitate communication with autistic persons. The system recognizes emotions and speech and enables them to ask for help when necessary. |
| Education and learning | Piaget | *Coco* is an intelligent classroom assistant which aims to encourage project-based self-learning |
| Infodemic | Lovelace | *WikiFacts* is a plug-in that confirms the content of social media posts on the basis of user interaction |
| Infodemic | Shannon | *Infodemics* is a videogame for children aged 8 to 12 that aims to underline the importance of confirming information to avoid fake news. |

**Stakeholder Role**

The main stakeholder involved in CBI-Fusion Point since the start of the program is CERN. Students visit CERN three times during the course and through the help of IdeaSquare staff they are connected to researchers working in fields relevant to their technology of interest and get to use the lab's technical facilities. Students are encouraged to engage with CERN's scientific staff throughout the course, and at the beginning of the course there is a presentation providing guidelines for effective communication.[3] In addition to help connecting students with specific technologies and people, the IdeaSquare team offers students talks and workshops on innovation-related topics and methodologies that are informed or inspired by the work of CERN personnel.

Apart from CERN, CBI-FP engages a variety of stakeholders depending on the specific challenge the students must tackle. For example, during the autumn term of 2020, for the challenges on the theme of urban mobility, students also worked closely with Transports Metropolitans de Barcelona.

**Learning Goals and Deliverables**

The overall aim of the course is to enhance creativity and innovation, preparing students to create proof of concepts that make a positive contribution to a societal challenge and are sustainable by being further developed into start-ups. As such, the learning goals set for the course are as follows:

(1) Develop highly futuristic, technologically feasible ideas that have the potential to challenge the status quo in socially and globally relevant human centric challenges.
(2) Develop skills in applying design thinking tools and methods and product design in a practical real-world project.
(3) Develop skills in moving ideas into testable, tangible prototypes quickly.
(4) Develop skills in interdisciplinary teamwork and communication.
(5) Learn how to collaborate in a diverse and international research organization.

At the end of the course, students are expected to produce three main deliverables: (1) a project dossier, (2) a video of the final concept, and (3) a personal reflection. In addition, students exhibit a functional prototype during the final presentation. The project dossier consists of a research report, students' design proposals, a description of their final solution, a business model, and technical report. For example, the 2019 edition of CBI-FP focused on tackling SDG11: Sustainable Cities and Communities. One student team working on SDG 11-Target 6 – reduce the environmental impact of cities – focused on air pollution. Their solution was GreenCubi, a mobile green space that can be deployed in cities to improve air quality. During the final presentations and prototype expo that took place at CERN's Globe of Science and Innovation and IdeaSquare, the students presented a functional prototype of GreenCubi. Subsequently, in their 59-page-long final project dossier, they described how they understood the problem of urban air pollutants and refocused the broad challenge they were originally given to "How might we mitigate children's exposure to harmful pollutants from motorized vehicles in outdoor spaces in Barcelona." They also describe existing solutions before they a detailed description of their own solution.

**Course Structure**

Students are grouped in small multidisciplinary teams (five to six people) and each team has three coaches, one from each participating school. The students meet on a weekly basis during three types of learning activities (workshops, seminars, and coaching sessions). As mentioned above, they also travel to CERN three times during the course for a total of 15 days. At the end of the course, there is a final expo in which students present the results of their innovation journey and their proof of concept. The following elements are included in the design and execution of CBI-FP:

