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Towards a Sociotechnical Reconfiguration of Engineering and an Education for Ethics : A Critical Realist Investigation into the Patterns of Education and Accreditation of Ethics in Engineering Programmes in Ireland

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Towards a Sociotechnical Reconfiguration of Engineering and an Education for Ethics:

A Critical Realist Investigation into the Patterns of Education and Accreditation of Ethics in Engineering Programmes in Ireland

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Thesis submitted for the award of Doctorate

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Abstract

The focus of this thesis is on the education and accreditation of ethics in engineering programmes in Ireland. This examination is placed in the wider cultural context of engineering education. The study benefitted from the support of the national accrediting body Engineers Ireland, and included 23 engineering programmes from 2 institutes of technology and 4 universities in Ireland which underwent accreditation between 2017-2019.

By using a Critical Realist frame, the study undertakes a multi-level investigation of the engineering education system that takes into consideration the individual level of single agents such as instructors and evaluators, the institutional level comprised of engineering programmes, as well as the policy level represented by the national accrediting body. Furthermore, through retroduction, the generative mechanism affecting the activity at these levels is explained to be the culture of engineering education and its valorisation of the technical over the social dimension of engineering, at societal level.

The analysis suggests that the lower weight of ethics and its unsystematic implementation in the engineering curriculum, as well as the challenges encountered in the teaching, implementation and evaluation of ethics for accreditation are rooted in a cultural perception of engineering as a "nuts and bolts" discipline. To dismantle the two distinct societal and technical cultures existing in engineering education, the study proposes moving from a treatment of ethics as a curriculum add-on towards a reorientation and development of engineering curriculum "for" ethics. Engineering education "for" ethics is a transformative process, which aims to challenge existing core assumptions and values promoted in engineering education. The study argues that measures targeting each of the aforementioned levels need to be considered in the process of reforming engineering education towards its identification as a socio-technical discipline.

Declaration

I certify that this thesis which I now submit for examination for the award of Doctorate, is entirely my own work and has not been taken from the work of others, save and to the extent that such work has been cited and acknowledged within the text of my work. This thesis was prepared according to the regulations for graduate study by research of the Technological University Dublin and has not been submitted in whole or in part for another award in any other third level institution. The work reported on in this thesis conforms to the principles and requirements of the TU Dublin's guidelines for ethics in research.

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DA Martin

Signature ___________________________________

Date 19.07.2020

Candidate: Diana Adela Martin

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CHAPTER 1 INTRODUCTION

1.1 Context of project

If one is asked to picture an engineer's day of practice, the image that comes to mind will probably be of a person developing a new product in a lab, carrying complicated technical calculations or choosing materials for building a hospital. One would probably not imagine that person reflecting about the values or prejudices that might be embedded in a product's design, or whether technological risks are distributed evenly among the different categories of users. Yet, ethical concerns are at the heart of engineering artefacts and technological developments.

Whether it is designing energy efficient buildings, an algorithm for a self-driving car that might kill its owner to save five lives of passers-by, or artificial hearts, which at present fit a lesser proportion of female users due to their small chest cavities, engineering involves value judgements and requires ethically aware engineers. But how do engineering programmes prepare students to take their ethical responsibilities to heart?

In our current society characterised by fast paced engineering and technological developments, ethics education becomes crucial for the formation of socially responsible engineers. In recognition of the role of ethics in complementing the pervasiveness of engineering and technological developments, the accreditation systems of engineering programmes in several countries have introduced ethics as a mandatory component of engineering education. Among these, Engineers Ireland (2007) introduced the requirement for an "understanding of the need for high ethical standards in the practice of engineering, including the responsibilities of the engineering profession towards people and the environment" as an accreditation criterion of Engineering Honours programmes.

In Ireland, although many engineering programmes have been deemed to have met the accreditation criterion dedicated to ethics, limited research has been conducted into the extent and effectiveness of the ethics education provided, as well as on how ethics is evaluated for accreditation purposes. The project has thus undertaken the first investigation in Ireland on the education of ethics in Engineering Honours programmes and its evaluation by the national accrediting body. The findings are intended to contribute to an enhanced implementation, teaching and accreditation of engineering ethics, by determining the main characteristics as well as the challenging factors underpinning the discipline. The study can also serve as a guidance in the implementation of ethics in countries where engineering programmes undergo accreditation or whose national systems of accreditation are in the process of adhering to the Washington Accord.

There is limited research on how ethics is being incorporated in the curricula of engineering programmes in Ireland, with a focus on the description of single modules dedicated to ethics (Fitzpatrick, 2010; Byrne, 2012; Byrne *et al.*, 2013). Published work in Ireland signalled that engineering students are not prepared to address the social dimension of sustainability (Nicolaou & Conlon, 2012). In regards to the process of accreditation, it has been highlighted the influence of accreditation reports in the development and introduction of new modules dedicated to ethics (Fitzpatrick, 2010), but also some of the challenges in evaluating the ethical outcome for accreditation by professionals who do not represent the community, nor have a background in social sciences (Conlon, 2008). There is a need to go beyond these dispersed observations and pursue a more integrative approach that examines the implementation and evaluation of ethics in engineering programmes in the national context.

All the while, international research shows that the current state of engineering ethics education is marked by a deep fragmentation of pedagogical approaches and confusion as to which approach is most suitable in preparing socially responsible engineers, with limited empirical findings to serve as guidance in the implementation and teaching of engineering ethics.

The project thus aims to fill this gap by examining the education of engineering ethics in several engineering programmes across the country and its evaluation process for the purpose of accreditation. In light of these findings, the ultimate contribution of the project is to provide national accrediting bodies and the wider engineering education community with a radiography of the current state of engineering education in Ireland, which can inform policy and measures targeting the enhancement of engineering ethics education.

1.2 Significance of research

Given the limited empirical research on engineering ethics education undertaken at national level, the project provides a unique insight into the education and evaluation of ethics education in engineering programmes in Ireland. On a national and international level, the research has the potential to guide engineering programmes in their implementation of ethics education. The project can also help accrediting bodies in the introduction and formulation of accreditation requirements purporting to ethics and in the evaluation of ethics for the purpose of accreditation.

By identifying the major features of the current landscape of engineering ethics education together with the challenges experienced by instructors and evaluators alike, the project offers insights on how the discipline can better prepare engineering graduates for their responsibilities towards society. The findings are meant to contribute to an enhanced engineering ethics education. They can benefit programme chairs, engineering instructors involved in ethics instruction as well as accreditation evaluators and representatives of accrediting bodies. The study can be of significance to several *Research Priority Areas* set by the Irish Government (2018), involving technologies that raise ethical issues for engineers such as robotics and artificial intelligence, data security and privacy, medical devices, sustainable food production, sustainable living and decarbonizing the energy system. *The Irish Humanities Alliance Interim Strategy Report* (2015) also points to sustainable development as an area where ethics can beneficially complement engineering. At the same time, the project is in line with the goal of the *National Plan on Corporate Social Responsibility* (2017), which aims to promote Ireland as a "Centre of Excellence for responsible and sustainable business practice through the adoption and implementation of best practice in Corporate Social Responsibility in enterprises and organisations" (Department of Business, Enterprise and Innovation 2017, p. 6).

Although the scope of research is limited to Irish Engineering Honours programmes, the findings have a wider application. They have the potential to guide engineering ethics practitioners across the globe, by contributing to the ongoing debate on the conceptualisation, implementation, teaching and evaluation of engineering ethics education.

1.3 Project aims

The project is guided by three main research questions. The first question asks how is ethics education incorporated in engineering Honours Programmes in Ireland? The second questions asks how is ethics education in engineering Honours Programmes evaluated for the purpose of accreditation by the panels appointed by the accrediting body Engineers Ireland? The third question has an explanatory role and asks how can the findings revealed by the first two questions be explained considering the broader context of engineering education?

Consequently, to address the aforementioned questions, three aims have been set for the project. The first descriptive aim is to examine the education of engineering ethics in

Engineering Honours programmes in Ireland, while the second descriptive aim is to examine the process of evaluation of ethics education for the purpose of accreditation. Furthermore, there is a third encompassing aim, of explaining the findings related to the education and evaluation of engineering ethics in light of wider structural contexts.

These aims are framed through a critical realist lens, described in chapter 4, which takes into account the complex nature of engineering education and places the practices of teaching and evaluation identified in the broader context of the cultural forces shaping them.

A clarification is needed before proceeding further. As mentioned, the study is focused on the examination of ethics education in the context of accreditation. The formulation of accreditation programme outcomes is taken into consideration by engineering programmes in the development of their curriculum and of the documentation prepared for the purpose of accreditation. It is important then to note that throughout the study there will often be a conflation between what is mentioned to fall under the scope of engineering ethics education and what is mentioned to fall under the scope of an accreditation outcome dedicated to ethics. In the case of Engineers Ireland's accreditation criteria, this is programme outcome E, while in the case of ABET, this is outcome 3.e.[1] While it is fair to say that ethics education falls under programme outcome E and is a significant component of outcome E, this outcome does not deal exclusively with ethics, as it includes also financial and business considerations. Whenever the conflation of the terms "engineering ethics education" and "programme outcome E" would be inaccurate, the term that serves best the scope and purpose of the ongoing analysis will be adopted.

[1] Beginning with the early 2000s, the signatories of the Washington Accord reshaped the accreditation process, by focusing on the attainment upon graduation of a set of learning outcomes. (Lucena *et al.*, 2008). At present, signatory countries as well as candidate countries must include and define similar graduate attributes, and must demonstrate that Engineering students of accredited programmes achieve these learning outcomes.

1.4 Thesis outline

The thesis starts with an introductory chapter, which looks at the context which motivates the present study in light of the research aims to be pursued. Chapters 2 and 3 are dedicated to the literature review. While chapter 2 looks at the theoretical underpinnings and empirical findings about engineering ethics education, chapter 3 examines ethics education in the context of accreditation. Chapter 4 outlines the research design, by first presenting the research questions and the aims and objectives set to address them, before placing the research in the theoretical tradition of critical realism. This will be followed by a presentation of the mixed method approach employed in the present study, a description of the selection process for the participants in the present study, as well as considerations about validity and reliability, ethics compliance and limitations of the study. Chapter 5 is focused on examining the conceptualisation of engineering ethics education, by exploring what type of curricular content is considered to fall under the scope of engineering ethics education, as well as the goals set in connection to ethics education. Chapter 6 examines the implementation of ethics education in the curricula of the participant engineering programmes in Ireland, by determining the weight given to outcome E in the curricula of the participant programmes and establishing its method of delivery. Chapter 7 is dedicated to an examination of case studies, which revealed themselves as a popular method of teaching engineering ethics. Chapter 8 determines the main curricular content themes purporting to ethics. Chapter 9 moves the attention to the process of evaluation of ethics for the purpose of accreditation, by examining the response of evaluation panels to the participant programmes' process of preparation for accreditation, with a focus on programme outcome E. Chapter 10 explores how the status of ethics in engineering curricula is articulated by programmes and instructors. Chapter 11 builds on all the data collected in order to put forward a retroductive explanation of the cultural aspects that are seen to contribute to the current state of engineering ethics education revealed in the previous chapters. Finally, the conclusion offers a perspective to the findings of the present study, presenting the implications of the project for engineering programmes, instructors, evaluators and the accreditation body. The study concludes by reminding the reader of the main findings of the project and proposing new lines for continuing the research.

CHAPTER 2 LITERATURE REVIEW: SURVEYING THE EDUCATION OF ENGINEERING ETHICS

The purpose of this chapter is to examine the literature related to the integration of ethics education by engineering programmes. The chapter is divided into three main sections. The first section is historical in nature, and is focused on the historical development and rationale of engineering ethics education. The second section is theoretical in nature, examining the goals set in connection to engineering ethics education and the major theoretical frames employed to make sense of the goals and methods used to teach engineering ethics. The third section is empirical in nature, offering a review of the empirical research carried out about the implementation of engineering ethics education. The chapter concludes with a summary of the key issues arising for the present study based on the empirical findings and theoretical models identified in the literature in relation to the implementation of engineering ethics education. The implications of the findings for the current research study will be analysed in the summary of the next chapter, which concludes the literature review.

2.1 Historical motivation of engineering ethics education

Ethical concerns are a contemporary addition to engineering programmes. Traditionally, disciplines of exact sciences such as engineering were regarded as morally neutral (Roeser, 2012) or even as morally good,[2] and henceforth did not require ethical instruction (Ehrlich, 2000). Looking at the history of engineering education and current trends, three paradigms of engineering professional identity emerge (Jamison *et al.*, 2014), as seen in Table 1. These represent three competing visions about the nature of the engineering profession and engineering knowledge, as well as about the educational approaches supporting these visions.

[2] I want to thank my external examiner, Carl Mitcham, for the suggestion that engineering might have been considered as morally good.

Table 1. Contending Models of Engineering Education (Jamison *et al.*, 2014)

Educational Approach	Science Driven	Market Driven	Socially Driven
Conception of Engineering	(Applied) science	Economic/ Technological innovation	Public service
Role of the Engineer	Expert, consultant	Entrepreneur, manager	Change agent, citizen
Identity, values	Academic	Commercial	Hybrid
Forms of Learning	"by the book" Theoretical	"by doing" practical	"in context" situated

First, there is the academic vision of engineering as applied science, dominant in science universities. Second, a market-driven vision of engineering as technological innovation, present in an entrepreneurial university model. Thirdly, we have the integrative vision of engineering as public service, promoted by an ecological oriented university. Describing the later approach, Jamison *et al. (*2014, p. 264) notes that it mixes elements of both the academic and market driven models into a "socially oriented hybrid." This hybrid model of engineering education favours an educational approach which includes the scientific, technical, social and environmental dimensions of engineering, and is considered to have played a less prominent historical role (Jamison *et al.*, 2014).

The development of engineering ethics education has been slow (Reed *et al.*, 2004; Mitcham, 2009). Two forces are credited for initiating the integration of greater social content in engineering education. The first was that of individual engineers pushing for change towards the primacy of public interest in engineering work, materialised in the engineering curriculum as well as in professional codes of ethics (Mitcham, 2009). Citizen movements, who demanded accountability for the social and environmental impact of engineering developments (Weil, 1984; Mitcham, 1994), played the second role.

In the first third of the twentieth century, engineering ethics was mainly understood as loyalty to the interests of the employer or of the client (Mitcham, 2009; Pfatteicher, 2003). As Kline (2001, p.15) remarked, in the period from 1910 to 1930s, “codes of ethics of professional engineering societies probably had very little effect on engineering practice.” The framing of engineering ethical conduct in terms of societal responsibility began to take shape during the middle of the last century. The need to recast the responsibility of the engineer in different terms appeared after two engineers were stripped of their professional membership for reporting the illegal actions of a contractor working for the Los Angeles Water Department as a breach of ethical conduct, on grounds of breaching ethical conduct (Mitcham, 2009). This was a recognition of the potential tension between engineers and their clients or employers (Conlon, 2013). Such that the 1930s marked the beginning of discussions that eventually caused the shift from understanding engineering ethics as loyalty to the employer or the client, towards a greater commitment to public safety, health and welfare.

Following WW2 and several aviation and car safety failures, the community also played an important role in raising awareness of the importance of engineers’ responsibilities towards people and the environment, by voicing concerns and expectations related to the use and safety of engineering artefacts. The political climate of the time and the controversies related to the use of engineering developments for political purposes led the public to contest the nefarious character of engineering artefacts such as nuclear weapons. The newly found demand for accountability of engineering developments, together with the prominence of environmental and civil rights movements, brought ethics into the spotlight of engineering practice (Weil, 1984; Mitcham, 1994; Seely, 2005).

In 1947, the US professional body of the time, Engineering Council for Professional Development – the current ABET – drew the first professional code of ethics, which stipulated that engineers should "have due regard for the safety, life and health of the public and employees who may be affected by the work for which he is responsible." By 1963, the provision received a slight upgrade, by replacing "due regard" with "proper regard" (Davis, 1995).

However, the institutionalization of ethics into the curriculum of engineering programmes was still slow in the period up to mid-1970s (Weil, 1984, p.343). In its incipient stage, engineering ethics fell under the concern of professional societies and was learned mainly through apprenticeships (Mitcham, 2009, p.44). It was in the late 1970s when engineering ethics began to take shape as an academic discipline, once research on engineering ethics started to feature in academic journals and textbooks on engineering ethics were published (Weil, 1984; Mitcham, 2009). An important moment was the report commissioned by the Hastings Center in 1977 with the aim of providing an overview of the status and prospects of engineering ethics in the US (Mitcham & Englehardt, 2019). The report addressed for the first time issues such as the aims and content of engineering ethics education, the qualifications required for instructors, as well as the available teaching material (Baum 1980).

The 1980s is considered the decade with the most influential changes in the technology education curriculum and its approaches (Reed *et al.*, 2004, p.106), with three major textbooks having been published (Mitcham 2009, p.44). Another significant moment for engineering ethics education was in 1989, through the development of the Washington Accord, signed by ABET in the USA, Engineers Australia, Engineers Canada, Engineers Ireland, Engineering Council UK and Institution of Professional Engineers New Zealand (International Engineering Alliance, 1989). The global accord led to an increased attention to engineering ethics education, paving way for the introduction of ethics as an accreditation criterion in signatory countries from 2000 onwards. Having an accreditation criterion dedicated to ethics helped move the discipline forward, towards an enhanced presence of ethics in the engineering curriculum (Lattuca *et al.*, 2006).

2.2 Rationale of engineering ethics education

In our times, engineering endeavors cannot be separated from the ethical concerns they comprise or give rise to (Conway, 2000). The rationale for incorporating ethics in the engineering curricula is manifold, and is explored in the present subsection.

2.2.1 Engineering is required to deal with complex ethical issues

The rapid pace of technological advances confronts engineers with challenges that require a much broader skill set, which renders technical skills insufficient (Hartman, 2008). The issues engineers tackle are complex, whether these are environmental problems, the advent of artificial intelligence, the privacy and security of technological systems or developing fair algorithms. Environmental problems are considered at the nexus between complexity and interdisciplinarity, given their inclusion of different type of problems, decision makers and stakeholders. Complex areas such as sustainable development or artificial intelligence also require an interdisciplinary approach at the intersection of science, technology and social systems (Frodeman *et al.*, 2010). Addressing such problems thus requires that engineers operate within a holistic conception of scientific knowledge and methods, leading to a “new dialogue of science and humanities” (Thompson Klein, 2004). Bostrom (2002) considers that the most pressing existential risks we face in our times are the outcome of the use or misuse of technology.

This holistic frame leads to a broadening of the mission of engineering, calling for reflection and action on social, economic and cultural issues. They can range from contributions to sustainable development to combating the inequalities generated by technology (Hansson, 2017). Ethical awareness becomes a crucial mandate of engineer professionals. As Stephan

(2001, p.7) remarks, in the society of the future, “a sound understanding of the theoretical and practical sides of engineering ethics will be as necessary to the proper education of engineers as a knowledge of differential equations is today.”