(1) *Seminars or "knowledge pills":* Moving away from traditional lectures, CBI-FP includes a small number of short seminars (typically max 1.5 hours) on topics that are specific to the overall challenge of the course or pertains to an innovation method that they are encouraged to apply. Oftentimes, these "knowledge pills" are delivered by guest speakers or stakeholders.
(2) *Workshops:* On average, there are around 10 workshops delivered during CBI-FP that help students dive into a specific issue related to their final innovation output. Workshops are typically 3 hours long and involve teamwork and hands-on activities.
(3) *Coaching sessions:* In general, student teams meet with their coaches biweekly to have a 45-minute session to discuss the state, deliverables, and strategies for the successful completion of their projects.
(4) *Teamwork:* A dedicated space and time for teamwork is allocated to the students of Thursdays, in orchestrated formats through workshops or self-directed while other teams are in the coaching sessions.
(5) *Field trip to CERN:* The students visit CERN three times during the course for a total of 15 days. The first visit focuses on getting to know CERN and its facilities, the second one aims to facilitate interactions with local stakeholders that can help enhance the links between the students' ideas and CERN technologies. These two trips are relatively short (2.5 days each) in contrast to the final one toward the end of the course that is 10 days long and where students prepare for their final presentations and expo.
(6) *Intensive weeks:* There are three intensive weeks in CBI-FP where the students spend the entire day working together. These weeks either precede or overlap with the three visits to CERN.
(7) *Check-point presentations:* At the end of each intensive week, the student teams present what they learned to the entire academic team and course stakeholders.
(8) *Gala/Exhibition:* It is the dedicated virtual showcase exhibiting the projects developed by students and it normally occurs at CERN.[4]
(9) *Academic team meetings:* In order to better manage all the activities during CBI-FP, the academic team has regular meetings to reflect and discuss the running of the course. These meetings take place weekly during the course, with three additional meetings outside of the course delivery, totalling an average of 11 yearly meetings. At the end of each edition, the role of the meeting is to reflect on the main challenges and lessons learned while delivering the course, while before the course begins, the meeting focuses on organizational aspects (Papageorgiou et al., 2021).

### *The Experience of Eindhoven University of Technology*

Eindhoven University of Technology (the Netherlands) provides a mandatory sequence of 4 USE (User, Society and Enterprise) courses for 20 out of 180 credits for BA students of all departments. The sequence opens with a 5 ECTS USE basic course on the ethics and history of technology, offered yearly to the approximately 2000 first-year students. In the second or third year, students choose one out of 16 learning lines, comprising three courses totalling 15 ECTS, on a particular theme or technology such as "The Future of Mobility" "The Secret Life of Light," "Patents and Standards," and "Responsible Innovation for the World" (Bekkers & Bombaerts, 2017).

In the academic year 2018–2019, a first CBL version was offered as a 5 ECTS course option to 240 USE basic students. Although the course was found to foster intrinsic motivation, students reported a lack of support when they were nudged toward developing technological solutions (Bombaerts et al., 2021). In this section, we report on the 2020–2021 version as a next step in the experimental process of providing CBL engineering ethics education. The "E$^3$Challenge2" course (E$^3$ stands for Eindhoven Engineering Education) was designed as a 10 ECTS course, with 5 ECTS on the ethics of technology and 5 ECTS of data analytics. Compared to the previous CBL version of the course where students had only ethics and history teachers, now there was a team of ethics and data analytics teachers. The course was offered for 10 weeks to 43 students from different engineering departments. Students were asked to apply and contextualize the data analysis skills they developed during a previous dedicated course to a real-life challenge. As such, the "E$^3$Challenge2" built on the previous technical knowledge as to further develop students' technical appraisal of how and why data are generated, as well as raising their awareness about the constraints inherent to the data analysis process that are rooted in ethical considerations related to users, society, and enterprise.

#### Course Setup

Over the years, the USE learning line underwent several redesign processes, with the overall goal of better supporting students' self-regulated learning (Vansteenkiste, Sierens, Soenens, Luyckx, & Lens, 2009). Following the tenets of self-determination theory, the course components were designed to enhance the autonomy, relatedness, and competence of students through the introduction of real-life challenges in cooperation with external stakeholders (Bombaerts et al., 2021). As such, the course aimed to give students the choice to opt for a case matching their interest (autonomy), to make a link to the research and teaching topics within the university's community (relatedness), and to meet the potential interests of different students from different programs (competence development).

For on-campus teaching, students can make use of the university's dedicated environment Innovation Space, which was launched in 2015 as a pilot initiative meant to support interdisciplinary teaching approaches, the integration of theory and practice, entrepreneurship and design (Reymen et al. this book). The

Innovation Space is now the central hub for CBL courses. During the academic year 2020–2021, the course took place online.

**Stakeholder Role**

To make the most of the university's ecosystem and to support the entrepreneurial initiatives of current students and staff, students worked on challenges brought by three stakeholders based at TU Eindhoven (Table 10.4). The stakeholders are represented by two student teams developing their own projects toward becoming a start-up and a researcher coordinating a project financed by the Dutch Research Council – NWO. All three challenges deal with data analytics aspects related to mobility, health, or energy, respectively.

The three stakeholders participated voluntarily and had four contact moments with students throughout the 10 weeks of the course. While the aim of the first meeting was to familiarize students with the context of the challenge, the three other meetings had a different role, with students presenting their intermediary or final proposal to address the challenge raised by the stakeholder. Each meeting had dedicated time for Q&As.

Table 10.4. Participating Stakeholders during Spring Term 2020/2021

| Stakeholder | Brief Description |
|---|---|
| 5G-Mobix | 5G-Mobix is a student team based at TU/e, 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 core scenario is that some of the sensors in the car 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 aim 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 TU Eindhoven, Maxima Medisch Centrum, and HRH diabetes Games. |
| Red | The student team RED was asked by TU/e to provide insights into how to be more sustainable. For this, it needs a model that can simulate the physical environment (main campus buildings), which will allow users to add and configure various technologies such as solar panels, wind turbines, and charging points. (https://teamred.nl/) |

**Learning Goals and Deliverables**

The course aimed to get students more engaged with ethics at the cognitive level. This encompassed an understanding of ethics both in its conceptual dimension and as ethics in action, in as much as what students are designing is rich in values. As such, the course's ambition was to foster an awareness of how values are linked to engineering design. The learning goals set for the course thus include the following:

(1) Identify a core data analysis problem and its scope.
(2) Identify the functional and nonfunctional requirements for a data analysis problem with reference to a USE context.
(3) Select and apply established suitable data analysis methods for solving the defined problem using the collected data.
(4) Present statistically relevant results and method overviews suitable for a given audience.
(5) Demonstrate self-reflective awareness of the technical and USE constraints on data analysis problems.

Students were asked to provide three deliverables. First, in the online version, students had to produce a report answering questions one to three, while for the on-site course version, they were encouraged to deliver hands-on, tangible products like maquettes, toolboxes, or demos. Students were coached to write an "executive summary" to learn to summarize the important message for the stakeholder. Second, students prepared a 15-minute presentation for the stakeholder, followed by 15 minutes Q&A, accounting for learning objective 4. Third, students were coached in writing a weekly reflection, documenting what they learned that week. The collection of these weekly reflections and a final reflection was the deliverable for learning objective 5.

For the "E$^3$Challenge2" offered by TU Eindhoven, students developed a data analysis linked to the line of activity of the stakeholders that could be further taken on. Student deliverables include guidelines for a safe and effective transition between direct and remote driving, a user test for finding the lowest driver reaction time given different visual and auditory information, a model to detect meal intake using data gathered from smart wearable devices, developing data packages for building owners to determine energy use and energy saving options. Both ethical and technical considerations informed these deliverables, with students reporting changing their strategy following testing to accommodate ethical considerations and values.

**Course Structure**

The course gathered an extensive and interdisciplinary team, made up of 14 teaching staff, three researchers observing the course, and three stakeholder groups. The roles of the teaching staff were distributed as follows: one ethics lecturer, one data analytics lecturer, three coaches, five expert generalists, and nine TAs (master students in ethics and/or data analytics or students preparing a master thesis in one of the cases).