2.2.2 Engineering practice takes place in ill structured contexts

The interdisciplinary nature of engineering problems means that students need to be prepared for working in an environment where “technological, humanistic, and social issues are all mixed together” (Williams 2003, p.4). Engineering graduates will be part of ill structured environments, characterised by “conflicting goals, multiple solution methods, non-engineering success standards, non-engineering constraints, unanticipated problems, distributed knowledge and collaborative activity that rely on multiple forms of problem representation” (Jonnasen *et al.*2006, p.148).

The collaborative context in which engineers work also bears an ethical weight. In her analysis of the causes of the explosion of the *Challenger* shuttle, (Vaughan, 1996) argued that the interaction of different subjectivities led to a change in the meaning and range of the value of “safety.” What was deemed “safe” by the engineering team responsible for the shuttle launch was incrementally altered through their continual interaction and experience with previous launches. The outcome was a “normalization of deviance” that deemed as safe what in fact were unsafe test ranges.

2.2.3 Engineering has a wide range effects for the population and the environment, across space and time

The complex nature of the issues tackled by engineers has the potential to affect negatively the society and the environment. A nuclear failure, the collapse of a bridge, the advent of sentient artificial intelligence are only a few of the major ways in which the work of an engineer can have a lasting impact on society. This impact is not confined only to the time of the deployment of technology, but can also make itself felt at a later point in time. A nuclear reactor can fail decades after its construction, leading to numerous casualties and rendering an area unliveable for a considerable period, with Chernobyl and Fukushima serving as stark reminders. The same goes for the geographical impact of engineering artefacts, given that problems such as climate change are of a global scale (Son, 2008). As Stephan (2001, p.10) concludes, engineering artefacts affect "more people in a larger variety of ways than ever before, and many of these effects are increasingly difficult for the responsible engineer to anticipate."

2.2.4 The epistemological nature of engineering

Engineering artefacts influence and shape the way we live, and many times they do so in unanticipated ways. Due to the complex nature of the issues addressed and its potential risks, engineering is a profession of "managing the unknown," which turns engineering projects into "social experiments requiring morally responsible engineering behaviour" (Barakat, 2011). This understanding of engineering as "social experimentation" was initially proposed by Martin and Schinzinger (1983), and was further elaborated by Mitcham (1997, p. 138), who argues that "engineering takes the world for a laboratory."

Technologies aimed at tackling climate change attract risks that are difficult to quantify. This is the case with the development of biofuels which can negatively impact food prices, or technologies for carbon capture and storage that can pose safety risks to local communities and the surrounding environment (Riesch, 2012). There are speculations about the risks to which the entire human race is exposed to through the development of artificially intelligence, with warnings that this might lead to extinction (Hawking, 2014). The changing nature of social relations (Wilks, 2010) or that of work and employment (Acemoglu and Restrepo, 2018) are other areas where AI's impact is significant, yet hard to predict.

2.2.5 The metaphysical nature of engineering

Besides technical knowledge, engineering artefacts incorporate also social, cultural and political values and can have socio-economic and political effects. Marzano (1993), now a retired chief design officer of Electrolux, stated that "design is a political act," such that "every time we design a product we are making a statement about the direction the world will move in." This seems to be the case with the bridges in Long Island designed by Moses, whose low height did not allow busses to pass under them. Automobile owning white people of "upper" and "comfortable middle" classes, as Moses called them, would be free to use the parkways for recreation and commuting. But poor people and black people, who normally used public transit, were kept off the roads because the twelve-foot tall buses could not get through the overpasses.

As Winner (1986) argued, the bridge displays one's view about race or social class, inasmuch as they display technological expertise. Bijker (1995) further elaborates on how technical artefacts are important in the constitution of power. What seems now an unproblematic everyday engineering artefact, the fluorescent lamp, is in fact the outcome of a complex economic power play in which General Electric, the electric utilities, the U.S. government and consumers all played a role, paving way to a major change of the manufacturing scene in the US.

Engineering artefacts can incorporate dominant stereotypes or the designer's biases, thus excluding the needs or characteristics of different categories of users. One such example are artificial hearts, which were found to fit only 20% of women due to their smaller chest cavities, as opposed to 86% of men (Michefelder *et al.*, 2017). When looking at how algorithms discriminate against people of colour, Umoja Noble (2018) notices a systematic algorithmic culture of oppression. This bias goes beyond search engines such as Google or

Yelp, affecting also electoral politics and financial markets (Pasquale, 2014; 2015; Umoja Noble, 2018).

Given the complex nature of engineering artefacts, of engineering practice and of the issues addressed by engineers, it is evident that a solely technical engineering education is insufficient. Thus ethics education is of crucial importance in the engineering curriculum.

2.3 Goals of engineering ethics education

There is a broad and diverse set of goals envisioned for engineering ethics education. The limited research on the effectiveness of the various strategies and goals set for engineering ethics education is a major challenge revealed in the literature. According to Hess & Fore (2018, p.551), there is a “multiplicity of ethics related learning goals vying for attention among engineering educators”, with no “consensus regarding which strategies are most effective towards which ends, nor which ends are most important”. The instructors surveyed by Romkey (2015, p.25) were also found to employ a “very diverse” set of overall teaching goals, but "the goals and practices did not always align." As stressed by Keefer *et al* (2014, p.250), “variability in instructional goals within the same content areas raises the spectre of significant problems with curricular alignment”. A coherent strategy implies that the goals set for engineering ethics education inform decisions about assessment (Borrego & Cutler, 2010, p. 366), and are congruent with the delivery and pedagogical methods employed (Li & Fu, 2012, p.343).

In the first report commissioned in the US on the state of engineering ethics, the discipline was defined as “dealing with judgments and decisions concerning the actions of engineers (individually or collectively) which involve moral principles” (Baum, 1980, pp.2–3). The discipline is thus considered a “study of the decisions, policies, and values that are morally desirable in engineering practice and research” (Martin & Schinzinger, 2013, p. 8). Herkert

(2002) considers that the key concept in engineering ethics is "professional responsibility," a concept understood by Whitbeck (1998) as the "exercise of judgment and care to achieve or maintain a desirable state of affairs." As such, engineering ethics must address questions about "ethical principles, rules of practice, justification, good judgment and decision-making." (Pritchard, 2005).

The goals proposed for engineering ethics education can be grouped under 11 major thematic categories, as seen in Table 2. Inspired by the goals described by Van de Poel and Royakkers, (2011), six of these categories relate to the development of moral sensibility, analysis, creativity, judgement, decision-making and argumentation. Additionally, we identified goals that could be grouped under categories such as moral knowledge, design, agency, emotional and character development, and situatedness.

These goals can be further subsumed under broader theoretical models used to conceptualise engineering ethics education. Recent decades witnessed the development of several theoretical approaches, such as microethics, macroethics, virtue ethics, value sensitive design and feminist ethics of technologies. The following subsection examine the theoretical attempts made to subsume these goals under a broader model of engineering ethics education.

2.4 Conceptual models of engineering ethics education

There are two major models for teaching engineering ethics according to Herkert (2005): a microethical approach focused on ethical dilemmas faced by individual engineers, and a macroethical approach concerned with "the collective responsibilities of the profession and societal decision-making about technology." In what follows, we focus on the characteristics and assumptions behind each model.

Table 2 Goals posited for engineering ethics education (* category borrowed from Van de Poel and Royakkers, 2011)

Categories	Goals
Moral sensibility *	Developing proficiency in recognizing social and ethical issues in engineering (Harris et al, 1996; Van de Poel & Royakkers, 2011; Martin & Schinzinger, 2013) Encouraging students to take ethics seriously (Harris et al, 1996) Increasing students' sensitivity to ethical issues (Harris et al, 1996; Davis, 1999) Acknowledging the societal dimension of engineering practice (Author)
Moral analysis *	Analyzing moral problems in terms of facts, values, stakeholders and their interests (Van de Poel & Royakkers, 2011) Comprehending, clarifying, and assessing arguments on opposing sides of moral issues (Martin & Schinzinger, 2013) Facilitating the analysis of key ethical principles (Harris et al., 1996) Exploring the perspective of those in other positions (Lynch & Kline, 2000; Author)
Moral creativity *	Considering different options for action in the light of (conflicting) moral values and relevant facts (Van de Poel & Royakkers, 2011) Stimulating ethical imagination (Harris et al, 1996; Martin & Schinzinger, 2013) Allowing students to creatively explore solutions rather than choosing one horn of a dilemma (Lynch & Kline, 2000) Enhancing divergent thinking (Haws, 2001)
Moral judgment *	Making moral judgments based on different ethical theories or frameworks, including professional ethics and common sense morality (Van de Poel & Royakkers, 2011) Improving ethical judgement (Harris et al., 1996; Davis, 1999) Forming consistent and comprehensive viewpoints based on consideration of relevant facts (Martin & Schinzinger, 2013)
Moral decision-making *	Enabling students to make decisions based on different ethical theories and frameworks (Van de Poel & Royakkers, 2011) Providing conceptual tools for reflecting on how organizational practices can potentially threaten public safety and welfare and how to counter the normalization of deviance (Lynch & Kline, 2000) Helping students deal with ambiguity in decision-making situations (Harris et al, 1996)
Moral argumentation *	Developing the ability to morally justify one's actions and to discuss and evaluate them (Van de Poel & Royakkers, 2011)
Moral knowledge	Gaining knowledge of professional standards and codes (Harris et al, 1996; Davis, 1999) Giving students access to the language of ethics to express and support one's moral views adequately to others (Haws, 2001; Martin & Schinzinger, 2013)
Moral design	Considering how values, as well as modes of use and interaction, can be implicitly or explicitly inscribed into engineering artefacts at the design stage (van de Poel & Verbeek, 2006; Verbeek, 2008)
Moral agency and action	Empowering students to reshape the social, economic and legal context of practice (Author) Encouraging students to take an activist stance "for what is right, good and just" (Hodson,1999)
Moral emotional and character development	Increasing students' ethical willpower (Harris et al, 1996; Davis, 1999) Cultivating students' sense of professional identity (Loui, 2005; Miller, 2018) Reflecting on the role of emotions in the development and acceptability of risky technologies (Roeser, 2012)
Moral situatedness	Understanding the social relations of expertise in connection with technology management and decision-making (Devon, 1999) Helping students see their work through the eyes of their community (Haws, 2001)

2.4.1 Microethics: the dominant model of engineering ethics education

Engineering ethics education is considered to be preponderantly microethical in outlook (Herkert, 2000a; Colby & Sullivan, 2008; Bielefeldt *et al.,* 2016). The microethical model is characterised by an individualist approach focused on exposing students to ethical dilemmas. These are scenarios that put the spotlight on the decision-making of an individual engineer faced with an ethical dilemma, such as whether to go along with the design of an unsafe product or accept a bribe. The answer to these dilemmas is most often straightforward and can be reached by appealing to the provision of professional ethics codes or ethical theories, most often represented by the categorical imperative in the Kantian deontological ethical system (Harris *et al.,* 2009). There is a specific line of reasoning – ethical heuristics - for reaching the solution to the dilemma presented, with solutions seen to allow for a win-win outcome (Conlon, 2011). Hence, for microethical approaches, the goal of engineering education is strongly focused on enhancing students' knowledge of professional codes, character development and refining their moral reasoning.

The following assumptions have been noted in connection to the microethical approach:

2.4.1.1 Responsibility

Microethical approaches have a strong emphasis on the individual responsibility of engineers. Basart and Serra (2013, p.179) capture the spirit of the microethical model by noting that it "is usually focused on engineers' ethics, engineers acting as individuals." An engineer's individual responsibility is guided by precepts stated in professional codes (Davis, 2006; Harris *et al.,* 2009). Mundane engineering situations that require the exercise of an engineer's responsibility include conflict of interest, quality testing, trade secrets, representation of test data (Herkert, 2005), while the responsibility of engineers is framed in terms of a heroic or whistle-blower response.

2.4.1.2 Agency

The individualistic focus on the individual engineer's decision-making presupposes that the engineer has full agency to solve the ethical dilemmas encountered (Conlon & Zandvoort, 2011). It thus neglects the possible barriers and hindrances that can be encountered while pursuing what, from an ethical standpoint, is considered to be the right course of action. Microethical approaches were found to emphasize the Kantian duty to do the right thing, such as "resisting immoral managers" (Lynch & Kline 2000). As such, microethics focuses exclusively on right doing at any cost, without considering the need to address and remove structural obstacles that come in the way of acting right (Swierstra & Jelsma, 2006).

2.4.1.3 Goals

Several goals of microethical case instruction have been highlighted, such as refining moral judgement, enhancing ethical will-power and familiarising students with professional standards of conduct (Davis 1999; 2006). In light of the conception of agency that microethical approaches rely on, the impediment to an engineer behaving ethically is not external but found within herself. The goal of engineering ethics interventions is thus seen to shape the character, knowledge and reasoning abilities that would enable an engineer to identify the right course of action and pursue it. There is a high emphasis on preventing disasters and enhancing safety through the behaviour of an individual engineer, which leads to a conception of engineering ethics as a "kind of behaviour internal control" (Ladd, 1982).

2.4.1.4 Stance towards values

Microethical goals are thus linked with the adoption of a value neutral stance, which does not ask of engineers to take a stance in regards to the "kind of world they want to engineer" (Mitcham, 2017). For microethical approaches, values are external and independent of engineering practice. Thus for an engineer to act ethically, it suffices to recognize what the right course of action is, based on professional codes and ethical theories.

2.4.1.5 Curricular content

To promote ethical behaviour, the coverage of microethics education has a heavy emphasis on professional codes and ethical theories, health and safety, and honesty (Besterfield-Sacre *et al.*, 2000; Lynch & Kline, 2000; Herkert, 2005; Davis, 2006; Colby & Sullivan, 2008; Harris *et al*., 2009). The advantage of ethical theories is that utilitarian and deontic theories can be simplified in a layperson's language (Davis, 1999). In this regard, Glagola *et al*. (1997) and Lynch (1997) propose a "theory modest" approach which does not rely on ethical theories as a more appropriate coverage for the engineering students' first encounter with the discipline of ethics.

2.4.1.6 Teaching methods

In terms of the teaching methods employed, the prevalent method employed are case studies rooted in a microethical outlook (Winner, 1990; Herkert, 2002; Colby & Sullivan, 2008; Kline, 2010). Verbeek (2006, pp.223-4) considers that engineering ethics education is "focused on disaster cases, with the suggestion that such disasters could have been prevented by responsible behaviour on the part of engineers or by whistle blowing." In terms of coverage, popular scenarios employed by case studies focus on presenting disasters such as the *Challenger* shuttle explosion, nuclear accidents, plane crash or building collapses, as well as more mundane situations encountered by engineers, such as conflict of interest or receiving gifts (Haws, 2001, p.226; Herkert, 2005, pp.306–7; Freyne & Hale, 2009, p.8; Harris *et al.*2009, pp.12–3). There is a "tendency […] to have only bad news cases, cases in which some bad outcome occurs because of poor choices" (Huff & Frey, 2005, p.401). This type of microethical "bad news" cases are formulated according to a binary scenario focused on disaster and prevention. Thus, concerns about societal welfare are often reduced to "situations of extreme crisis (such as being ordered to design an unsafe structure)," narrowing a potentially broad concept to microethical concerns about health and safety (Little *et al.*, 2008, p.216).

The framing of microethical case studies on disaster scenarios focused on health and safety leads to a neglect of the political or social beliefs that govern the creation of engineering artefacts and the manner in which technology mediates human activity or shapes power structures. For example, a systematic review examining the relationship between risk management and ethics described in 21 journals of engineering education and ethics found that the analysis of risk and safety is often devoid of complexity and context (Guntzburger *et al.*, 2016). The review suggests that risk management is mostly introduced as an anecdote or an example when addressing ethics issues in engineering education. Furthermore, according to Guntzburger *et al.* (2016), the topic is perceived as an ethical duty or requirement, achieved through rational and technical methods, and only a small number of publications included a critical analysis of ethics education in engineering. In a similar spirit, Winner (1990, pp.53-4) also highlights that while microethical case studies focus on "relatively rare, narrowly bounded crises, […] the contexts that underlie particular cases are never themselves called into question." The focus of case studies on disaster situations is seen by Verrax (2017, p.77) to ignore questions regarding power structures and individual empowerment. In the words of Little *et al.* (2008, p.325), micro-focused cases offer "precious little in terms of how engineering decisions may either liberate publics or reinforce power relations over them."

Although microethical education has several benefits, such as familiarizing students with moral reasoning and ethical dilemmas that reveal the opposing values and interests at stake between engineers and the various stakeholders (Davis, 1995; 1999), there is a recognized need to complement them with broader approaches.

Two alternative models have been developed in response to the minuses of an educational approach consisting exclusively of microethical interventions. These are the macroethis and value design models. Notable is also the explanatory framework put forward by Conlon *et al. (*2018) for understanding the different conceptualizations of engineering ethics education and the call for a hybrid approach based on the interplay between human agency and social structure. These alternative proposals are addressed in the subsequent subsections.

2.4.2 Macroethics: a broader model of engineering ethics education

The macroethics model moves beyond the analysis of an individual engineer's action to the analysis of the profession as a whole and the wider implications of technological developments (Ladd, 1982; Vanderburg, 1995; Herkert, 2003). Herkert (2005, p.373) has emphasized the concern of macroethical approaches with 'the collective responsibilities of the profession and societal decision-making about technology'. The main assumptions of the macroethical model target the following aspects:

2.4.2.1 Goals

The macroethical approach overlaps with the least common paradigm of engineering practice identified by Jamison *et al. (*2014), aimed at public service and promoting common good. The goal of macroethical approaches is for engineers to correct the context of engineering practice in a way that enables ethical and social responsible behaviour (Zandvoort *et al.*, 2000; Conlon, 2011). This might refer to developing technologies that are congruent with egalitarian and democratic structures and institutions (Vanderburg, 1989) or to an active involvement in public policy for formulating rules and regulations that promote socially just practices (Martin & Schinzinger, 2013; Conlon, 2008). The scope of macroethics goes beyond the physical consequences of engineering artefacts and includes also nonphysical consequences such as globalization or inequality (Son, 2008).

Goals set at the macro-level encompass “the quality of human life, the well-being of the community or the vitality of the eco-system” (Vanderburg, 1989; Bowen, 2009). Engineering ethics has traditionally overlooked issues such as overconsumption of western societies (Woodhouse, 2003; Swearengen & Woodhouse, 2003), poverty reduction (Boyd, 2010) or the contribution that the profession can make to a life of engagement, enlivement and resonance (Moriarty, 2001).

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 (Devon, 1999). Macroethics thus aims to cast light on what Devon (1999) calls “mutable social arrangements” for the decision-making related to the development and use of technology, which is considered a joint responsibility of engineers and the different stakeholders involved or affected by it.

2.4.2.2 Responsibility

Macroethics moves the weight from an individual engineer’s responsibility to the collective responsibility of engineering as a profession (Herkert, 2005; Martin & Schinzinger, 2013). Vanderburg (1989) 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.” The concept of responsibility is no longer divorced from the context of engineering practice itself.

2.4.2.3 Agency

As such, an engineer's agency is not taken for granted, but is considered to be affected by the structure in which the engineer operates, be it the cultural or political climate, or the institutional ethos. This view on agency highlights the importance of the goal set by macroethics of correcting the very structure an engineer is part of. In order to enhance the engineer's agency in pursuing a socially responsible practice, is thus important to modify the tools that affect the structure of engineering practice, such as laws, policies and regulations, and also to strengthen support structures, such as professional associations or civic movements (Zandvoort, 2005; Son, 2008; Conlon & Zandvoort, 2011).

2.4.2.4 Stance towards values

Macroethics is not a value neutral approach. On the contrary, it requires that engineers commit to a set of values deemed worthy of governing engineering practice, and also that they question the current values dominating engineering practice. Vanderburg (1995) highlights the opposition between the values guiding technological development in current times, such as productivity, cost-effectiveness and profitability, and values belonging to the human, societal or natural sphere, such as quality of life or protecting the ecosystem. Macroethical approaches promote an active stance that requires engineers to reflect on the kind of world they want to construct and inhabit, leading to a conception of engineering ethics that is "more than engineering ethics" (Bucciarelli, 2008).

2.4.2.5 Curricular content

Macroethics is described by Bielefeldt *et al. (*2016) to include issues such as "sustainability, poverty and underdevelopment, security and peace, social justice, bioethics, nanoscience, and social responsibility." For Martin and Schinzinger (2013), issues regarding legislation and future directions in technological development also fall under the scope of macroethics. Another area of coverage that is considered to support a broader ethical outlook are science and technologies studies. Science and technology studies[3] are seen to focus on the historical and contemporary developments of science and technology and their co-dependency of societal issues (Gallagher, 1971). For Mitcham (2003), this includes a criticism of scientific and technological practices themselves, guided by a sense of professional idealism. A survey carried out by Pritchard and Baillie (2006, p.564) shows that key themes for STS practitioners revolve around participation, citizenship, politics and policy, yet these are mostly absent from the engineering curricula. Students are considered to be receptive to STS approaches, finding the content relatable and less abstract (Ozaktas, 2013).

2.4.2.6 Teaching methods

The pedagogical approaches suitable for conveying this type of curricular content are creative, affective, reflexive, critical, place based, and experiential (Pedretti & Nazir, 2011). Common methods of macroethical instruction comprise service learning, humanitarian engineering and macro case studies. Canary *et al. (*2014) are proponents of pedagogical methods encouraging critical thinking and engagement, which are considered to foster the societal engagement of students.

Lathem *et al. (*2011) consider that service learning can induce a positive perception among engineering students about the importance of ethics and the role of environmental engineering practice. The personal involvement at an emotional and social level encouraged by service learning is seen to foster deep learning (Ozaktas, 2013).

To reinstate complexity to case based instruction, Lynch and Kline (2000) propose the expansion of scenarios to include "more actions and more agents." Case studies can have a macroethical outlook allso by focusing on institutional and policy issues that prompt students to consider the wider social, economic or political context of engineering practice

[3] Henceforth abbreviated as STS.

and the need to address it in their work. For example, case studies developed at University of Virginia ask students to analyse how engineers can correct inequalities rooted in the political context of South Africa, by looking at how the "world's fourth largest utility tried to get power to the people by connecting rural townships in South Africa to the grid" (Gorman *et al.*, 2000; Gorman, 2001-2002). Newberry (2010) proposes a case study based on the Hurricane Katrina, incorporating macro topics such as the cumulative effect of policies and infrastructure planning on the affected communities, as well as priorities in the allocation of resources and the dependence of engineering projects on federal subsidies and grants. Wilson (2013) focuses on the repressing force of social and political structures in the role-play of the Chernobyl nuclear disaster. The scenario assigns students to one of three factions - The Soviet State represented by the "Ministry of Atomic Power Stations, the State Committee for Safety in the Atomic Power Industry and the whole framework of the Soviet bureaucracy at the highest levels," the management of the nuclear plant and the engineering crew at the reactor. Engineering students get to explore ethical issues in a wider context, "where personal well-being quite often ran up against professional responsibility in a political system that could often be quite brutal and unforgiving."

Macroethical case studies can make students aware that not only individual decisions may be right or wrong, but also the structures within which decisions are taken may promote or hinder ethical actions (Doorn & Kroesen, 2013). Students can thus learn to navigate through constricting institutional dynamics (Kroesen & Van der Zwaag, 2010). Cases that contain the perspectives of different agents and stakeholders have been shown to convey some key aspects related to the social dimension of the engineering profession, namely that engineering artefacts contain social values and that the process of design and decision-making are social processes, contributing to students' acknowledgment of the social dimension of engineering (Martin *et al.*, 2019).

Summing up, Table 3 captures the main differences between the micro and macroethical approaches.

Table 3. Models of engineering ethics education: Microethics vs Macroethics

FRAME	MICROETHICS	MACROETHICS
Goals	Refine moral reasoning Develop moral character	To motivate and enable correcting the context that gives rise to ethical problems
Responsibility	Individualistic	Collective and societal
Agency	Assumption of full agency of the engineer	Dependent of enabling or constraining contextual factors
Values	External to the context of practice Neutral stance	Embedded in the context of practice Commitment to a set of values
Curricular content	Professional codes Ethical theories and heuristics Health and safety Honesty and plagiarism	Social, cultural, economic and political dimension of engineering Sustainability Science and Technology Studies
Teaching Methods	Black and white ethical dilemmas that allow for win-win answers	Ill structured learning environments Ambiguous and complex scenarios Service learning and humanitarian engineering

2.4.3 The explanatory quadrant micro/macro objective/subjective

The micro-macro dichotomy for explaining approaches to engineering ethics education is not without problems. Kline (2010) notes that it reinforces the boundaries that in fact it aims to bridge and promotes a vision of technological determinism.

Conlon *et al. (*2018) argued that the move to a macro approach conflates a number of different issues, thus requiring us to interrogate more closely what a shift to a macro focus might entail. According to Conlon *et al. (*2018), the shift to a macro approach has led in some cases to a broadening of the scope and goals of engineering, while for others it implied a focus on the wider institutional context in which engineering practice takes place.[4]

[4] Doorn and Kroesen (2013, p.1516) discuss the micro/macro distinction and suggest, in relation to the focus on macro issues, that "although different authors have different foci, we can establish that many authors point

Drawing on sociological theory and debates within the discipline, the aim is to provide a framework for understanding the macro/micro distinction.

The framework rendered in Table 4 is based on four different levels of analysis which emerge from the interaction of two social continua: the macro/micro and the subjective/objective. The macro/micro refers to the magnitude of social phenomena ranging from whole societies to individual action. The objective/subjective distinction refers to whether a phenomenon has a real material existence (e.g. bureaucracy) or exists only in the realm of ideas and knowledge (e.g norms and values).

Table 4. Quadrant model of analysis in engineering ethics education

<table>
<tr><th colspan="4">Microscopic</th></tr>
<tr><td rowspan="2">Subjective</td><td>Micro-subjective
Focus on the consciousness of individual engineers: their ability to identify and solve ethical dilemmas and their ethical will power</td><td>Micro-objective:
Focus on engineering practice and organisational culture</td><td rowspan="2">Objective</td></tr>
<tr><td>Macro-subjective:
Focus on the values and the responsibilities of the profession</td><td>Macro-Objective:
Focus on social, economic and political structures and public policy</td></tr>
<tr><th colspan="4">Macroscopic</th></tr>
</table>

This framework draws attention to the fact that a macro focus should involve interrogating both the goals of the profession and the social context in which engineers practice. This should allow us to avoid a moralism that may burden engineers with responsibilities they cannot meet, while allowing us to better identify those circumstances that would facilitate

to the broader context of individual decisions, whether they call this the institutional context, macro ethics, or some other name.”

the attainment of broad goals, such as enhancing human welfare and sustainable development.

The quadrant model suggests that the key analytical focus should be on the relationship between the agency of engineers and the social structures in which they work (Swierstra & Jelsma, 2005), as well as on the extent to which these constrain or enable a socially responsible engineering practice. Swierstra and Jelsma (2005, p.224) argue that a sociologically informed way of studying engineering practice should help reveal "the particular moments and particular characteristics of practice at which and by which the conditions to execute this individual moral responsibility are favourable or limiting." The argument is that it is both necessary and possible to influence the institutional environment of engineers, so as to enable and stimulate them to behave responsibly. While the construction of such an environment is usually in the hands of other actors, engineers can be called on to demand changes in their environment (Winner, 1990), and can play a role in accomplishing reforms. The manner in which engineers can do this "should be part and parcel of engineering ethics" (Swierstra & Jelsma, 2005, p.225).

This approach moves the focus away from the scale of the issues that ethics addresses, which is the focus of the macro/micro debate. It also counters the challenge of distinguishing between the micro and the macro approaches, as they are oftentimes intertwined.[5] It would seem then that the key issue is not just the scale of the issues addressed by engineering ethics, but also how different mechanisms, operating at different levels, come together to produce particular effects in the practice of engineering (Conlon *et al.*, 2018). In this, the

[5] Herkert (2005) has, for example, identified the design of safe products as a micro issue. But the safety of engineering products and processes is affected by the attitudes, practices and organisation of engineers, organisational structures and culture, the regulatory regime, production pressures and public policy, which includes policy on product liability identified by Herkert as a macro issue.

commitments of engineers and the goals of the profession matter, but so does the context in which engineering takes place.

2.4.4 Value sensitive design[6]

In recent years, an alternative theoretical approach developed in the Netherlands, aiming to integrate micro and macro ethical aspects in engineering education. This has included a call for a new focus in engineering ethics, which would move away from "disaster ethics" and widen the responsibilities of engineers (Verbeek, 2008; 2011). Drawing on the philosophy of technology and STS, Verbeek seeks to connect the analysis of the influence of technologies on their environment with moral decision-making during the design process. He uses the concept of *technological mediation* to argue that the impact and effects of technology transcend its functionality. When technologies fulfil their functions they also help to shape the experiences and actions of their users.

Verbeek is critical of the traditional approaches to the ethics of design as it tends to follow what he calls an externalist approach. Such approaches are seen to focus on the outcomes of technology development, more specifically on disasters, rather than on the "internal dynamics of these processes" (van de Poel & Verbeek, 2006). By revealing the influence of technologies on human actions through what STS scholars call *scripts* – a prescription of how to act that is built into an artefact- he charges technologies with morality. The notion of scripts can help engineering ethics overcome its externalist orientation, which overemphasises how engineers can prevent negative impacts of technology, in order to focus more on the engineering design process and how artefacts invite specific actions and inhibit others. Thus, there is a requirement to expand the scope of engineering ethics to include the moral dimension of the artefacts so that engineers can take responsibility for the future

[6] Henceforth abbreviated as VSD.

mediating role of technology in design. Verbeek is concerned with how mediation theory can inform design practices, so that they can effectively contribute to the realisation of specific moral values. By answering this question, he argues, mediation theory can contribute to value-sensitive design (Verbeek, 2016).

VSD focuses on decisions made in the early stages of an engineering project, when ethical considerations may emerge when formulating requirements, specifications and criteria and then assessing trade-offs between criteria and what would constitute an acceptable trade-offs (van Gorp & van de Poel, 2001). The values prioritised by VSD are those that target societal good over instrumental values aiming at enhancing economic profit (Friedman *et al.*, 2013). The focus is on encouraging students to design value driven artefacts and solutions that contribute to societal welfare or diminish the negative societal effects of existing technologies (Gorman, 2000; 2001; Verbeek 2008; 2011). Areas such as safety, sustainability and inequality are of major concern for VSD (van Gorp, 2005; Mok & Hyysalo, 2018; Mouter *et al.*, 2018). The concern of VSD with ensuring that no potential user group is being excluded or negatively affected by the development of engineering or technological artefacts (Van de Poel, 2011), makes VSD one of the favourite approaches of feminist philosophers of technology (Michefelder *et al.*, 2017; Simon, 2017).

In this sense, VSD is forward looking and anticipative in its nature. One advantage of this approach is that it moves away from the focus on disaster cases, which is retrospective, by starting from effects and moving backwards to causes (Kline, 2010). The other advantage of the forward looking character of VSD is that it requires engineers to envision the type of society one would live in, and to commit to a set of values that would inform the design contributing to its actuation. In this sense, VSD can be considered an example of an integrative teaching practice (Jamison *et al.*, 2014).

2.4.5 Feminist philosophy of technology

Another popular recent theoretical model of engineering ethics education is linked to the development of a feminist philosophy of technology. This is an inclusive and value-laden approach that employs a critical discourse on modern technological development (Loh, 2019). In the articulation of feminist philosophy of technology, the concern lies with the development of tools and knowledge for enhancing women's "ability to develop, expand, and express their capacities" (Layne, 2010, p.3). The goals of this approach range from addressing the status quo of women to restructuring social arrangements in ways that adjust the power relations between genders (Layne, 2010). These goals are aligned with the precepts of Value Sensitive Design (Whitbeck, 1998; Pantazidou & Nair, 1999), by reflecting on the gendered assumptions inherent in technological design and promoting the development of technological artefacts that do not discriminate against the female gender (Riley, 2013; Michefelder *et al.*, 2017). Thus, for feminist philosophy of technology, technological artefacts cannot be divorced from the social, political and economic context of their development and modes of use (Whitbeck, 1998; Layne, 2010). In this sense, feminist philosophy of technology has a common history and agenda with social justice movements, through the focus on ending "different kinds of oppression, to create economic equality, to uphold human rights and dignity, and to restore right relationships among all people" (Riley, 2008, p.5; Riley *et al.*, 2009).

2.4.6 Virtue ethics

The adoption of virtue ethics in engineering ethics education is another movement rooted in the attempt to bridge the gap between ethical theories and engineering practice (Hillerbrand, 2010). Virtue ethics is oftentimes cast in opposition to preventive ethics, which focuses on the prevention of disasters, crisis and the adverse outcomes of engineering decisions and designs. For Harris (2008, p.155), the negative formulations of preventive ethics neglect the "internal, motivational and often idealistic element present in professional life." According to Harris (2008, p.153), aspects of engineering professionalism such as sensitivity to risk, awareness of the social context of technology, respect for nature, and commitment to the public good, cannot be adequately accounted for in terms of rules and preventive precepts.

The focus of virtue ethics is thus seen to lie not on the rightness of engineering decisions, actions or outcomes, but on the attitudes or virtues of the deciding moral subjects (Schmidt, 2014; Hillerbrand & Roeser, 2016). In this sense, virtue ethics is an aspirational theoretical frame (Schmidt, 2014). Virtue ethics emphasizes the importance of context sensitivity and the acquisition of practical judgment (*phronesis*) for dealing with particular concrete situations (Nair & Bulleit, 2020). According to virtue ethics, traditional approaches that focus on moral action and its consequences need to be complemented by training the future engineer in obtaining certain character traits (virtues).

Some of the virtues that are proposed to be fostered by engineers are *phronesis*, care, humanity, justice, courage, honesty, objectivity and resilience (Moriarty, 2009; Schmidt 2014; Löfquist, 2018). *Phronesis* is considered a particularly relevant intellectual virtue for dealing with risks and uncertainties, and can help integrate ethics into engineering education. As Davis (2012) notes, "once we see judgment as central to the discipline, we can also see how central ethics is to its competent practice. There is no good engineering […] without good judgment and no good judgment without ethics." Humanitarian engineering, storytelling about moral exemplars and exposure to social justice contexts have been proposed as suitable training mediums that offer students the possibility to develop their character and cultivate ethical behaviour (Pritchard, 1998; Mitcham, 2009; Campbell & Wilson, 2011; Löfquist, 2017; 2018).

2.5 Engineering ethics education in practice

In what follows, the survey moves beyond the different theoretical attempts at making sense of engineering ethics education, in order to examine how ethics education is incorporated in engineering programmes, together with the challenges and dissatisfaction expressed in regards to its implementation.

Currently, the presence of ethics has increased in the national engineering systems across the globe. Nevertheless, the current state of engineering ethics education points to fragmentation and variations in how the discipline is implemented along five major lines of enquiry: related to (i) the goals of engineering ethics education (explored previously), (ii) the method of delivery, (iii) teaching methods, (iv) assessment methods and (v) coverage of issues.

The limited research on the effectiveness of different strategies for the implementation of ethics education is a major challenge for engineering programmes. We can witness a “multiplicity of ethics related learning goals vying for attention among engineering educators,” with no “consensus regarding which strategies are most effective towards which ends, nor which ends are most important” (Hess & Fore, 2018, p.551). Instructors in Canadian engineering programmes surveyed by Romkey (2015, p.25) were also found to employ a “very diverse” set of overall teaching goals, but "the goals and practices did not always align." It is important to have a coherent and well thought strategy, where goals set for engineering ethics education are congruent with the delivery and pedagogical methods deployed. Jessica Li and Shengli Fu (2012, p.343) warn that lack of clarity can lead to missed opportunities. They argue that decisions on delivery strategy should precede decisions on instructional strategy, given that the former influence how ethics will be implemented in the curriculum.

2.5.1 Method of implementation of engineering ethics education

There are two major approaches for implementing ethics education in engineering programmes: in standalone modules dedicated to ethics or across the curriculum, with ethics permeating technical as well as non-technical modules. Among faculty, there is a "significant divide" in perspective on which of the two strategies should be followed (Romkey 2015, pp.13-4). Katz and Knight (2017, p.13) also note disciplinary differences between instructors on how the engineering curriculum should cover ethical issues. For example, electrical engineering faculty show a lower preference for integrating ethics in multiple courses than faculty from chemical engineering, followed by civil, general and industrial engineering instructors.

2.5.1.1 Across the curriculum

The integration of ethics across the curriculum means that ethics is taught and assessed in several modules throughout the programme, in dedicated modules as well as in technical modules. There are several advantages noted in connection to an approach across the curriculum. Cruz and Frey (2003, p.545) argue that integrating ethical considerations throughout the engineering curriculum "mirrors the ways in which ethical issues arise in day-to-day engineering practice." This method of delivery is for them "holistic, interdisciplinary, and proceeds by ethically empowering faculty and students." For Ocone (2013, p.e114), ethics across the curriculum allows engineering students "to see ethics in action." It also helps students become aware of the intrinsic connection between ethical and societal concerns and engineering, tackling the preconception that ethics is just "add-on material" (Newberry, 2004, p.346; Ocone, 2013). The belief in the effectiveness of implementing ethics the curriculum in improving engineering students' moral reasoning and sensitivity to ethical issues is further reinforced by Drake *et al. (*2005, p.223), who consider that ethics delivery must be "integrative, delivered at multiple points in the curriculum, and incorporate specific discipline context."