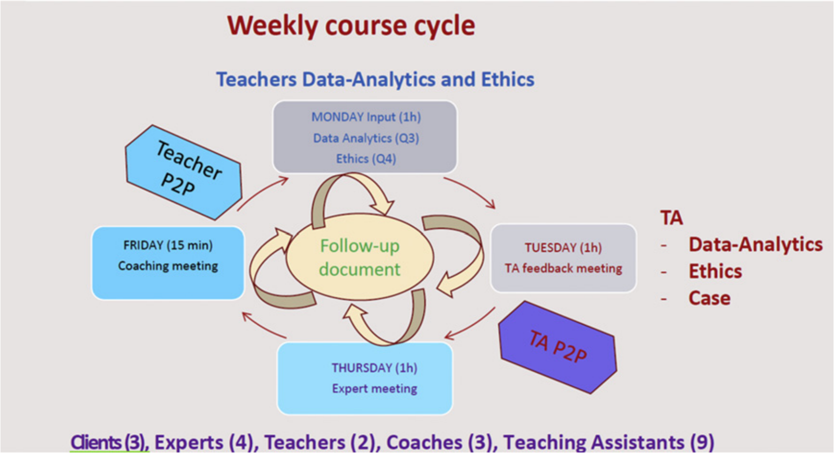


Fig. 10.1. Course Structure for the Course "E[3]Challenge2" (TU Eindhoven).

Per Fig. 10.1, the course comprised five types of learning activities dedicated to students, in addition to two weekly peer-to-peer meetings for the teaching staff:

(1) *Ethics workshops:* Each week, students participated in ethics-centered learning activities under the guidance of a specialist ethics lecturer. During these sessions, students practiced ethical reflection on topics relevant to their case and their assignment. The instructor prepared video lectures containing information about ethical theories, codes of practice and examples of ethical misconduct that students watch prior to attending. The workshops highlighted the ethical issues presented in the videos and accommodated further discussions about their implications or strategies to counteract them.
(2) *TA sessions:* These weekly sessions were grouped by case and had two major components. First, student teams gave and received feedback from other teams regarding their approach to solving the challenge. Second, a team of three data analysis and ethics TAs per case offered additional support to students in the form of feedback and advice. The TA sessions made extensive use of online breakout rooms that mix students from different teams working on the same challenge.
(3) *Coaching sessions:* Each case had an assigned coach who met weekly with each student team of four students for 30 minutes. During these sessions, students received feedback and guidance relevant to them as an individual or as a team on how they approach the challenge. The focus of these sessions is on the learning process (how the student is doing, how the student is learning), with the aim of supporting the students' self- and shared-regulated learning.

(4) *Expert meetings:* These are weekly tutorial-type sessions in which students discuss remaining questions and gain insight into how well they engaged with a particular topic. The meetings are facilitated by a mix of technical, ethics and educational experts, and sometimes the external stakeholders were also present. The meetings took place on the Spatial Chat platform, which allowed students to "move" and interact with the expert they wanted or follow the discussions of other groups, thus more closely mimicking an in-person meeting space.
(5) *Stakeholder meetings*: there were three meetings organized with the participation of external stakeholders. In the first week, stakeholders introduced the challenge and answered any questions students might have. An intermediary meeting was scheduled for the middle of the course, with students preparing a presentation on their tentative approach, for which they received feedback from the stakeholder. The final meeting took place in the last week, when students delivered their proposed solution, as an outcome of the work conducted throughout the semester. The solution to the challenge posed by the client addressed both its technical and ethical dimensions.
(6) *Peer-to-peer meetings:* every week, there were two different meetings dedicated to the academic team. Students did not take part in them. One meeting allowed the coaches and the ethics lecturer to support the work of the TAs, providing guidance when needed on their overall role and responsibilities and on the organization of the TA sessions. A second meeting brought together the experts and coaches to discuss notable aspects that came up during the week, identify potential causes for students' struggles and how to address them. Both meeting types fostered reflection on the experiences of the academic team, how to better support students, and the progress of the CBL course. The meetings created a feedback loop which contributed to the continuous improvement of the course as it unfolded.