The method of delivery across the curriculum does not come without challenges. Among these, the most significant are related to the background of engineering faculty and an already cramped curriculum. Newberry (2004, p.348) counts the attitude of faculty from what most often are technical driven programmes towards ethics as an impediment to the successful implementation of an approach across the curriculum. He roots this attitude in the engineering instructors' own formation in undergraduate and graduate educational systems in which ethics education was mostly absent, systems that offered "no incentive to develop such a background." Another disadvantage to a successful implementation of ethics across the curriculum, according to the survey carried out by Bielby *et al.* (2011, p.8), are the students themselves. They observed a negative response of students in the first years of study to the overexposure to ethics, which led to the conclusion that the quality of ethics instruction is more important than the quantity of ethics exposure. To be successful, the integration of ethics across the curriculum is not sufficient by itself if it is not accompanied by an assessment of the ethical components of technical modules (Bairaktarova & Woodcock, 2017, p.1132).

2.5.1.2 Standalone dedicated modules

Standalone ethics modules can be mandatory or optional, and can be either taught by faculty within the programme or from a different programme. Based on student feedback, Buckeridge (2006, p.4) claims that a standalone ethics module is preferable. Standalone ethics courses also have the advantage of providing more in-depth coverage as well as exposing students to ethical issues for an extended period of time (Poel *et al.*, 2001; Newberry, 2004). This method can also ensure that the instructors teaching ethics have expertise and an interest in the topic, which is difficult to ensure in the case of the across the curriculum approach (Newberry, 2004). Nevertheless, the main minus of standalone ethics modules is the risk of giving students the impression that ethics is peripheral and separate from engineering practice (Jessica Li & Shengli Fu, 2012, p.345).

2.5.2 Teaching methods employed in engineering ethics education

A diversity of teaching approaches has been reported in engineering ethics education (Harding *et al.,* 2013). These range from case studies, lectures and presentations from multiple sources, role-playing activities, in class or online discussion, debates, voting, games, online modules, films and videos, creative fiction, science fiction, community service, field trips and visits (Pritchard, 2000; Berne & Schummer, 2005; Lloyd & van de Poel, 2008; Kang & Lundeberg, 2010; Alpay, 2011; Finelli *et al.,* 2012; Itani, 2013; Voss, 2013; Bielefeldt *et al.,* 2014; Atwood & Read-Daily, 2015, Rabb *et al.,* 2015; Génova & González, 2015; Lumgair, 2018; Burton *et al.,* 2018). A common complaint is that engineering programmes lack "consistent, accurate, and reliable methods of teaching ethics and measuring its outcome" (Bairaktarova & Woodcock, 2015).

Case studies are considered to be a very popular method in engineering ethics instruction in the US (Colby & Sullivan, 2008; Haws, 2001; Herkert, 2000). Nevertheless, there is limited empirical research on the effectiveness of different types of case content that could guide instructors (Bagdasarov *et al.*, 2013; Thiel *et al.*, 2013, p.267), as to identify "the mechanism by which the case study method is able to achieve its alleged superiority as a pedagogical model" in the area of engineering ethics (Abaté, 2011, p.589). As such, despite their popularity, "instructors know little about the influence of cases on students' ethical understanding" (Yadav & Barry, 2009, p.138).

Case studies have been described as scenarios meant to closely reflect features of a profession (Herreid, 1994). They are expected to contain authentic professional problems, thus raising students' awareness of the type of situations and problems they might encounter in the workplace (Merseth, 1994; Davis, 1997; Davis & Yadav, 2014; Martin, 2019).

2.5.3 Assessment methods in engineering ethics education

As Goldin *et al. (*2015, p.790) point out, "one's methodological approach to teaching ethics also affects assessment", and "given the variations in teaching applied ethics, one must be clear about the goals of teaching, and the real opportunities for assessment." Keefer *et al. (*2014, p.259) also highlight the importance of aligning goals with teaching methods and ensuring that they are "appropriately assessed", at the same time noting that alignment is "still a weakness in the present state of ethics education."

Assessment of ethics raises a number of challenges, mostly related to the unfamiliarity with evaluating and grading the ethical components of courses and a lack of guidance about what assessment methods are suitable for nontechnical subjects (Sinha *et al.,* 2007; Romkey 2015; Goldin *et al.,* 2006).

Bielefeldt *et al. (*2016) note that engineering ethics instructors admit to using between zero to four assessment methods, with an average of two assessment methods per module, and none of the instructors surveyed has been using a standardised assessment method. Freyne and Hale (2009, p.8) also observed that discussions and essays are the most common used methods of assessment, but also that several instructors indicated that they "made no effort to assess students' understanding of ethics." Other popular assessment methods are presentations, group projects and portfolios (Sunderland *et al.*, 2013)

The lack of ethics assessment tools is seen by engineering educators as one of the major minuses of the accreditation criteria introduced in 2000 (ABET, 2006).[7] There are different

[7] The set of the accreditation criteria introduced by ABET is known under the abbreviated name of EC2000, which will be used henceforth.

assessment methods in use, which Newberry (2004, pp.349-50) considers to be linked to a personal understanding of engineering ethics by instructors unfamiliarised with the discipline.

There are also difficulties in grading students on ethical abilities and character (Davis, 2012). Many of the faculty with a technical background consider ethics to be a personal and subjective discipline, ignoring how humanities faculty assess students' work and provide feedback (Davis & Feinerman, 2012). The ill-structured nature of engineering case studies is another contributor to the difficulty of assessing ethics education (Goldin *et al.*, 2015)

These challenges led to a call for the development of standardized assessment instruments, scoring rubrics and instruments. Some of the most used are the Defining Issues Test - DIT developed by Rest (1979) and its revised version DIT2 (Rest *et al.*, 1999). The test is designed to determine the maturity of students' reflection on ethical issues when asked to evaluate a number of ethical dilemmas, but it can be too general and omit the assessment of specific issues (Borenstein *et al.*, 2008). The largest survey of ethical instruction in engineering at the moment is the Student Engineering Ethical Development - SEED project (Finelli *et al.*, 2012; Harding *et al.*, 2015), which looks at both the formal and informal ethical experiences of engineering students, as well as their influence on students' social behaviour. Another assessment instrument developed is the Engineering Professional Responsibility Assessment - EPRA that measures students' views on social responsibility (Canney & Bielefeldt, 2016). The Test for Ethical Sensitivity in Science and Engineering – TESSE (Borenstein *et al.*, 2008, p.2) was developed to measure "ethical sensitivity and the ability to identify and recognize relevant ethical issues emerging from a situation", which is considered to overlap with the goal of developing moral imagination (Johnson, 1993; Harris *et al.*, 1996; Coeckelbergh, 2006, Umbrello, 2020). For measuring ethical reasoning and contemplation of technical dilemmas, the Engineering and Science Issues Test - ESIT was developed by Borenstein *et al. (*2010). With a similar focus on ethical dilemmas, the University of Pittsburgh and Colorado School of Mines developed a test that would assess students' abilities to recognise and address ethical dilemmas, focused on five attributes of attainment: recognition of an ethical dilemma, argumentation, analysis, perspective taking and resolution (Sindelar *et al.,* 2003). Sindelar *et al*'s (2003) initiative builds on a previous test rubric developed by the team at Colorado School of Mines, focused on design projects provided by industry stakeholders, which takes into consideration how engineering students identify the client's need, specify the purpose of the project, bring evidence supporting their approach, and whether the organization and content of the project is coherent and clear (Moskal *et al.,* 2001). A test with a similar focus to that of Moskal *et al. (*2001) is the Engineering Ethical Reasoning Instrument – EERI, which aims to assess individual ethical decision-making in a project-based design context (Qin Zhu *et al.,* 2014). The assessment instrument developed by Qin Zhu *et al. (*2014, p.6) aims to address the complexity of engineering practice by integrating microethical and macroethical goals. With a focus on decision-making in real-world scenarios bearing ethical implications, the ethical decision-making - EDM instrument developed by Mumford *et al. (*2006) can also be applied to engineering undergraduate students (Bagdasarov *et al.,* 2016), showing the importance of providing knowledge and expertise for ethical decision making (Bagdasarov *et al.,* 2016, p.140).

An advantage of assessment instruments is that results can serve as feedback for instructors in the process of curricular improvement, revealing "where future instructional resources might be allocated" (Moskal *et al.,* 2001; Sindelar *et al.,* 2003; Keefer *et al.,* 2014, p.258). A significant drawback is that none of the instructors surveyed has been using a standardised assessment method, which according to Bielefeldt *et al. (*2016, p.3) is due to the instructors' being unaware of their existence due to a lack of training in ethics instruction. Another drawback refers to the Western centric nature of existing standardized tests. The aforementioned tests have been developed in the US, and the risk is that of excluding the cultural characteristics or traditions of other geographical regions or the individual characteristics of respondents that are shaped by their gender, ethnicity, cultural background or social class (Qin Zhu *et al.,* 2014, p.10). Goals associated with the feminist and value based design approaches are also missing from the scope of existing standardized tests.

2.5.4 Coverage of ethics issues

The diversity of approaches is present also when it comes to the content of engineering ethics education. We find coverage such as professional codes, ethical theories, ethical heuristics, plagiarism science and technology studies, humanist readings and service learning (Lynch, 1997; Haws, 2001; Kline, 2001; Atesh *et al.*, 2017). However, not all types of coverage is of "equal value for the implicit goals of enhancing divergent thinking, helping engineers to see their work through the eyes of the broader community" (Haws, 2001, p.227). Colby and Sullivan (2008, pp.329-30) highlight the uneven coverage of key issues, claiming that engineering ethics education shows a strong emphasis on professional codes, while the broader mission and implications of engineering are neglected. Polmear *et al. (*2019) notice geographical differences in terms of coverage, with a "higher percentage of non-US Anglo and Western European educators teaching sustainability and environmental issues in their courses compared to US respondents" and "US educators teaching codes of ethics, ethics in design, and safety more than those in Western Europe." Nevertheless, Atesh *et al. (*2017) claim that in engineering programmes in the UK, there is a higher focus on issues such as plagiarism and honesty than on respect for life, law and public goo, reflected in the higher importance attributed by students to these former issues students.

Defenders of professional codes point to their role in familiarising students with the importance of ensuring a safe and ethical working environment through adherence to their rules (Unger, 1994; Davis, 1998), as well as making them aware of the individual responsibility and accountability of their actions (Glagola *et al.,* 1997). Codes show why individual conscience is not sufficient to serve as a guide in engineering practice, offering a supraindividual and generalizable understanding of how an engineer should behave (Davis, 1991).

Mitcham (2009) points out that while more attention is being given to engineering ethics and professional codes, the critical histories of ideas about engineering and engineering ethics are neglected. In his view, discussions about public safety, health and welfare should be complemented by reflection on the historical and social character of public safety, public health and societal welfare. Bielefeldt (2016) also observes there is a poor understanding of the extent to which macroethical topics are included in engineering ethics education. This is consistent with the difference in perception between instructors and students in regards to the coverage of ethical issues revealed in the survey by Holsapple *et al. (*2012). Despite the fact that faculty describe their instruction as including not only codes but also a nuanced treatment of complex issues, students reported hearing "simplistic, black-and-white messages about ethics" (Holsapple *et al.,* 2012, p.101).

2.6 Challenges and barriers in engineering ethics education

According to the literature, the main challenges and barriers to implementing and teaching ethics in engineering programmes fall under five main themes, related to engineering culture, the guidance provided by accrediting bodies, institutional support, faculty expertise and the characteristics of the student cohort.

2.6.1 Engineering culture

A major obstacle to the implementation of ethics in the engineering curriculum is represented by the dominant traditional conception of engineering. Engineering education is heavily focused on promoting the dichotomy between "hard" and "soft" skills, according to which ethical concerns fall outside the scope of "real engineering" (Polmear *et al.*, 2018). Ethics instruction is treated within engineering programmes "merely as a requirement to fulfil" for accreditation purposes. This stance towards engineering ethics education is seen as leading to a minimal teaching approach confined to safety and plagiarism issues (Polmear *et al.*, 2018, p.14).

2.6.2 Institutional support

Another important challenge is linked to the institutional support needed for an enhanced implementation of engineering ethics education. In this regard, LeBlanc (2002) notes the wide scale of transformation, curricular as well as cultural, that a programme needs to undertake in order to accommodate ethical concerns.

There are also voices pointing to the insufficient space in the curriculum. Given the already crowded curriculum of engineering programmes, priority is given to technical and scientific subjects. It is thus difficult for programmes to decide which technical modules to sacrifice in order to introduce new ethics modules (Harding *et al.,* 2009; Walczak *et al.,* 2010; Romkey, 2015; Polmear *et al.,* 2018).

Another challenge is represented by the lack of peer and institutional support for instructors interested in teaching ethics (Walczak *et al.,* 2010; Romkey, 2015; Polmear *et al.,* 2018). Instructors teaching ethical content report feeling isolated and lacking a group of peers within their institution with whom they could discuss and get advice about their teaching approaches. They also report "resistance on the institutional level, including a lack of support and promotion systems that do not recognize the value of ethics education" (Polmear *et al.,* 2018, p.13).

2.6.3 Faculty expertise

The engineering faculty's technical background and expertise is another major challenge highlighted by empirical research. This is partly due to a lesser familiarity with the topic, which gives rise to challenges in linking ethical concerns with technical subject matters, as well as finding pedagogical content. This challenge is perceived to be rooted in a lack of guidance and training related to the implementation and teaching of engineering ethics (Vesilind, 1991; Sinha *et al.,* 2007; Harding *et al.,* 2009; Walczak *et al.,* 2010; Romkey, 2015; Monteiro, 2016; Polmear *et al.,* 2018). Also notable are the day to day time pressures experienced by faculty members, and the significant time commitment needed for instructors to get accustomed with an unfamiliar topic. Budgetary concerns and limited institutional resources are seen as a hindrance for bringing external instructors that have expertise in this area (Walczak *et al.,* 2010; Romkey, 2015).

There is also uncertainty about how to assess the ethical components of modules, combined with a lack of guidance about what assessment methods are suitable for nontechnical subjects (Sinha *et al.,* 2007; Romkey, 2015; Goldin *et al.*, 2006).

Furthermore, there are also concerns about ethics education leading to indoctrination or imposing bias (Vesilind, 1991; Walczak *et al.,* 2010; Romkey, 2015). There are instructors that consider that ethics instruction does not have a place in engineering institution because it is a subjective and personal issue that falls under the responsibility of the students' family.

2.6.4 Characteristics of the student cohort

According to studies carried by Harding *et al. (*2009) and Romkey (2015), engineering ethics instructors consider that the students' skills, background and reception of ethics is a challenge they experience in their teaching. Students prefer and are more prepared to address technical subjects than nontechnical ones. Students are also found to show "disinterest, resistance, and difficulty learning about ethics and societal impact" topics (Polmear *et al.*, 2018, p.9).

2.6.5 Guidance provided by accrediting bodies

A significant challenge is linked to understanding the formulation of the ethics outcome and the expectations of the accreditation body in regards to how to implement it in the programme (Besterfield-Sacre *et al.*, 2000; Herkert, 2002; Colby & Sullivan, 2008; Sheppard *et al.*, 2009).

The feedback following accreditation events is perceived as minimal and unhelpful. There is a lack of guidance from the accrediting body on how to proceed in the implementation of ethics (Barry & Ohland, 2012; Conlon, 2013).

There are also several challenges related to the programmes' preparation for the accreditation of the ethics outcome. A frequent challenge faced by programme representatives is about the type and amount of evidence needed to show that the programme is meeting the ethical requirements for accreditation (Ferguson & Foley, 2017). The guidance on how to prepare evidence in support of ethics for accreditation events is perceived as insufficient (Barry & Ohland, 2012). Another challenging aspect is related to the development of metrics for evaluating and self-assessing how the programme meets the ethical requirement for accreditation (Fromm & McGourty, 2001).

The challenges highlighted by empirical research are primarily of an institutional nature, but there are also challenges related to the technical background and interests of engineering faculty and students. These challenges seem to suggest the complexity behind an effective integration and instruction of ethics in engineering programmes. They point to structural issues such as the traditional paradigm of engineering as a technical discipline, which dominates engineering education and which was formative for the current generations of engineering academics, as pointed by Jamison *et al. (*2014).

2.7 Dissatisfaction with current state of engineering ethics education

Two major lines of criticism in regards to the current state of engineering ethics education are taking shape. One strand of criticism targets the minor role given to ethics in the curricula of engineering programmes, while the other strand focuses on the need for a broader approach to engineering ethics education.

2.7.1 Dissatisfaction with the weight given to engineering ethics education

As mentioned, the first strand of criticism points to an educational landscape where engineering ethics has little priority. Empirical research reveals a marginal presence of ethics even in engineering programmes belonging to educational systems where ethics features among the accreditation criteria (Colby & Sullivan, 2008; Barry & Ohland, 2012; Ocone, 2013). In countries where ethics education is not mandatory for accreditation, ethics is found to have a low presence in the engineering curricula (Monteiro, 2016, Monteiro *et al.*2016; 2017). There is also a significant disparity between the perceived importance of ethical and societal related practices by engineering faculty and their actual presence in the engineering curriculum (Romkey, 2015, p.14).

The weight given to ethics in the engineering curricula appears to be a symptom of a deeper issue, reflecting the prevailing conception about what is engineering and what should be the focus of engineering education. As such, the main risk associated with a weak presence of ethics education in engineering programmes is that of perpetuating a traditional view of engineering as a solely technical discipline. With it, passing on to students the message that ethics is not as important for their education and future profession as other skills, such as technical abilities (McGinn, 2003, p.525). In our times, the two cultures of science and humanities described by Snow (1959) can no longer exist separately and on different hierarchical levels.

Cech (2014b) warns about the dangers of separating the “two cultures” in engineering education, noting the correlation between the emphasis placed by a programme on ethical and social issues and students’ concern for their ethical and social responsibilities as engineers. According to Cech (2014b), students from engineering programs that favour the development of technical skills to the detriment of ethics and social engagement tend to have declining beliefs about the importance of public welfare from their first to their last year of studies, and their engagement with public welfare issues does not rebound upon graduating and entering the workforce. Throughout their studies, engineering students are also found to develop strong and rigid views about the lower value of academic disciplines oriented towards people and society (Adams *et al.*, 2011), express less commitment to social activism and concern for society than students from other disciplines (Sax, 2000), and to consider that it is unrealistic to expect engineers to have an ethical behaviour (Stappenbelt, 2013). Furthermore, Tormey *et al.* (2015) found that the moral reasoning of engineering students diminished during the second term of their degree, despite having received ethics training. According to Tormey *et al.* (2015, p.2), this is the outcome of the broader culture of the programme, highlighting the risk that “courses addressing ethical issues may be swimming against the hidden cultural tide of the programme as a whole”.

Given that university education is the propitious period when engineering students start to develop their identities as future professionals (Loui, 2005). The weight given to ethics in the engineering curricula, together with the attitude and involvement of engineering faculty, are extremely important in sending students the message that ethics is not peripheral to engineering, but a substantial aspect of their profession (Jessica Li & Shengli Fu, 2012).

The stakes are thus high when considering the weight that should be given to ethics in engineering programmes.

Besides an increased presence of ethical concerns in engineering education, a hybrid socio-technical professional identity can be fostered by the integration of macroethical issues alongside microethical issues (Canary *et al.,* 2014). Both corrective steps are needed to address what Bairaktarova and Woodcock (2015) notice to be a "misalignment between the importance, content, pedagogy, and assessment used in teaching ethics."

2.7.2 Dissatisfaction with the approach to engineering ethics education

The prevalent model of microethical education started to attract criticism in the last decade. Despite being an important model for familiarizing students with moral reasoning and the concept of professional responsibility, it is deemed insufficient by itself for preparing students to consider the broader mission and context of engineering practice (Conlon & Zandvoort, 2011). The strong emphasis of microethical interventions on the engineer's individual responsibility is considered to put into brackets the structural impediments that might constrain an engineer to act ethically and also the collective responsibilities of engineering as a profession. For example, emerging technological developments give rise to ethical issues that are in the grey area between individual responsibility and public policy (Pine, 2012). One such example is the malware Stuxnet developed by the United States and Israel, whose aim was to disable the nuclear facilities of Iran (Tavani, 2016).

The individualistic focus on engineers' active responsibility to behave ethically risks overburdening the engineer who is "only one of many players, without much power or foresight, to behave responsibly" (Swierstra & Jeelsma, 2005, p.314). Microethics education is thus instilled with a moralistic tone, which is not adequate in light of an individual engineer's limited agency or control over the use of the final artefact she contributed to

(Johnston *et al.,* 1996). The microethical emphasis on the full agency of engineer neglects the need to correct the broader context of practice that cultivates an immoral behaviour. Engineers may face pressure and impediments of an organizational, political or economic nature, such that identifying the right course of action cannot be followed by ethical action in all situations. Microethical approaches elude the complexity of engineering practice and the structural forces in play that can restrict an engineer's ethical and socially responsible action, such as those exercised by individuals on a higher hierarchical scale than the engineer in question.

The emphasis on individual action and sanctions attached to the failure to obey the prescriptions of professional codes imply a treatment of ethics in legal terms, insufficient for calling into question the engineering profession itself (Ladd, 1991). Ladd (1991) argues that engineering ethics education is reduced to a "utilitarian interpretation of the problem itself [*n.m.* safety] and a utilitarian answer to it, including a utilitarian view of the value of moral consciousness and moral education."

Given the low membership rates of engineering professional or disciplinary societies, there is the concern that the prescriptions encapsulated in professional codes will be not be considered necessary for graduates who opt out of such membership (Glagola *et al.*, 1997).

Microethical approaches are also criticised for failing to provide a justification for the criteria or rules spelled out by professional codes. If we are to take the provision set in professional codes as the grounds on which we judge an individual action as right or wrong, we also need to provide a justification of the morality of the rule or code itself (Gewirth, 1986). Both levels of justification are needed in professional ethics, but microethics only takes into account the level of justification of the individual action. In the absence of a fundamental principle or an overarching goal for justifying the morality of the rules and codes themselves, we dismiss at theoretical level the possibility for corrective actions targeted at improving those codes and rules that we experience as inadequate, wrong or immoral. Johnson (1992, p.29) stresses the need to conceive the engineering profession as "a set of social arrangements which must be justified by something higher." In order to achieve this, we have to move beyond the microethical level of analysis.

Another criticism pointed at the overreliance of microethics on professional codes is that ethical and socially responsible behaviour goes beyond what is prescribed by these (Ladd, 1991). Moral codes often do not suffice to make agents understand their moral responsibility or take a proactive stance in regards to ensuring that technological developments promote human welfare (van der Burg & van Gorp, 2005; Little *et al.,* 2007). In fact, it might mislead individuals into believing that as long as they adhere to the prescriptions of codes of ethics, they fulfil their duty towards society. Trailer trucks are one such an example that shows that ethical behaviour spills over the boundaries set by professional codes (van der Burg & van Gorp, 2005). Engineers developing trucks might not consider that is their responsibility to develop and inctegrate safety measures beyond what is legally required, and what is legally required is not sufficient to avoid accidents and fatalities. Professional codes also fail to address issues related to distributive justice, although as Hansson (2017, p.51) stresses, "technological resources are among the assets that can be justly or unjustly distributed among people."

Microethical case studies have also been questioned. Despite their widespread use, there is little or no empirical evidence proving their effectiveness compared to other teaching methods (Yadav & Barry, 2009; Abaté 2011, p.589). Moreover, Shuman *et al. (*2005, p.11) remark that while students show an ability to recognize obvious black and white ethical dilemmas, they fail to do so for "more subtle but possibly more serious dilemmas contained in the short cases."

There is a growing criticism of the microethical use of case studies for teaching engineering ethics, pointing to its inadequacy in capturing the complexity of the profession (Lynch & Kline, 2000; Bucciarelli, 2007). As described by Martin *et al. (*2018; 2019), the objections fall under two main categories, suggesting a weakness of microethical case instruction on both metaphysical and epistemological grounds. From a metaphysical perspective, the microethical use of case studies fails to fully capture features of the engineering profession related to the nature of (i) the artefacts produced (Winner, 1986; Bijker, 1995), (ii) engineering practice (Vaughan, 1996; Beder, 1999, p.15; Devon & Van de Poel, 2004) and (iii) the professional environment (Davis, 1991; Johnston *et al.*, 2000; Zandvort *et al.*, 2008; Conlon, 2011). The epistemological deficits of the microethical use of case studies, focused on clear cut dilemmas and situations of crisis, rest on the assumption that (iv) engineering knowledge is fully explicit and readily available by consulting codes and theory, neglecting its strong tacit and practice based character (Vincenti, 1990; Gorman, 2001; Gainsburg *et al.*2010, p.209; Vermaas *et al.*, 2011).

2.8 Key findings

The theoretical underpinnings of engineering ethics education point to four key findings:

First, three paradigms aimed at explaining engineering education policies and practices are academic, market-driven and integrative (Jamison *et al.*, 2014), with the later manifesting a greater concern with integrating the ethical and social dimension of engineering;

Second, the review noted the existence of a diverse set of goals envisioned for engineering ethics education.

Third, there are different theoretical models explaining the goals of engineering ethics education, the most common tracing a distinction between an individualistic micro approach versus a macro approach focused on the collective mission of engineering.

Fourth, the review identified several minuses associated with an exclusive reliance on micro approaches to engineering ethics education, highlighting the need for a more comprehensive approach.

There are three main empirical findings about the implementation of ethics education:

First, there is a wide spread fragmentation and variation in how ethics education in engineering is conceptualised and implemented along five major lines of enquiry: related to the goals of engineering ethics education, the method of delivery, the teaching and assessment methods employed, as well as to the coverage of issues;

Second, there are engineering programmes and instructors report numerous challenges when it comes to the implementation and teaching of ethics.

Third, there is a correlation between the emphasis given to ethics in the curriculum and the formation of engineering students' professional identity as socially responsible engineers.

After identifying the key findings related to the theoretical underpinnings of engineering ethics education and its implementation, the next chapter surveys the literature in order to identify the major empirical findings related to the current state of engineering ethics education in the context of accreditation. The two chapters of literature review will conclude with a reflection on the implication of these findings for the research study undertaken.

CHAPTER 3 LITERATURE REVIEW: AN OVERVIEW OF ETHICS AS AN ACCREDITATION CRITERION

The aim of this chapter is to provide an overview of engineering ethics education in the context of accreditation. I start by presenting the main features of the accreditation process, before describing the global accords governing the recognition of accredited engineering programmes. The chapter proceeds by focusing on the presence of ethics in the criteria for accreditation of engineering programmes. For this, the chapter first focuses on Engineer Ireland's accreditation process, before surveying existing scholarship on the impact of having an accreditation criterion dedicated to ethics in countries such as the USA, Australia and the UK. More attention is given to the USA, given the wide empirical research available and the influence exercised on different accreditation systems across the globe. The chapter concludes with a summary of the key issues arising for the present study based on the empirical findings identified in the literature about the role of accrediting bodies in the development engineering ethics education and the evaluation of ethics for accreditation purposes.

3.1 What is accreditation?

By accreditation is understood both the status of an educational programme that was recognized following an evaluation by a relevant authority to have met certain criteria for preparing graduates to start their professional practice, and the process itself by which a programme prepares and submits evidence of meeting such criteria (Banta *et al.*, 1996). Accreditation should not be an end in itself, but express the programme's value of continuous improvement and commitment to academic quality, as well as make higher education programmes accountable for the education provided (Banta *et al.*, 2010).

Germaine & Spencer (2016, pp.69-71) list six benefits of accreditation, such as: enhancing student learning, supporting the achievement of the envisioned education, building faculty capacity for continuous improvement, strengthening a culture of continuous improvement, enhancing faculty cooperation and meeting the societal demands for accountability. This latter role of accreditation is also stressed by Harvey (2004), who considers that accreditation helps establish or restate the status and legitimacy of a programme of study.

The accreditation process combines two major elements (Kam, 2011). First, accreditation includes an element of self-assessment, by which the programme conducts a "comprehensive internal self-study by its principals" (Kam, 2011, p.1). Second, accreditation also relies on an element of peer-assessment, by which a programme is reviewed by representatives of the respective profession from different sectors, such as academia, industry, government (Kam, 2011). These elements can be seen as equating accreditation with quality assurance and quality improvement (Stensaker, 2011; Uziak *et al.,* 2013; Quiles-Ramos *et al.,* 2017; Kumar *et al.,* 2020).

Kam (2011, p.2) considers that the accreditation process follows three steps that are "common in almost all current practices of Engineering, Technology and Computing accrediting bodies." The first step is linked to the element of self-assessment, which requires faculty, administrators and staff to conduct a self-study guided by the relevant accrediting body's standards and expectations. The second step of the accreditation process is linked to the element of peer-assessment. The accrediting body names "a team of peers" tasked to review the evidence prepared and undertake a campus visit comprising interviews with faculty and staff, followed by the preparation of a report of their assessment together with recommendations for improvement. The third step involves the review of evidence and recommendations by the accrediting organization, leading to an official final decision, which will then be communicated to the institution.

In Ireland, the accrediting body of engineering undergraduate degree programmes is Engineers Ireland, which is also the professional body representing engineers based in Ireland. In the US, accreditation falls under the responsibility of a federation of 35 professional societies in applied and natural science, computing, engineering, and engineering technology called ABET (n.d.). Accreditation activities are the responsibility of more than 2000 trained volunteers that receive no financial benefits.

Engineers Ireland, like ABET, accredits individual programmes rather than an entire college or institution. This means that each programme offered by an engineering college or faculty undergoes a separate accreditation process, for which it prepares its own set of documents.

3.2 The advent of engineering ethics education through global accords

Currently, several global accreditation accords of mutual recognition are in place for the field engineering, such as the Washington Accord (for the degree of Professional Engineer), the Dublin Accord (for the degree of Engineering Technician) and Sydney Accord (for the degree of Engineering Technologist). Ireland signed the Washington Accord targeting the mutual equivalence of BE degrees in 1989, and its signatory body is Engineers Ireland. The role of global accords is to accept the accreditation of all signatory members as providing equivalent academic standards for their graduates (International Engineering Alliance, 2015a; Philips *et al.*, 2000).

The Washington Accord was signed in 1989 and numbers six original signatory members, representing engineering education systems from English speaking countries. These are ABET in the USA, Engineers Australia, Engineers Canada, Engineers Ireland, Engineering Council UK and Institution of Professional Engineers New Zealand (International Engineering Alliance, 1989). Not coincidentally, the year when the Washington Accord was signed marks the end of the Cold War brought by the fall of the USSR, and with it a recognition of the increasing open nature of economies across the globe (International Engineering Alliance, 2015b, p.2). This is a year of great change in the political and economic world order. The outcome of the globalization process (Sthapak, 2012) and of the domination exercised by the US in the engineering education landscape (Haug, 2003; Gray *et al.,* 2009; Anwar & Richards, 2013), is that the Washington Accord has expanded and currently includes 20 countries with full rights as well as eight provisional signatories. As Klassen (2018) notes, since its inception over 30 years ago, the Washington Accord has grown in scope and power. Furthermore, it continues to expand its reach, accepting new members.

The adoption of the global accord has led to the alignment of accreditation systems in signatory countries, and as such, to the formulation of accreditation requirements that, although not completely overlapping (Patil & Gray, 2009, p.20), nevertheless have a similar focus (Hanrahan, 2008). For the Washington Accord, ethical responsibilities and the societal role of the engineering profession is of a significant importance. In this regard, the Washington Accord states that graduates are expected to "apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice," as well as to "apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems" and "understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts" (International Engineering Alliance, 2014). The emphasis of global accords on ethical and societal considerations in the practice of engineering is considered to have led to the establishment of engineering ethics education as a mandatory accreditation requirement in signatory countries (Coates, 2000). The six countries that drew up the Washington accord in 1989 –

the USA, Ireland, the UK, Australia, Canada and New Zealand – all have an accreditation criterion dedicated to ethics.

3.3 The introduction of ethics as an accreditation requirement

Looking at the adoption of ethics as an accreditation criterion, the year 1996 marked a turn towards a stronger emphasis on engineering ethics education in the US, as ABET approved a new set of accreditation requirements. One novelty of the ABET Engineering Criteria 2000 (EC2000) was the introduction of student outcomes. Student outcomes represent the set of knowledge, skills and attitudes that students are envisioned to possess upon graduation. The focus of the accreditation process shifts from teaching content to ensuring that student outcomes have been met. There are eleven student outcomes stated in EC2000, falling under the Criteria 3.a through k. The new set of accreditation criteria EC2000 comprises both nontechnical skills and an equally important set of six nontechnical skills that engineering students are expected to possess upon graduation. Among these, the three student outcomes bearing an ethical weight are criterion 3.f, which requires students to attain "an understanding of professional and ethical responsibility," criterion 3.h which emphasizes the "understanding of the impact of engineering solutions in a global and societal context" and criterion 3.j which requires knowledge of contemporary issues (ABET, 1997).

The key benefits associated with the implementation of EC2000 are related to an increased importance given to ethics by Engineering programmes, a change in the teaching methods used favouring active learning and an increased student awareness about the importance of ethical concerns and societal involvement of engineers.

1998–2000 marked a period of transition from the old accreditation criteria to the new EC2000, during which programmes had the freedom to choose according to which set of criteria to be reviewed. EC2000 became mandatory in 2001.

At the time of introduction, EC2000 were believed to constitute a significantly step forward towards a more important role given in the curriculum to societal and environmental topics, as well as to the professional and ethical responsibilities of engineers (Herkert 2001a; Johnston & Eager, 2001). The engineering academic landscape prior to EC2000 was neglecting the ethical dimension of the profession (Herkert, 2002; 2004). A survey of US course catalogues carried by Stephan (1999, pp.460-1) showed that in 1998 less than 27% of colleges required all their students to take a course whose description mentions ethics. Of the 242 institutions surveyed, only 24 required students to take one ethics related course, and 18 offered at least two such mandatory courses. All these 18 had a religious root or current tie, as Stephan (1999) points out that in the definition of an ethics related course he included religion and philosophy, raising doubts about the depth of the engineering ethics instruction provided.

According to Herkert (2001a), the change in the accreditation criteria was expected to lead to an “increased attention in the curriculum to the ethical responsibilities of engineers and the societal context of engineering." Indeed, later studies have confirmed an increase in the number of ethical courses engineering undergraduates are required to take, provided either by their own programme or by liberal arts and humanity oriented programmes within the institution (Barry & Ohland, 2012; Volkwein *et al.*, 2004). Furthermore, a study commissioned by ABET carried by Lattuca *et al. (*2006, p.3) noted an “increased emphasis on nearly all of the professional skills and knowledge sets associated with Criterion 3.a-k, according to the programme chairs and faculty surveyed.

The increased weight given to ethics and professional skills required by Criterion 3.a-k was expected to also lead to a change in the teaching methods used, confirmed by Lattuca *et al.* *(*2006, p.4), who in their study noted that half to two-thirds of the faculty members surveyed had reported that they "have increased their use of active learning methods, such as group work (52%), design projects (54%), case studies (60%), and application exercises (65%), in a course they teach regularly." Open ended problems were also mentioned to have increased by 65% (Lattuca, 2006, p.4).

In regards to the engineering students' attitude towards ethics, the same study also highlights that compared to their 1994 counterparts, 2004 graduates report higher ability levels on nine learning outcomes, with the most substantial differences related to "awareness of societal and global issues that can affect (or be affected by) engineering decisions, applying engineering skills, group skills, and awareness of issues relating to ethics and professionalism (Lattuca, 2006, p.9)." This attitude of engineering students towards ethical matters contrasts a survey carried at Georgia Tech in 1998, prior to the introduction of EC2000, which shows that student respondents did not acknowledge the importance for engineering programmes to address the engineer's role in society (Peters, 1998, p.874).

The empirical research available on the reception and impact of the ethics accreditation criteria is predominantly US based, with limited findings available from other countries. The key benefits associated with the implementation of EC2000 in US are related to i) an increased presence of ethics in Engineering programmes, ii) a change in the teaching methods used favouring active learning and iii) an enhanced student awareness about the importance of ethical concerns and societal involvement of engineers. Research carried in Australia and the UK show similar findings in regards to the increased presence of ethics in the curricula of engineering programmes following the introduction of ethics as an accreditation criterion.

In Australia, the redesign of the accreditation criteria took place in 1997, following a multiyear process started in 1994, as to include the "understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development" and "understanding of the principles of sustainable design and development" (Institution of Engineers, Australia, 1997). A survey of Australian engineering faculties carried out in 1993, prior to the introduction of an ethics accreditation criterion, showed that "apart from a few mentions of sustainability and professionalism, there was no indication of any scholarly interest in these areas" (Johnston *et al.,* 2000). Following the change in accreditation requirements, engineering programmes require an "integrated exposure to professional engineering practice, including management and professional ethics in not less than 10% of courses, up to a coverage of 20%, by allowing the focus on one or more criteria through elective courses weighing 10% of total courses" (Skinner *et al.,* 2007, p.136).

In the UK, the teaching of ethics in engineering curriculum was "rather patchy" prior to the introduction of ethical specifications in accreditation, according to a survey carried out by the Royal Academy of Engineering (Ocone 2013, p.263). The results showed that 46% of the departments surveyed offered "some" ethical instruction. Engineering Council, the institution responsible for the accreditation of engineering degrees in the UK, currently states six key area of learning that engineering programmes need to meet for gaining accreditation, one of them encompassing the "economic, legal, social, ethical and environmental context" (Engineering Council, 2016).

In Portugal, where ethics does not feature among the accreditation criteria for engineering degree programs, 61% of the courses were found not to provide any mandatory or optional ethics units in their curriculum, while only 29% required ethical training, according to research conducted by Monteiro *et al. (*2016). Monteiro (2016) puts this situation down to the strong influence of the instructor in shaping curriculum development, combined with a reduced ethical background and training of engineering instructors. She notes that "almost all engineering teachers had made an academic career that did not include any curricular explicit form of ethics education." This is most important in light of Portugal's pedagogical autonomy of higher education institutions. Here, higher education institutions have "the freedom of teaching and learning […] based on the recognition of the university's competence to define what knowledge is relevant and how it should be transmitted" […] which makes curriculum development "the privileged place of teachers' action in higher education, based on their own views and perspectives of education and knowledge," points out Monteiro (2016).