As mentioned previously, this first iteration of the course took place exclusively online. Three online spaces were used. One such space is the official internal webpage of the course, where students could find all the formal information, such as the study guide, the assignment descriptions, and the information needed to prepare for the ethics workshops and activities. The other space is supported by the institutional MS TEAMS account, with channels for holding group meetings and feedback sessions, participation in the ethics workshops, the TA and coaching sessions, as well as in the stakeholder meetings. Finally, the Spatial Chat platform was used for the expert meetings.

## Lessons Learned

In what follows, we present the lessons learned from teaching and implementing CBL activities, considering the involvement of institutions, students, and stakeholders.

### *Institutional Support*

The authors agree that CBL courses require more human power, dedicated resources, and instructor flexibility than a non-CBL approach. It also benefits from a different infrastructure, consisting of specially customized learning spaces. Thus, successfully setting up and running a course in this format depends on the institutional support received and the commitment of the academic team.

The second author encountered more challenges than the other authors, as at the University of Lübeck he could count on less resources, such as TAs or a dedicated learning space. The lesser institutional support translated into a higher workload for the instructor. On the opposite side, as TU Eindhoven placed CBL at the core of its educational vision for 2030, the fourth author received financial support for running CBL educational experiments. The third author found that the workload of the teaching staff cannot be predetermined. Furthermore, a high level of flexibility and willingness to improvise and to adapt to needs and problems as they arise is required from the teaching staff (Papageorgiou et al., 2021). As such, a CBL course does not take only students outside of their comfort zone but also the instructors. With the change in how higher education subjects are taught and an increasing self-directed role of students comes a different role for the teaching staff. The third author's research showed an emergent set of skills which is becoming more valuable for teaching staff than delivering traditional lectures: coaching, facilitation, content curation, and learning experience design (Papageorgiou, 2021).

### *Student Experience*

In general, the real-life component of CBL instruction was received positively by students. At CBI-FP, the course was described by many students as a "life-changing experience," even though frustrating and difficult at times. Student evaluations of previous CBL ethics courses offered by TU Eindhoven also indicate that the approach enhanced students' intrinsic motivation and effort (Bombaerts, 2020; Bombaerts et al., 2021; Bombaerts & Spahn, 2021; Bombaerts & Vaessen, 2022). Engineering students also appear to invest more effort in the CBL version of the course compared with the non-CBL version (Bombaerts, 2020). Another positive outcome of CBL instruction points to the students' enhanced awareness of the importance of integrating both ethical and technical considerations for the data analytics solution they developed, per interviews conducted at the end of the 2020–2021 "E$^3$Challenge2" course iteration (Martin & Bombaerts, 2021). Similarly, at the University of Lübeck, most frequently mentioned positives include the stakeholder projects and the freedom to choose a challenge of one's own interest. The course's organization and group work were also positively mentioned.

The main criticisms brought up by students who undertook the CBL courses offered by TU Eindhoven and the University of Lübeck relate to the lesser time allocated to in-depth discussions and the need for more clarity about the assignments. This leads us to suggest that the open-ended and ill-structured nature of CBL activities benefits from being complemented by clear and detailed descriptions of the graded course components and what is expected of students.

In light of the open-ended and ill-structured problems that are at the core of CBL approaches, an important determinant of the success of a CBL course is how instructors react to and foster students' mindset. The authors found that the lack of predefined answers or of a standard strategy for addressing the real-life challenges can be intimidating to students or can lead to moments of frustration. At the University of Lübeck, final evaluations showed a decreasing interest in the subject prior to and after taking the course (2.7 ± 1.49 sd, avg.: 2.32 ± 1.23 sd and 3.12 ± 1.42 sd, avg.: 2.37 ± 1.27 sd, resp.). A potential reason may be the frustration with ethical challenges that do not allow for a clear solution, but rather demand a procedural kind of approach reminiscent with responsible research and innovation approaches (cf. Auer & Jarmai, 2017). This might be linked with the engineering mindset that favors certainty over vagueness.