The findings of Monteiro *et al. (*2016) are consistent with empirical research in the US and Australia that revealed ethics to have a low presence in the engineering curriculum prior to the introduction of a dedicated accreditation criterion. Accreditation bodies can thus influence how programmes shape their curriculum, and an ethical criterion has been shown to lead to an increased emphasis on engineering ethics education.

Furthermore, the findings of Monteiro (2016) point to the distinction between what Snow (1959) calls two divergent cultures, the technical and the humanities, which is considered to influence the pedagogical approach of engineering instructors formed in a technical culture to the detriment of social or ethical considerations.

3.4 Challenges related to the introduction of an ethics criterion for accreditation

The introduction of ethics as an accreditation criterion does not come without challenges. There have been several challenges associated with the implementation or formulation of a dedicated ethics criterion for accreditation. Sheppard *et al. (*2009) note that criterion 3.f. of EC2000 "has probably been the most difficult for engineering faculty — and students — to come to terms with." Besterfield-Sacre *et al. (*2000, p.100) captures this sentiment remarking that at the time of the adoption there was "much concern as to how to best operationalize each outcome for use within one's own institution."

Some of the difficulties are related to the effective design and integration of ethics into an engineering program (Sheppard *et al.,* 2009). Conlon (2008) points to the focus of accreditation on individual programmes, as most often their curricular orientation is determined at institutional level. Another difficulty pointed out by Conlon (2008) is linked to the componence of the accreditation panels, given that its members appear unprepared to evaluate the programme outcome related to ethics and social responsibility.

One of the key minuses of the criterion lies in its vagueness, which "makes it difficult to implement a standard model for teaching engineering ethics" (Herkert, 2002). This is reflected in the disparity of approaches used to teach engineering ethics (Harding *et al*., 2013) and for assessment (Bielefeldt, 2016). Colby and Sullivan (2008, p.328) also note that the student outcomes mentioned by EC2000 lack clearly formulated goals or strategies to meet them, and the survey carried out in 2002 on 100 programs at 40 engineering schools in US has indeed highlighted an uneven coverage of topics in engineering ethics and professional responsibility (Colby & Sullivan 2008, p.329). Among these, macroethical topics appeared deficient, with few schools having "instituted systematic programs to educate for this broad sense of professional responsibility" (Colby & Sullivan 2008, p.330).

The vagueness of the accreditation requirement related to ethics, combined with the unfamiliarity of engineering instructors with engineering ethics at the time of its introduction, constitute a significant challenge in the implementation of ethics in engineering programmes. Henceforth, there is the risk of a limited coverage of ethics, to the particular detriment of macroethical approaches. Bielefeldt *et al. (*2016) is especially concerned that the ABET self-study documents "generally do not distinguish between micro and macroethical issues," noting that the popularity of the Fundamentals of Engineering exam as an outcomes assessment method implies a focus on microethical issues.

When it comes to preparing for the accreditation process under the EC2000 criteria, another significant difficulty that programmes face is related to the type and amount of evidence that should be collected in order to sufficiently represent the attainment of the nontechnical requirements (Ferguson & Foley, 2017), as well as about how to develop metrics for evaluating them (Fromm & McGourty, 2001). Not only administrators and instructors in engineering programmes encounter this difficulty, but accreditation evaluators also struggle in evaluating students' progress on non-technical outcomes. LeBlanc (2002, p.7.452.1) notes that, as an evaluator, he encountered the same challenges as an instructor and administrator in regards to understanding the new nontechnical accreditation criteria.

Barry and Ohland (2012, p.389) mention that when it comes to evaluating criterion 3.f., the feedback received by programmes from the accrediting body "is either significantly lacking or not constructively useful to the evaluated programs," which might impede the aim of the accreditation process to foster the improvement of a programme's educational offer. They further stress that the "intentionally limited specificity of Criterion 3, coupled with an apparent lack of accreditation review feedback specific to Criterion 3.f has left most programs uncertain of their chosen quantity of curriculum content" (Barry & Ohland 2012, p.389).

There is limited empirical research to serve as guidance to programme representatives and evaluators alike on how to prepare or assess the evidence in support of the ethics outcome. Twenty years after the approval of EC2000, in order to address some of the challenges that arose in regards to its interpretation and implementation by programmes, ABET (2015a, 2015b) proposed the introduction of a new set of accreditation criteria, with a special emphasis on revising Criterion 3. For this, a task force was created to develop a systematic process for assessing, evaluating, and recommending improvements to Criterion 3 (ABET, 2015a), but also to query constituencies, develop metrics for evaluating the criterion, and foster educational innovation and greater differentiation across institutions. (Hickman, 2014; Akera, 2017). First, the number of student outcomes required by Criterion 3 will be reduced from eleven to seven, and second some of those outcomes will be condensed. Ethics related outcomes 3.f. and 3.h. are now subsumed under a single outcome numbered 5, which will require that students show “an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts,” while outcome 3.j. is no longer included.

3.5 Key findings

Since the adoption of the Washington accord in 1989, there is a growing focus on ethics in the accreditation criteria for Engineering programmes, as well as in the curricula of programmes offering engineering degrees. Considering some of major engineering accreditation systems, a number of common themes surface:

First, the main factor linked to an enhanced emphasis on ethics in the engineering curriculum is the introduction of an ethical criterion for the accreditation of engineering programmes (Volkwein *et al.*, 2004; Skinner *et al.*, 2007; Barry and Ohland, 2012; Ocone, 2013).

Second, the introduction of ethics as an accreditation criterion also led to an increase in the use of active learning methods in engineering ethics instruction (Lattuca *et al.*, 2006).

Thirdly, students graduating after the introduction of ethics as an accreditation criterion show substantial differences from the prior cohorts related to an enhanced awareness of ethics, societal and global issues (Lattuca *et al.*, 2006; Peters, 1998; McGinn, 2003).

Fourth, the low presence of ethics in the engineering curricula is explained by the traditional educational background of instructors trained in the perspective of engineering neutrality (Monteiro, 2016).

Fifth, despite an increased presence of ethics and societal responsibility in the national systems of engineering education, this programme outcome is perceived to be very challenging both by programmes in the preparation of evidence supporting this outcome and by the accreditation panels in its evaluation (Fromm & McGourty, 2001; Leblanc, 2002; Sheppard *et al.,* 2009; Barry & Ohland, 2012; Ferguson & Foley, 2017). The members of accreditation panels have reported challenges in the evaluation of evidence in supporting the programme outcome dedicated to ethics (LeBlanc, 2012).

Sixth, the formulation of the ethical programme outcome is considered problematic due to its vagueness (Herkert, 2002), and because it does not distinguish between micro and macro issues (Bielefeldt, 2016).

3.6 Summary of literature review in perspective

The main findings of the literature surveyed in chapters 2 and 3 show that the current state of engineering ethics education is characterised by a fragmentation of pedagogical approaches, together with confusion and lack of consensus as to which approach is most suitable in preparing socially responsible engineers. There are limited empirical findings to serve as guidance in the implementation and teaching of engineering ethics. Noteworthy is the growing presence of ethics education in engineering educational systems where ethics features as an accreditation criterion. Nevertheless, there is still a low priority given to ethics in the engineering curriculum, as well as numerous challenging aspects encountered in the implementation, teaching and evaluation of ethics. The stakes are considered to be high given the correlation between the weight of ethics in the curriculum and the formation of engineering students' professional identity as socially responsible engineers.

All these features combined draw the image of a discipline that is still in development and in need for deeper reflection and empirical research to aid its formation. Behind the current state of engineering ethics education, we can see the role of conceptualizations about the nature of engineering in determining educational approaches. The historically prevalent paradigm of engineering as a technical profession has led to valorising and prioritising technical-scientific education at the expense of socio-humanistic pedagogical components (Ehrlich, 2000; Jamison, 2013; Jamison *et al.*, 2014). In order to reform engineering education and enhance the implementation and teaching of ethics in engineering programmes, the popularization of what Adams *et al.* (2013) call a *socio-technical* conception of the engineering profession and Jamison (2013) a *hybrid engineering identity* appears to be a necessary first step.

The next chapters will provide an analysis of the current state of engineering ethics education and evaluation in the context of the Irish system of accreditation, having as a point of reference findings from the international literature on engineering education. In light of the key findings identified in the literature review, the study addresses the following questions:

- How is ethics understood and defined by instructors and programmes?
- What is the weight given to ethics education in the curriculum of engineering programmes, compared with other outcomes required for accreditation?
- What methods of delivery appear to be favoured in the implementation of ethics education? Is there a homogenous approach in regards to the methods of implementation?

- What is the frequency of topics covered in modules dedicated to ethics and under what theoretical approach can these be subsumed?
- What is the prevalent method of ethics instruction?
- What challenges have instructors encountered in ethics instruction?
- How do evaluators approach the evaluation of outcome E?
- How do evaluators relate to the supporting evidence for ethics and the self-assessment prepared by the programmes?
- What challenges have evaluators encountered during accreditation events?
- What support would members of the accreditation panels consider beneficial for the evaluation of ethics?
- How is the status of engineering ethics articulated?

The research thus aims to reveal patterns in the education and evaluation of engineering ethics, which can be compared to those revealed in the literature. Moreover, the patterns identified are framed in light of the tripartite paradigm model of engineering education proposed by Jamison *et al. (*2014). Following Sterling (2004), the project aims to link the description of practices and policies identified through empirical research to explanations about the paradigms of engineering culture. Although the project starts at the descriptive level, the ultimate aim is to provide explanations about the mechanisms and paradigms in play that come to shape the practices and policies identified empirically.

CHAPTER 4 RESEARCH DESIGN

This chapter presents the research design that frames the present study. It is structured according to the key criteria for the design protocol formulated by Crotty (1998), Maxwell (2013) and Robson and McCartan (2015). The questions that direct the planning of the project's research design are:

- What are the research questions addressed by the study?
- What are the aims and objectives set by the researcher in order to answer the research questions?
- What theoretical perspective – philosophical stance – does the researcher adopt?
- What methodology – strategy or plan of action that links methods to outcomes – governs the researcher's choice and use of methods?
- What methods for data collection and analysis does the researcher employ to reach the objectives set?
- How does the researcher ensure the validity of the approach?
- What are the limitations of the research?

Each of these issues are dealt with separately in the following subsections of the chapter.

4.1 Research questions

The project is guided by three main research questions:

Q1: How is ethics education incorporated in Engineering Honours Programmes in Ireland?

Q2: How is ethics education in Engineering Honours Programmes evaluated for the purpose of accreditation by the panels appointed by the accrediting body Engineers Ireland?

Q3: What is the broader explanation behind the current education and evaluation of engineering ethics?

While the first two questions have a descriptive dimension, by extracting findings related to the education and evaluation of engineering ethics in Ireland, the later questions attempts to pin point their underlying causal mechanisms. The importance of including both a descriptive and explanatory dimension has been highlighted by surveying the literature on engineering ethics education. As such, in the previous chapters, the literature review identified some of the main characteristics of the education and evaluation of engineering ethics, as well as the challenges and cultural models influencing it.

The empirical findings and theoretical frame guiding the present study are predominantly based in the US, where extensive research has been conducted on these topics[8], but also takes into consideration empirical research conducted in Australia, United Kingdom or Portugal. The literature review showed that engineering ethics education is influenced by individual beliefs and practice, as well as by accrediting bodies and the institutional context of engineering education. It has also revealed that engineering ethics education, in its coverage or institutional method of implementation, in turn shapes and affects the professional identity of engineering students.

In light of the findings of the literature review, there was a growing awareness that a simplistic understanding of engineering ethics education that stops at the surface level of practice is insufficient for the purpose of this study. Nevertheless, given the limited research carried out in the Irish context on engineering ethics education and its evaluation for the purpose of accreditation, a necessary first step was *to describe* the existing teaching practices and the implementation of ethics in the engineering curriculum, before proceeding

[8] An explanation for the abundance of empirical studies on ethics education in the context of the US engineering education system can be explained due to the existence of dedicated funding schemes such as those of the National Science Foundation, and an absence of such schemes for STEM education at European level. In the European context, we witnessed the development of an intellectual tradition of scholarship that is more philosophically informed, and which is focused on articulating socio-technological relations and actor-network theories.

to theoretical generalizations that would allow the researcher *to explain* the structural processes shaping the way in which ethics education is taught, implemented and evaluated.

4.2 Aims and objectives

Consequently, given the approach mentioned above, the aims of the project for addressing the two research questions are:

Aim 1: to examine the education of engineering ethics in Engineering Honours programmes in Ireland

Aim 2: to examine the process of evaluation of ethics undertaken by the evaluation panels appointed by Engineers Ireland.

Aim 3: to explain the findings related to the education and evaluation of engineering ethics in light of wider structural contexts

In order to address the aforementioned aims of the research project, the following objectives have been set:

O1: to identify existing themes and theoretical approaches to engineering ethics;

O2: to survey empirical findings about international pedagogical approaches used in engineering ethics education;

O3: to survey empirical findings about the evaluation of ethics for accreditation purposes;

O4: to explore how engineering ethics education is conceptualised in Engineering Honours programmes in Ireland;

O5: to examine the weight given to ethics in the curricula of Engineering Honours programmes in Ireland;

O6: to explore how ethics is being implemented in Engineering Honours programmes in Ireland;

O7: to identify the major pedagogical methods employed in ethics instruction in Engineering Honours programmes in Ireland;

O8: to identify the major themes employed in ethics instruction in Engineering Honours programmes in Ireland themes;

O9: to explore how accreditation panels approach and respond to the evidence presented by Engineering Honours programmes in support of outcome E;

O10: to explore how the status of ethics in the engineering curricula is articulated;

O11: to identify any constricting or challenging factors encountered in the implementation and evaluation of ethics in Engineering Honours programmes in Ireland.

Objectives 1, 2 and 3 help situate the research project in the wider global context of engineering ethics education and engineering accreditation. Their role is to illuminate the current theoretical underpinnings of engineering ethics education, as well as the current state of engineering ethics education and accreditation. The findings are presented in chapters 2 and 3, representing the literature review.

Objective 4 sets to reveal how the discipline of engineering ethics is understood by instructors, as well as the aims related to ethics education set by engineering programmes. The findings are presented in chapter 5 “The conceptualization of engineering ethics education.”

Objectives 5 and 6 are connected, by examining the presence of ethics education in engineering programmes in Ireland. Chapter 6 “The implementation of ethics in engineering programmes in Ireland” sheds light on the delivery method of ethics in the engineering curriculum, as well as its allocated weight compared with other programme outcomes for accreditation.

Objective 7 and 8 are focused on the teaching of ethics in Engineering Honours programmes in Ireland. While Chapter 7 “Instruction in engineering ethics education” examines the use of case studies in engineering ethics education, chapter 8 “Curriculum content in engineering ethics education” is dedicated to the main themes employed in ethics instruction.

Objective 9 focuses on how accrediting panels approach the process evaluation of ethics education. The chapter “The process of evaluation of programme outcome E for accreditation” examines how evaluators approach the evidence offered by the participant programmes in support of outcome E, their reaction to the evidence and the self-assessment scores for outcome E, as well as their views on the weight given to ethics by Engineering programmes. These findings are presented in chapter 9 “The process of evaluation of ethics in engineering programmes in Ireland.”

Objective 10 explores the explicit or implicit ways in which programmes and instructors perceive the status of ethics in the engineering curricula. The findings are present in chapter 10 “Articulating the status of ethics in the engineering curricula.”

Finally, objective 11 has an overarching explanatory character. It aims to identify enabling and constricting factors for the implementation and evaluation of engineering ethics education, based on the explicit views expressed by instructors and evaluators, but also on the implicit ways in which engineering education is described. The findings are presented in chapter 11 “The two cultures of engineering education.” The role of this chapter is to move from the analysis of the empirical findings presented in previous chapters towards a structural explanation of the underlying phenomena that shape the education and evaluation of ethics.

4.3 Theoretical perspective

In light of the descriptive and explanatory aims of the project, the theoretical stance favoured for this research study is critical realism.[9] CR has emerged as an attempt to bridge divergent approaches in the philosophy of social science which emphasise the external world of social facts and their causal relationship, and the more interpretative approaches focused on how individuals interpret the world and confer meaning to their own and others' actions (Benton & Craib, 2011).

CR was adopted as the theoretical frame for this study due to three main reasons:

First, from an ontological perspective, CR admits that reality is a stratified and open system of emergent entities (Bhaskar & Lawson, 1998). It is committed to understanding the embedded nature of human action and the interaction of structure and agency (Archer, 1995). This seemed important given Sterling's (2004) argument for regarding education as a complex system with a number of different levels. The failure to integrate different levels into models for change has been identified as a gap in engineering education research, with different research communities having focused separately on different levels (Seymore, 2002; Froyd *et al*, 2008). More so, higher education research has largely neglected the social context which shapes the activities of individuals (Trowler, 2005; 2008; Ashwin, 2009; Scott, 2000; 2007). A CR research study on higher education would thus place the individual in the wider context, as "change based on 'improving' individuals will usually be a disappointment if not done with an awareness of the context individuals operate in." (Trowler 2008, p.151).

Building on this observation, the second reason for opting for CR is axiological in nature, due to its commitment to social change. CR puts forward an emancipatory axiology

[9] Henceforth, abbreviated as CR.

(DeForge & Shaw, 2012; Mingers *et al.*, 2013; Haigh *et al.*, 2019). According to Fletcher (2017, p.182), the ability of CR to engage in causal analysis, rather than relying on thick empirical descriptions of a given context, makes it a useful frame for analysing social problems and suggesting solutions for social change. As Hannah and Lester (2009) and Graham (2012) point out, change strategies need to link different levels in order to generate long lasting and organic transformation. Godfrey (2014, p.438) agrees that the analysis of engineering education should focus not only on "characteristics of behaviours and practices", but also on the values, beliefs, and assumptions that underpin "how these came to be," in order to enable the development of strategies for change. This can explain why engineering education reform has a relatively long but slow history (Heywood, 2005).

Thirdly, from an epistemological perspective, CR looks beyond the empirical, in order to posit causal explanations that target the underlying mechanisms for current experiences, beliefs, practices and events (Bashkar, 1975).

4.3.1 The ontological tenets of CR

CR was first conceptualised by Bhaskar (1975), who argued that the world is structured, stratified and changing. According to CR, the world is independent from our thoughts about it. CR traces a distinction between the intransitive (objects of study) and the transitive (theories and discourses about these objects) dimensions of knowledge (Sayer, 2000). This distinction implies that the world should not be conflated with our experience of it. As such, it lays the foundation for a CR ontology which emphasises looking beyond the empirical in order to identify underlying mechanisms that "cause" the events which may be experienced. Ontology is considered to have primacy when "explaining society" (Danermark *et al.*, 2002).

4.3.1.1 The depth ontology of CR

With CR, the weight has shifted from epistemological questions to ontological concerns. Within ontology, the focus is on structures that affect the manifestation of empirical phenomena and the activity of social agents. There is a strong concern with explaining the mechanisms that cause the phenomena we observe and experience. By mechanism is understood the constitution, action and interrelationships of the processes which are responsible for observed regularities (Pawson & Tilley, 1997, p. 68). As such, the questions that a CR research study aims to explore go beyond discovering what is an event or phenomena, towards the attempt of understanding its structural context, as well as the mechanisms affecting it (Danermark *et al.*, 2002).

CR posits the centrality of a realist ontology in pursuing explanations (Danermark *et al.*, 2002). It acknowledges the existence of different ontological domains (Koro-Ljungberg & Douglas, 2008, p.165), as well as different ontological scales (Bhaskar *et al.*, 2010). Bhaskar (1975) distinguishes between three domains of existence: "the empirical" (comprised of observable or experiences entities and events), "the actual" (events that take place and which may or may not be experienced) and "the real" (comprised of independent mechanisms and causal powers that generate both actual events and experiences, even if they may be not directly observable). According to CR, structures exercise causal power over individual and collective agents, but agents can also affect the structures they are part of (Sayer, 1992; 2000). In this sense, reality is considered to be socially constructed and emergent.

In light of this layered ontology, CR assumes that there is more to the world than individual experiences. The role of the researcher is then "to use perceptions of empirical events to identify the mechanisms that give rise to those events" (Volkoff *et al.*, 2007, p.835). Such explanations are not reached through prediction or description, but by identifying the mechanisms that generate what is observable in the empirical domain (Volkoff *et al.*, 2007, p.835; Danermark *et al.*, 2002, p.73). In light of its stratified ontology, CR identifies mechanisms of causation, by connecting experiences in the empirical domain with structures belonging to the domain of the real (Huckle, 2004; Easton, 2010; Ackroyd & Karlsson, 2014).

4.3.1.2 Structure and agency in CR

CR offers a particular social ontology whose key framing device is the relation between structure and agency (Scott, 2010). CR is committed to an explanatory model "in which the interplay between pre-existent structures, possessing causal powers […] and people possessing causal powers […] of their own results in contingent yet explicable outcomes" (Carter & New, 2004, p.6). CR's commitment to analytical dualism implies that structure and agency are considered as possessing radically different properties and powers (Carter & New, 2004).[10]

While CR acknowledges the value of the focus on discourses, beliefs, motivations and meanings promoted by interpretivist methodologies, [11] nevertheless it opposes their neglect of the underlying social structures that may causally influence the perspectives of individual agents and enable or constrain their actions (McEvoy & Richards, 2006, Maxwell & Mittapalli, 2010). An example relevant to engineering ethics refers to accident causation. Pearce and Tombs (1998) draw explicitly on CR to argue that much work on accident causation concentrates on first-order empirical causes, such as immediate production

[10] Archer (1995) provides an extensive treatment of this issue from a critical realist perspective. Archer describes various forms of conflationism in how social theory has addressed the agency/structure relation. On one hand, there is downward conflation which emphasises the determining effect of social structures and allows very little role for intentional human activity in explaining social forms. On the other hand, there is upward conflation which places undue emphasis on the creative and intentional dimension of human activity and downplays the way human beings are both immersed in and constrained by the way society is constructed. She identifies a third kind of central conflationism, according to which agency and structure are "mutually constitutive" and fundamentally inseparable. This framework has been used by Conlon (2015) with the aim of understanding different approaches to engineering ethics education.

[11] These are human reasons, or as Carter and New (2004) call them "psychological mechanisms".

pressures, poor communication and training, and less on the second-order underlying processes that generate them. In explaining "safety crimes," Tombs (2007, p.29) argues for an approach that places their occurrence within "prevailing systems of economic, social and political organisation, dominant value systems and beliefs, and the differential distribution of power." According to Tombs (2007), such analysis should consider factors operating at distinct analytical levels, ranging from individual agents to the structures in which they operate, such as the work group, workplace or the wider environment in which the company is based. CR thus allows us to understand the embedded nature of human action (Archer, 1995; Scott, 2010).

From a theoretical point of view, the different ontological domains are not considered to be causally divorced from each other. In this regard, Smith and Elger (2012) note that according to CR, "social action takes place in the context of pre-existing social relations and structures, which have both constraining and facilitating implications for such action." CR researchers are thus encouraged to focus on the interplay between structure and agency and the possibility of change arising from social interactions (Conlon *et al.,* 2018). This is because agents can formulate projects for change and structures can provide them with the power to carry them through. The transformative potential inherent in human agency can only "begin to bite when structural contexts […] are generally supportive of those potentialities being actualised in some durable form" (Reed, 2005, p.302).

The ontological tenets of CR allow for an understanding of the empirical findings about the education of engineering ethics and its evaluation in a deeper manner, which points to the structural characteristics of engineering education. It is thus possible to trace explanations about the underlying mechanisms that influence the practices encountered in the present study and to suggest structural strategies for effecting change that take into consideration all levels.

4.3.2 The axiological tenets of CR

The axiology of a theretical framework refers to what the respective framework values when conducting research or as a research output. The axiology of CR has been described as emancipatory (DeForge & Shaw, 2012; Mingers *et al.*, 2013; Haigh *et al.*, 2019). According to Danermark et al. (2002), CR research is driven by the belief that improvement of society is possible. As such, it is considered to offer "exciting prospects in shifting attention to the real problems that we face and their underlying causes" (Mingers *et al.*, 2013, p. 796). Thus, the ultimate aim of the emancipatory worldview advocated by CR is to identify how the features examined in the research study may be influenced in order to ameliorate harmful effects or to enhance beneficial effects (Haigh *et al.*, 2019). This implies a "strong focus on 'what to do'" to improve the situation under investigation (Haigh *et al.*, 2019, p. 1575).

Furthermore, CR acknowledges that not all beliefs, experiences, practices or events registered in the empirical or actual domains can be changed through measures targeting exclusively the respective ontological layer (Collier, 1994). For CR, in order to affect change in the empirical or actual domain, deeper structures need to be posited and addressed (Conlon & Zandvoort, 2011).

For the purpose of the present study, the ultimate goal is to facilitate change in the beliefs, experiences, practices or events related to the education and evaluation of engineering ethics. To achieve this, after identifying the main characteristics of engineering ethics education belonging to the empirical and actual domains, a generative explanation will be sought placed in the domain of the real, followed by recommendations for change targeting the different ontological layers of the system of engineering education.

4.3.3 The epistemological tenets of CR

CR combines a realist ontology with an interpretive epistemology: the real world exists independently of our knowledge of it, but our knowledge of the world is always fallible as it is shaped by the “social position of knowers and theories on which they draw” (Carter & New, 2004). For CR, ontology is not reducible to epistemology, nor can the objects of our knowledge be equated with the contents of knowledge (Porpora, 2015, p.73). While CR admits that the objects of our knowledge are real, nevertheless our knowledge of the world may be socially constructed, with some constructions of reality being considered “epistemically superior” to others (Porpora, 2015, p.73).

4.3.3.1 Fallibilist epistemology

A fallibilist conception of human knowledge means that what we consider to be true at the present time might me proved false in the future. The epistemological advantage of CR over a simple, so called naive realism, is that it does not presuppose that the world is entirely knowable (Sayer, 2000; Scott, 2005; Zachariadis *et al.*, 2010).

This theoretical assumption about the knowability of the world might be suitable for positivist research, which deals with closed, finite and determinate systems. The approach of the research study, though, is focused on social systems, which by their nature are open and indeterminate. The ultimate goal of research for CR is not to identify generalizable laws (positivism) or to identify the lived experience or beliefs of social actors (interpretivism), but to develop “deeper levels of explanation and understanding” (McEvoy & Richards, 2006, p.69).[12]

4.3.3.2 Theoretical generalisation

As such, the claim made in this thesis is not that the data reported here is representative of the Irish engineering education system in its entirety, but rather that it provides useful insights into the way ethics is being understood and integrated. The aspiration is towards

[12] It has been argued that mainstream quantitative research presupposes a Humean regularity view of causation, which has been the dominant conception of causality in the philosophy of science (Maxwell, 2004; Maxwell & Mittapalli, 2010). This view rejects any reference to inferred entities or mechanisms. On the other hand, those who adopt a strong constructionist position reject the view that the world is analysable in terms of causes.

“theoretical generalisation” (Robson, 2011, p.160), which means that the data gained can provide theoretical insights that, if acted on, may have a profound effect on the development of engineering ethics education. The CR enquiry thus aims at “developing causal explanations that map the components of a social phenomenon across stratified reality, spelling out what the relevant objects, structures, mechanisms and conditions are to that phenomenon” (Hoddy, 2019, p. 113). This means there is a “judgemental rationality” operating, that allows researchers “to select theories which most accurately represent the ‘domain of real’ given our existing knowledge” (Xiaoti Hu, 2018, p.130).

CR has been criticised for being overly focused on theory.[13] As Belfrage and Haus (2017, p.256) point out, CR is “an underlabouring philosophy of science,” which can only provide “a general idea of the relations that it is concerned with”. According to Belfrage and Haus (2017, p.256), “making substantive sense of ‘reality’ necessitates a theoretical apparatus and a methodology capable of analysing the interplay of discursive/semiotic and structural/material dimensions of the social”. Given the focus on unobservable generative mechanisms, CR realism research tends to seek to provide theoretical explanations of the social world. Although mechanisms are not observable, their effects are felt nonetheless. They can be inferred through empirical investigation and theory construction.

4.3.3.3 Abstraction and retroductive explanations

When conducting research, CR emphasises the importance of abstraction, abduction and retroduction.

Since social systems are open, it is very difficult to examine their structures in controlled conditions (Sayer, 2000). CR’s logic of abstraction allows researchers to conceptualise the components of an open system and investigate each component’s influence on the system

[13] One such critic is Robson (2011), who describes his approach as “realism-lite.”

in isolation. Abstraction encourages the development of conceptual frameworks, which identify what is significant when examining the phenomena under investigation. CR researchers use two distinct explanatory logics in moving from the domains of the empirical to the real: abduction and retroduction. The former describes the observed in an abstracted or more general sense in order to describe the sequence of causation that gives rise to regularities in the pattern of events, while the latter seeks to ascertain what the wider context must be like in order for the mechanisms we observe to be as they are (O'Mahoney & Vincent, 2014).

The explanatory process supported by CR is retroductive in nature, by drawing *a posteriori* inferences about the causes of individual phenomena. As Belfrage and Haus (2017, p. 255) suggest, “to identify generative mechanisms, critical realists ask the question: What must be true for events to be possible? From observable phenomena, we go back to possible explanations”. As such, retroductive explanations move “from a description of some phenomenon to a description of something which produces it or is a condition for it” (Bhaskar 2009, p. 7). This inferential process is conceptual in nature. Thus, based on the analysis of empirical data, the CR researcher draws inferences that can shed light on the operation of mechanisms. As McEvoy and Richards (2006, p. 72) argue, “detailed observation may provide a platform for making retroductive inferences about the causal mechanism that are active in a given situation.” Retroductive explanations ultimately propose generative mechanisms, while also pointing out the phenomena that occur most frequently (McEvoy & Richards, 2006, p.72; Hurrell, 2014, p.244).

These explanations are fallible and do not conflate frequency with causality. CR researchers justify their explanations about structural characteristics through inference towards the best explanation, in light of the empirical data available. In this mode of analysis, events are studied with respect to what may have, must have or could have caused them. According to

Sayer (2000, p.27), this inferential process towards the best explanation amounts to distinguishing “what must be the case from what merely can be the case” when seeking associations between phenomena and mechanisms.

4.3.4 Implications of the CR paradigm for the research study

In light of the layered ontology supported by CR, the research study acknowledges the need to identify the actors and main characteristics manifest within each domain. As a CR study, it admits the existence of three different ontological domains. Within these three ontologically distinct domains, the study further identifies four levels of analysis. As such, within the empirical and actual ontological domain, there is the level of the individual agents, represented by instructors and evaluators serving on accreditation panels, the level of institutional structures, represented by engineering programmes and institutions, and the level of policy, represented by the national accreditation body. Finally, the overarching societal level within the domain of the real comprises the generative mechanisms affecting the activity at the individual, institutional and policy levels belonging to the empirical and actual domains.

The ontological constituency of the research study is rendered in Figure 1, allowing us to see what aspects are addressed at each ontological domain and level of analysis. As such, within the domain of the empirical, the study investigates the beliefs, understanding and attitudes towards engineering ethics education. It does so at three levels of analysis, each of a different scale. At individual level, the study focuses on the beliefs, understanding and attitudes of instructors and evaluators; at institutional level, the focus is on the beliefs, understanding and attitudes expressed on behalf of a programme or institution, while at policy level, the focus is on the beliefs, understanding and attitudes of representatives of the accrediting body towards engineering ethics education. Considering the domain of the

Figure 1. The ontology of the CR research study on the education and evaluation of engineering ethics

actual, the study examines the practices and measures taken in relation to the education and evaluation of engineering ethics. At individual level, the focus is on the teaching practices of instructors; at institutional level these are represented by the measures taken by programmes and institutions, while at policy level, the concern is with the measures taken by representatives of the accrediting body. Finally, within the domain of the real, the study hypothesizes the existence of a societal level, comprised of generative mechanisms affecting the activity and perceptions encountered at the levels of the previous ontological domains.

While the first two aims of the study aim to examine the main features of engineering ethics education and its evaluation encountered within the domains of the actual and the empirical, the third explanatory aim of the project is to put forward an explanation about the generative mechanism affecting these. Engineering ethics education is thus revealed as a complex system determined by multiple interactions between different ontological domains, at different scales (Bhaskar & Danermark, 2006; 2007).

Through the adoption of CR, this study starts by developing claims about the occurrence of individual phenomena within the empirical and actual domains, in order to reach explanations about their underlying generative mechanisms situated within the domain of the real (Hurrell, 2014; Sayer, 2000). The project also strives to enquire what the individual experiences and practices might reveal about the characteristics of institutional, policy or societal levels, and how the instructors' own background, their views on engineering ethics and their approach to teaching are influenced by the broader cultural conception of engineering education. The present study thus aims to put forward a causal explanation for these findings, and in light of its emancipatory axiology, to also identify structural impediments and enablers in the education and evaluation of engineering ethics. The novelty of this study lies in its attempt to explore the interrelationship of different levels belonging to different ontological domains in the context of the Irish engineering education system.

4.4 Methodology

CR has been dubbed a "methodologically handicapped philosophy" (Yeung, 1997, p.56). A main line of criticism directed at CR is its lack of methodological prowess for carrying empirical research compared with other theoretical frames, with Yeung (1997, p.53) noting that CR is a philosophy, not a methodology, and Oliver (2012, p.371) suggesting that "its lack of connection to a familiar research methodology may be limiting its application."

However, recent years witnessed the adoption of a mixed method approach employed in CR social science research (Danermark, 2002; Oliver, 2012; Bunt, 2016).

It has been argued that CR is versatile in terms of the methods that can be employed, and is a theoretical framework particularly suitable for mixed methods research[14] (Danermark *et al.,* 2002; Easton, 2010; Zachariadis *et al.*, 2010). The MMR approach is considered to integrate both quantitative and qualitative data, such that the inferences generated have more explanatory strength than either approach alone (Creswell & Plano Clark, 2011). By including both qualitative and quantitative data, MMR supports a comprehensive analysis, by combining the participants' views and experiences with broader, generalizable quantitative results (Hesse-Biber, 2010). MMR is also considered to put into brackets the existing fracture between disciplines and methods based research communities, and is suitable in interdisciplinary research, such as the present study (Levine, 2016). MMR thus allowed the research study to achieve a broader picture of the current patterns in the education and evaluation of engineering ethics.

It can be said that interpretivist and positivist theoretical traditions have ontologies of their own, which are not incompatible with CR. This allows CR to use a mixed method approach based on the different roles of each method in identifying mechanisms and their application in different contexts (Danermark *et al.,* 2002). Mixed methods are thus necessary to reveal different features of the same layered reality, as to offer a robust option for uncovering generative mechanisms, while also constructing claims about which phenomena occur most frequently (Hurrell, 2014; Sayer, 2000). As well as uncovering different facets of the same layered reality, mixed methods are also necessary to explore the interaction of structure and agency, which for Scott (2007) is the key ontological framing device of CR research.

[14] Henceforth, abbreviated as MMR.

According to Scott (2007, p.15), the reconciliation of qualitative and quantitative methods is focused on “the vertex of agential and structural objects, or the intersection between the different levels or layers of social reality.”

Scott (2007) mentions three strategies for the adoption of a MMR approach, for a meaningful integration of qualitative and quantitative methods:

(i) First, there is an *alignment* at the level of method, with the aim of producing a coherent set of data. Similar questions are addressed in a sequential manner. As such, quantitative approaches reveal issues that demand a closer investigation through qualitative methods.

(ii) Second, the different epistemic frames employed by qualitative and quantitative methods require *translation*. The two type of methods focus on different properties of their object of investigation. Thus, the explanatory vocabulary of qualitative methods is intensional, resting on the subjectivity and contingency of individual beliefs and accounts, while quantitative methods that group a significant number of observations are extensional in nature, attempting to reach generalizable explanations about social processes and mechanisms.

(ii) Third, there is a process of *compensation* operating at the ontological level. This approach is considered by Scott (2007, p.8) the ontological starting point of CR, as the quantitative and qualitative methods are considered to explore different ontological levels. According to Scott (2007, p.15):

> quantitative approaches and qualitative approaches are different symbolic systems […] for describing the properties of objects; however, if each is focused on different properties of social objects, then it is possible to reconcile them.

As such, individual beliefs and practices within the empirical and actual domains are best rendered through qualitative methods, which can help “illuminate complex concepts and relationships that are unlikely to be captured by predetermined response categories”

(McEvoy & Richards, 2006, p.71). Quantitative methods can be used to develop comparisons and to reveal general structural patterns and associations which may otherwise be masked (McEvoy & Richards, 2006). More so, these might "provide a platform for making retroductive inferences about the causal mechanism that are active in a given situation" (McEvoy & Richards, 2006, p.72), thus bringing to light the operation of hidden mechanisms.

For the present research study, the MMR approach operates at distinct levels, in order to reveal different features of the same layered reality. The individual level represented by the views and practices of instructors and evaluators has been explored through interviews, documentary analysis and participant observation, while the weight given to ethics in the engineering curriculum and the frequency of curricular content has been examined through numerical analysis. The project has enquired whether the findings revealed by the application of mixed methods represent a manifestation traceable to a deeper ontological domain and whether these can be linked to the theoretical models of engineering education proposed by Jamison *et al. (*2014). Through the use of MMR, the project starts by developing claims about the occurrence of individual phenomena, in order to reach explanations about their underlying generative mechanisms (Hurrell, 2014; Sayer, 2000).