The authors observed that students' frustration fluctuated during the course, encountering peaks in the first two weeks of the course and then again in the middle of the course. It is thus important to prepare students for what can be considered a positive state of frustration, which leads to growth and self-reflective learning experiences. As they navigate the course, students learn to make sense of the process of dealing with open-ended questions, similar to those they would encounter in their professional practice. During the initial peer-to-peer meetings at TU Eindhoven accompanying the course, the academic team discussed how to deal with frustration. An instructor might wonder whether s/he should intervene or not. In this case, the decision of the teacher theme was not to intervene and keep the frustration. It is important to note the difference between the frustration and uncertainty students might experience due to the organization of the course as opposed to the epistemic character of open-ended challenges and ill-structured learning environments.

The authors recommend that to prevent the first type of frustration, it is important for students to receive detailed information about the setup of the course, the type of support available to them, the role of different sessions and teaching staff, the type of deliverables expected, as well as the deadlines and contribution required from them on an individual and group level for the deliverables, the expectations for passing the course, and, finally, how to communicate with stakeholders and balance the feedback from the teaching team with that from the stakeholders. The information can be made available to students on the webpage of the course, via videos, and during sessions. Steps that should be considered are the design of a detailed and clear study guide that might include, among other, tips and tricks from former students and TAs, FAQs, clear and detailed instructions about each deliverable, with a focus on both format and content, as well as a clear and transparent grading rubric explained to both TAs and students to avoid the spread of contradictory information.

Frustration in an ethics-oriented CBL course can also arise due to engineering students' unaccustomedness to critical reflection in a societal context. This can potentially be attributed to a clash in scientific cultures that occurs when engineering students first engage with Humanities topics (Martin & Polmear, 2022).

For courses that have components drawing from the Humanities (ethical reflection and analysis, report writing), supporting students require additional tools or measures (such as the Ethics Canvas, cf. Reijers, Calvo, Lewis, & Levacher, 2016; the envisioning cards, cf. Friedman & Hendry, 2012) or having staff with a Humanities, STS, or Social Sciences background represented in the academic team.

### *Stakeholder Involvement*

CBL activities allow for leeway in the range and degree of specificity of the expected deliverables, given the characteristics of the student cohort. As students progress in their studies, more complex outputs can be expected. Being committed to a concrete ethical challenge associated with the line of activity or problem faced by a stakeholder may create confusion among students whether to focus on fulfilling the course's requirements or on addressing the challenge satisfactorily for the stakeholder. Ideally, these expectations would align, but as the evaluations of University of Lübeck suggest, there is still room for improvement.

More specifically, the teaching staff of the different universities observed fluctuating degrees of criticism of the students toward the stakeholders. While some student groups decided to confront the stakeholders with comparatively harsh objections and criticism at the beginning, including lack of data relevant for their assignment, stakeholder responses were quite effective in muting these, when alluding to the intense and complex challenges small businesses or student teams face, from regulation and meagre financial resources. In turn, teaching staff perceived it to be their duty to reencourage these students to remain critical without making it a habit to preemptively tone down reasonable objections by predicting potential counterarguments from the stakeholders. As the University of Lübeck's course involved the stakeholders on a fortnightly basis, it remained a challenge to guide the students in developing their own critical stance. It may seem that such a way of regularly involving stakeholders in the discussions can help to develop mutual understanding and to lead toward students adopting the role of "critical friends" – in fact, it at least seemed that this was the dominant stance adopted at the end of term. It should be noted that the stakeholders were not involved in the actual grading process at any time, but did provide informal feedback. TU/e invested time in coaching the stakeholders in their ethics role and how they should bring the ethics part in a way that fits the students' work. Fusion Point has created two new roles for staff, "industry relations" and "ecosystem architect," to help build the appropriate frameworks and enhance the participation of external stakeholders in CBI.

### *Online CBL Pedagogy*

When considering the online format, the authors found that it was more challenging to create a dynamic learning environment. For this, the fourth author found that relying solely on breakout rooms may not be enough. He recommends the use of online tools, such as Wonder, Spatial Chat, or Gather Town, which allow participants to talk with everyone and "walk around" the virtual space, and as such more closely replicate the movement in a classroom. The third author also recommends creating an online environment that would give students similar experiences to those they would have during an academic year taught on campus. Fusion Point developed a dedicated online space to offer involved stakeholders or the general public a virtual tour or virtual gala showcasing students' projects.[5] For the second author, there were advantages to delivering the course online. While he found that there might be less interaction between students during the online meetings, the online space can more easily accommodate more interactions outside the scheduled classes. The online space can also be used to emulate a dedicated learning space that does not currently exist physically.

## Future Directions

Connected to the lessons previously mentioned, we suggest conducting additional research exploring how the experiences of the four authors translate into other educational contexts, with different resources available or set in higher education institutions with different visions. Whether using CBL to teach ethics or other subjects, there is a need to go beyond individual experiences and ascertain on more rigorous grounds what are the institutional resources and incentives needed for supporting CBL, the guidance and professional development needed by instructors to engage with CBL, as well as how to navigate students' emotional responses to CBL, support their learning, and conduct the assessment of CBL components (Table 10.5).

## Conclusion

The teaching initiatives presented in this chapter meet the six imperatives of the recent Cork Amendment (2021) to the 2004 Barcelona Declaration, related to the values, context, uncertainty, change, limits, and vision for today's higher education for sustainable development. All three courses foster experiential learning rooted in real-life challenges and contexts marked by high epistemic uncertainty. They show how ethics was implemented in the engineering curriculum via CBL to enhance students' critical reflection and engagement with grand societal topics. As such, the three examples presented help convey to engineering students a broad understanding of the nature of their ethical responsibilities as future professionals and of the sociotechnical dimension of engineering practice (Bielefeldt et al., 2016; Martin, 2020; Morrison, 2020).

Overall, the chapter provides a useful documentation of the process of setting up a CBL engineering ethics course that responds to the need for best practice examples and provides guidance for novice instructors (Fore & Hess, 2020; Martin, Conlon, & Bowe, 2021). Furthermore, given the challenges of the transition to online education brought by the COVID-19 pandemic (Wahab, 2020), the chapter identifies online strategies that instructors can use to maintain

Table 10.5. Future Directions for the Research and Development of CBL Ethics Education.

| Level | Research and Action Areas |
|---|---|
| Institution | *Implementation and adoption*<br>(1) Appropriating the ethical vision of the institution and specific characteristics of its ecosystem into challenge-based learning (CBL)<br>(2) Determining the factors of an effective implementation of ethics via CBL (goals, rate of adoption, budget) |
| | *Physical and financial resources*<br>(1) Examining the number and contribution of teaching staff for CBL delivery<br>(2) Establishing the workload and time commitment of CBL teaching staff, congruent with the institutional vision and resources on how much % CBL to pay for<br>(3) Examining the impact of classroom space or room design on CBL instruction, including redesign strategies of buildings, (class)rooms or laboratories to fit the (ethics) CBL pedagogy<br>(4) Examining the role and impact of different CBL components in the online and on-site teaching, and what online elements can be kept<br>(5) Determining how to feasibly scale up CBL within an institution<br>(6) Providing structural support and the role of maker spaces (like TU/e's innovation space; see Reymen et al. this volume) |
| | *Incentives*<br>(1) Recognizing CBL experiments for promotion lines or informal recognition<br>(2) Introducing reward schemes (i.e., "CBL instructor of the year" award)<br>(3) Enabling links between education and research (student teaching assistants (TAs) are no cheap labor sources), but relevance for teachers' research input can balance out some extra teaching time<br>(4) Supporting educational research on innovative education<br>(5) Developing strategies for hybrid pedagogical approaches (CBL and non-CBL for bigger course teams) as to allow instructors to opt out from teaching via CBL |

Table 10.5. *(Continued)*

| Level | Research and Action Areas |
|---|---|
| Instructor | *Guidance and professional development:*<br>(1) Developing training materials and programs for the implementation and teaching of CBL<br>(2) Developing teaching resources and online repositories<br>(3) Popularizing best practice examples<br>(4) Developing peer networks and working groups for CBL instructors, within and across institutions, or hosted by professional associations and engineering education societies (i.e., SEFI, ASEE, IEEE, CDIO)<br>(5) Setting up mentorship programs or establishing within institutions contact persons providing advice on difficulties encountered, when they arise<br>(6) Examining the changing roles and skills required of teaching staff<br>(7) Developing the role of students as coaches (via paid TA functions or in courses in which students of different levels give each other feedback) and TA trainings |
| Student | *Learning and assessment*<br>(1) Examining the different outcomes of CBL ethics instruction (skills, knowledge, personal and professional identity) and allowing flexibility about learning objectives in changes to CBL<br>(2) Determining on what outcomes students should be assessed<br>(3) Developing methods and strategies for assessment of individual and group work in CBL ethics instruction<br>(4) Exploring strategies for ensuring the quality of the students' project work, as a graded course component and as an end product that is of merit to the external stakeholder<br>(5) Exploring ways to communicate and pass on to students the value of CBL<br>(6) Providing scaffolding to reduce complexity if challenges are too complex<br><br>*Emotional and personal experience*<br>(1) Examining how students emotionally experience CBL<br>(2) Determining what components of CBL ethics instruction students enjoy and engage with and those that they enjoy and engage less with<br>(3) Determining how much frustration is useful for students as well as adequate strategies and moments for intervention |

Table 10.5. *(Continued)*

| **Level** | **Research and Action Areas** |
|---|---|
| | (4) Determining the main profiles of students that struggle or strive with CBL, as well as strategies for both groups |
| | (5) Exploring ways to support students to embrace the change associated with CBL |
| Stakeholder | *Role and responsibilities* |
| | (1) Being aware of type of stakeholder (large firm, SME, start-up, university research group, student-team, NGO, individual citizen with a question) and adequately integrating the stakeholder type in the course design and setup |
| | (2) Involving the ethical review board in the choice of stakeholder and case and ensuring balance with the time needed and improvements of learning outcomes. As such, ethically sensitive research (i.e., medical) will not be combined with short-time projects |
| | (3) Determining strategies for identifying, establishing, or maintaining stakeholder partnerships |
| | (4) Identifying ways to align the needs and expectations of students, instructors with those of the stakeholders |
| | (5) Identifying ways in which stakeholder participation in CBL ethics activities fosters the ethical learning and social responsibility of the stakeholders |
| | (6) Identifying meaningful ways in which CBL can contribute to the development of local communities and of the ecosystem of the higher education institution |
| | (7) Determining how stakeholders can or should be involved in grading the students |
| | (8) Agreements on intellectual property |

students' engagement and to more closely mimic real-life learning environments. Using online platforms and tools with different functionalities (Spatial Chat, Wonder, Gather Town, The Ethics Canvas, virtual exhibitions, and breakout rooms) can address the deficits of online communication and collaboration (Saniie, Oruklu, Hanley, Anand, & Anjali, 2015).

Although the experiences we describe are set in Engineering programs, the features of the courses related to their setup, structure, and learning goals can serve as inspiration for instructors searching to implement ethics instruction online or in-site via CBL in other disciplines, such as business, management, or accounting.

## Notes

1. Henceforth abbreviated as CBL.
2. Note that some start-ups may have changed names already now. Some of the start-ups listed here have not yet been properly founded as companies.
3. The guidelines are available at https://indico.cern.ch/event/941216/contributions/3954726/attachments/2077423/3488745/190912_Talk_to_experts_CBI.pdf.
4. The exhibition can be accessed at https://fusionpoint.eu/events-fusion/cbi-gala-2020/.
5. The virtual gala can be accessed at https://fusionpoint.eu/events-fusion/cbi-gala-2020/.

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