4.5 Participant selection

In light of the layered ontology presupposed by CR, the research study sought to gather information related to the different levels of the system of engineering education. As such, the study includes institutional participants, represented by engineering programmes, policy participants, represented by the national accrediting body, and finally, individual participants, represented by engineering instructors and members of accreditation panels.

4.5.1 Policy participants: the national accrediting body

The present study benefited from the support of the national accrediting body, Engineers Ireland, which facilitated researcher's access to documents such as accreditation reports, and also the participation in accreditation events. The views of the accrediting body are captured in the statements made by its representative during accreditation events. The views of the accrediting body are also manifest in the formulation of accreditation requirements.

4.5.2 Institutional participants: engineering programmes

The subject of the research are engineering Honours programmes in Ireland. According to the National Qualification Framework, these are Level 8 programmes, while Ordinary programmes are Level 7 programmes (Quality and Qualifications Ireland, n.d.). Honours programmes confer Bachelor Degrees, and are a required entry standard for the professional title of Chartered Engineer (Engineers Ireland, 2014, p.15). Ordinary programmes confer Diplomas, and are a required entry standard for the professional title of Associate Engineer (Engineers Ireland, 2014, p.15).

Given the breadth of the analysis, a decision was made not to focus on all engineering Honours programmes in Ireland, in order to avoid a superficial approach. Instead, the project focuses on the programmes that underwent accreditation in the period between autumn 2017 - spring 2019.

Before proceeding further, a brief historical note is useful to better understand the engineering educational system in Ireland. Ireland has a two-tiered system of engineering education, divided into universities and institutes of technology.[15] Thus for the current study,

[15] Technical education developed at the end of the 19th century as an applied type of study relevant to trade and industry, in a climate where universities held the monopoly on higher level studies (Walsh, 2018, pp.143-4). Beginning with the 1970s, policy changes were adopted that formally recognized technical courses and qualifications, thus contributing to the emergence in Ireland of a technological oriented higher education sector, which was distinct from universities (Walsh, 2018, p.268);

it is important to include programmes offered by both institution types. As such, 23 programmes participate in the research: 15 programmes offered by universities and 8 programmes offered by institutes of technology. In total, 6 institutions participated in the study, 4 universities and 2 institutions of technology. One institution of university type whose programmes underwent accreditation in the period under analysis declined to participate.

There is a wide range of engineering disciplines offered by the 23 participant programmes. These disciplines include Electrical Engineering, Electronic and Computer Engineering, Computer Science and Information Technology, Building Services, Civil Engineering, Structural Engineering, Environmental and Energy Engineering, Mechanical Engineering, Biomedical Engineering and Process and Chemical Engineering[16]. The participant selection thus offers a comprehensive overview of a different number of disciplines and institutional contexts of engineering ethics education.

4.5.3 Individual participants: engineering instructors

Given that instructors have the role of "curriculum workers" (Ornstein & Hunkins 2013), it was important to explore how their views about engineering and engineering education inform their teaching approach. The investigation of the views and background of engineering ethics instructors through in-depth interviews was considered to provide insights about the mechanisms that might affect the education of engineering ethics. The CR frame helps connect these individual perspectives to the encompassing structures they are part of, namely the culturally established conceptions about engineering education.

[16] The defended version of this dissertation, which was presented to the supervisors and examiners of the PhD research study, included a table presenting each participant programme and the abbreviation used. In the published version, this table has been omitted, in order to ensure the anonymity of participant programmes, according to the terms of the NDA signed with Engineers Ireland that govern this research study..

The criteria for including instructors was related to having taught or currently teaching modules of professional formation. This criteria is an outcome of the documentary analysis, which revealed a pattern among modules of professional formation in regards to their focus on ethics education. More specifically, modules of professional formation tend to include a high number of ethical themes, with an average of 5 themes, and are all positively highlighted in the documentation submitted for accreditation as well as in accreditation reports for how they meet outcome E. There was total of 12 modules that were found to fit into this category, with titles pointing to professional development, professional skills, fundamentals of the engineering discipline and introduction to the profession of engineering or an engineering specialty. More so, every participant institution offers at least one such module in its programmes.[17]

The instructors were identified either in the module descriptor or on the institutional website as currently teaching one or several modules of professional formation, or in the documentation prepared for accreditation by the programme as an instructor for the module, although not teaching in the current academic year 2019/2020. A module on professional formation belonging to one of the participant institutions was excluded on grounds that the researcher and the supervisor are the instructors. Nineteen instructors from all participant institutions were contacted, and 16 instructors confirmed their participation. For 4 modules of professional formation included in the analysis, both a former and a current instructor have been interviewed, as the documentation submitted for accreditation mentioned an instructor that is not teaching the module of professional formation in the current academic year 2019-2020. These four modules of professional formation are all offered by

[17] Professional formation modules were found to typically be common to several programmes offered by the same institution.

universities, which explains why a higher number of university instructors took part in the study compared to institutes of technology.

The demographic overview of the participants' age range, gender, specialization, previous professional experience and class size is available in Table 5.

Table 5. Demographic characteristics of participant instructors

Demographic Category	**Interview participants (n=16)**
Gender	F: 6 M: 10 non-binary/other 0
Age (in years)	<30: 0 30-39: 3 40-49: 7 50-59: 4 >60: 2
Specialization	Engineering: 13 Philosophy: 3
Professional Experience	Private sector: 11 Policymaking: 2 Non-governmental sector: 2 Healthcare: 1 Solely academia: 1
Student cohort	<50: 2 50-100: 5 100-150: 4 150-200: 3 > 200: 2
Affiliation	University: 13 Institute of Technology: 3

4.5.4 Individual participants: evaluators

In regards to the inclusion in the research study of interviews with evaluators, this is due to the significant role that their recommendations play in shaping engineering curriculum. For this research, the study selected evaluators who served on accreditation panels for the accreditation events observed. Ten evaluators were contacted, and seven agreed to participate. Given that the recording of the interview with one evaluator failed due to technical reasons, there was a final total number of six interviews with evaluators.

The demographic overview of the participants' age range, gender, specialization, previous professional experience and class size is available in Table 6.

Table 6. Main demographic characteristics of participant evaluators

Demographic Category	Interview participants (n=6)
Gender	F: 1 M: 5 non-binary/other 0
Age (in years)	<30: 0 30-39: 0 40-49: 3 50-59: 2 >60: 1
Domain of activity	Academia: 5 Private sector: 1 Public Sector: 0
Specialization	Engineering: 6

4.6 Research Methods

In this section, each of the research methods employed in the study are explored in more depth. A number of data collection exercises were conducted, with a particular focus on programme outcome E, as set by Engineers Ireland, which focuses on the need for high ethical standards in engineering. Data was collected through documentary analysis of documentation submitted by the participant programmes for accreditation, including module descriptors; quantitative analysis of self-assessment scores (POLO scores) measuring the contribution of modules to the programme outcomes set by Engineers Ireland; documentary analysis of accreditation reports; participant observation of accreditation events and interviews with instructors and evaluators involved in accreditation. The rationale for and details of these methods are presented.

The main strategy behind the MMR approach is summarized in Table 7, alongside a description of each research stage, the methods employed and the corresponding objectives. The research process is divided in structural stages rather than temporal stages, as stages 1-2 ran in parallel, while the research activity of stage 5 occurred during stages 1-4. The preliminary results obtained during stages 1-4 and the experience gathered during stage 5 informed the approach to the interviews conducted in stages 6-7.

Table 7. Summary of research stages

Stage	Method	Data Source	Objective[18]
Preliminary	Literature review	Empirical and theoretical research sources	O1; O2; O3
1	Document analysis (qualitative)	Programme document submission for accreditation	O4; O8; O10
2	Descriptive statistical analysis (quantitative)	Self-assessment rubric submitted for accreditation	O5; O6; O10
3	Document analysis (qualitative)	Module descriptors	O4; O7; O8
4	Document analysis (qualitative)	Accreditation reports	O4; O9; O10
5	Participant observation (qualitative)	Accreditation events	O4; O5; O6; O10;
6	Interviews (qualitative)	Instructors teaching modules of professional formation	O4; O5; O6; O7; O8; O10
7	Interviews (qualitative)	Evaluators on accreditation panels	O5; O6; O9; O10

The flexibility of CR suits the adoption of different methods at different times, or by combining data gathered from different sources (Ackroyd & Karlsson, 2014, p.21). This eclecticism happens because at the start of research, the researcher is not in the position to know what causal mechanisms are in play, these being discovered through the continuous deployment of various methods. It appears thus that the lack of a homogenous methodological approach, which might be a minus for a different theoretical framework, is in fact fitting for what CR considers its object of research: causal mechanisms and structures waiting to be discovered, rather than clearly defined phenomena or events. This flexibility coincides with the experience of preparing the research design for the present project. In order for the project to lead to a comprehensive picture about how engineering ethics is

[18] According to the full list of research objectives provided in the previous chapter.

delivered, taught and evaluated, as well as to explanations about the mechanisms affecting it, the researcher came to the realization that a mix of intensive and extensive research methods are needed.

In what follows, I first describe the extensive methods employed by the project in stages 1-3, before proceeding with the description of the intensive methods addressed during stages 4-6 of the project.

4.6.1 Preliminary stage: Literature review

The empirical research conducted for the current study was preceded by a non-systematic literature review. For this review, the core collection of the Web of Science (Clarivate Analytics, 2020) was used to find relevant sources. In order to retrieve sources that address issues falling under the scope of the objectives set by the study, the following combination of key terms were used to search in the titles and abstract of publications: “ethic*” AND “engineering” AND “education*”; as well as “ethic*” AND “engineering” AND “instruction”; “ethic*” AND “engineering” AND “assess*”; “ethic*” AND “engineering” AND “case”; “ethic*” AND “engineering” AND “challeng*”; “ethic*” AND “engineering” AND “accredit*.” This was followed by an overview of the references mentioned by publications to identify additional publications relevant to the objectives of the study that do not have the aforementioned combination of key terms in their title or abstract.

This preliminary stage of the literature helped clarify and define the research questions to be explored during the subsequent empirical research stages and also to narrow the appropriate methods to be used to address them.

4.6.2 Stage 1: Document analysis of programme submission

The document analysis examined the programme documents submitted by participant programmes for the purpose of accreditation. These documents were provided by the participant programmes and contain information relevant for the objectives of the research study, such as the aims and graduate outcomes set by the programme, as well as a narrative of how the programmes describe meeting each of the seven programme outcomes. The documentary analysis of the programme submission provided insights about how ethics education is understood by the participant programmes and how the programmes aim to adopt outcome E. The document thus offered a glimpse into the role that ethics plays for offering what the participant programmes deem to be a satisfactory engineering education.

The documentary analysis of the programme document submission has been an iterative process that followed a series of steps. First, the sections in which the programmes describe their approach to ethics education have been identified. The aspirational approach to ethics education is captured by the programme aims and graduate outcomes, where the aims related to outcome E have been singled out, based on the description of the outcome provided by the accrediting body. The incorporation of ethics education is mentioned in a rubric of the documentation submitted for accreditation in which the programmes are required to describe how they meet each of the seven programme outcomes. In this rubric, the programmes highlight the contribution of some of their modules to the programme outcome, and in some cases, they also provide comments about the method of implementation of ethics that they opted for.

These excerpts of the programme documents have been transcribed verbatim, using a template. The template was structured to include first the data obtained from the programme document submissions, followed by the data provided by the module descriptors, and finally the data from the accreditation reports. The transcription process was then followed by thematic coding for analysing the data gathered.

The approach to data collection and analysis adopted by the current study followed Fletcher's (2017) strategy. Fletcher highlights the importance of having a flexible coding process that draws on existing theoretical frames, literature review and key CR concepts, codes which can be later "changed, eliminated and supplemented with new codes during the process." This research stage enabled the identification of patterns in the educational aims set by the participant programmes in connection with programme outcome E.

4.6.3 Stage 2: Simple statistical analysis of self-assessment scores

The simple statistical analysis employed in the study was based on a rubric present in each programme document submitted for accreditation. According to Engineers Ireland (2015, p.4), this is "the most important section of the accreditation document." In this rubric, programmes are required to indicate how the learning outcomes set for each of their modules meet the seven programme outcomes set by the accrediting body. For this self-assessment process, Engineers Ireland recommends the use of a five-point scale with scores from 0 to 4 (Engineers Ireland 2015, p.4). These scores are known as POLO scores, and their meaning is described in Table 8.

Table 8. Five-point POLO scale for module contribution to programme outcomes

Score	Description
4	Module strongly contributes with a large component of assessment relating to the Programme Outcome.
3	Fairly strong contribution, with significant assessment relating to the Programme Outcome.
2	Some assessment relating to Programme Outcome, but the Programme Outcome is not a central theme of the module.
1	Only a small portion of assessment relates to the Programme Outcome.
0	Module does not contribute to the Programme Outcome.

The seven programme outcomes for the accreditation of Engineering programmes in Ireland set by Engineering Ireland (2014, pp 20-1) are described in Table 9.

Table 9. Programme outcomes for accreditation

Programme outcome	Domain of competence
A	Knowledge and understanding of the mathematics, sciences, engineering sciences and technologies underpinning their branch of engineering.
B	The ability to identify, formulate, analyse and solve engineering problems
C	The ability to design a system
D	The ability to design and conduct experiments and to conduct guided research, or advanced technical activity
E	An understanding of the need for high ethical standards in the practice of engineering, including the responsibilities of the engineering profession towards people and the environment.
F	The ability to work effectively as an individual, in teams and in multidisciplinary settings, together with the capacity to undertake lifelong learning.
G	The ability to communicate effectively on specialised engineering activities with the engineering community and with society at large.

The aim of this research stage was to calculate the average weight of the seven programme outcomes, based on the scores provided in the POLO rubric. However, only 13 programmes used the 0-4 scale recommended by the accreditation body for the purpose of self-assessment, while the other 10 programmes employed four different type of self-assessment scales.

Given this lack of uniformity, as well as the variety of self-assessment scales employed, the researcher made several attempts to convert the 4 types of scales employed by 10 programmes to the recommended 0-4 scale. To ensure the reliability of the conversion approach and the validity of the findings, an expert statistician was consulted. It was possible to calculate the average self-assessment score of the programme outcomes only for 17 programmes, thirteen that used the recommended self-assessment scale of 0-4, and the other four programmes that used a scale convertible to it. Six programmes used a self-assessment scale that could not be converted to the five point scale ranging from 0-4.

In what follows, the self-assessment scales employed by the programmes that did not use the recommended scale of 0-4 is described, followed by an explanation of the process of conversion.

4.6.3.1 The 0-22 scale

Four programmes from the same university institution used a self-assessment scale of 0-22 (Uni D1, Uni D2, Uni D3, Uni D4). The meaning of the scores is described by the programme as follows: “a score of 1-5 is highlighted in blue and indicates a small contribution. A score of 6-10 is highlighted in yellow and indicates some contribution. A score of 11-15 is highlighted in orange and indicates a fairly strong contribution. A score of 16-22 is highlighted in red and indicates a strong contribution.” Based on the interpretation of the scores provided by the programme, the following conversion to the 0-4 scale was applied. A score of 16-22 described by the programme to indicate “a strong contribution” was converted into a 4. A score of 11-15 was converted into a 3, while a score of 6-10 was converted into a 2. Similarly, a score of 1-5 was converted into a 1. The modules that received no score by the programme are understood to have no contribution to the programme outcome, which resulted in being assigned the score 0.

4.6.3.2 Colour mapping

Two university programmes (Uni E2 and Uni F2) employed a 4 colour mapping. They describe the meaning of the colour range in identical terms. As such, from the darkest shade to the lightest shade of green, the meaning of the four shades is “very strong,” “strong,” “moderate” and “limited.” One of these two programmes (Uni E2) further adds the percentage contribution to the programme outcome represented by each shade. According to the programme, the darkest shade of green, representing a “very strong” contribution, is interpreted as a contribution to the programme outcome of more than 30% of the module.

A lighter shade of green standing for a "strong contribution" is interpreted as having a contribution between 16-30%. An even lighter shade of green, standing for a "moderate" contribution, is interpreted as a contribution between 5-15%. Finally, the lightest shade of green, standing for a "limited" contribution, is interpreted as a contribution to the programme below 5%.

It is notable that there is no shade assigned for modules with no contribution to the programme outcome, which would correspond to the score of 0 on the recommended POLO scale. Thus, the two programmes have a self-assessment rubric according to which no module is self-assessed as having no contribution to the programme outcomes. This means that it was not possible to convert accurately the colour mapping to the scale 0-4, as there was no means to distinguish between a module that has a limited contribution and a module that has no contribution. Only a partial conversion was possible, covering the range of scores 2-4, given that the interpretation of each of the three darkest shades of colour is similar to the meaning of scores 2, 3 and 4.

4.6.3.3 ECTS[19] contribution

Typically, an academic year is comprised of 60 ECTS, with individual modules contributing by five or ten credits, more in the case of final year projects. Three university programmes from the same institution (Uni F1, Uni F4, Uni F5) mapped the contribution of the modules to the programme outcomes in terms of ECTS. As such, each module's contribution to the seven programme outcomes was capped at the number of ECTS offered, which was then divided among the different programme outcomes. In this case, the conversion to the scale 0-4 was not possible because a module that has a strong contribution to five programme outcomes would have to assign a lower score for each outcome compared to a module that

[19] ECTS stands for European Credit Transfer System.

has a strong contribution to only two outcomes. Thus, there is no uniform means of determining the self-assessment score for the module's contribution to the seven programme outcomes.

4.6.3.4 Percentage contribution

Finally, one university programme (Uni F3) mapped the contribution of the modules to the programme outcomes in terms of percentage. As such, each module's contribution to the seven programme outcomes was assigned a percentage, capped at 100%, which was distributed among the seven programme outcomes. Similar to the ECTS scale, the conversion to the scale 0-4 was not possible because a module with a strong contribution to five programme outcomes would have to assign a lower percentage for each outcome compared to a module that has a strong contribution to only two outcomes.

One of the outputs of this research stage was to determine the weight given to programme outcome E in the curriculum of the participant engineering programmes, according to the programmes' own assessment, and then compare it with the average POLO scores for the other outcomes. A second output was to indicate how ethics education is implemented in the curriculum of the participant engineering programmes, based on the percentage distribution of the five POLO scores for outcome E within each programme. Thirdly, this research stage also enabled the identification of a category of modules that consistently had high self-assessment scores, namely modules of professional formation, which were selected for the subsequent stage of interviews with instructors.

4.6.4 Stage 3: Document analysis of module descriptors

The module descriptors were either provided by the participant programmes as an annex to the documentation submitted for the purpose of accreditation, or acquired from the institutional website. In the latter case, the study relied on the module descriptors for the academic year 20182019. The module descriptors contain information relevant to the objectives of the research study, such as the learning outcomes set for the module, topics covered, teaching methods and assessment methods employed and a list of reading material. This information was identified and transcribed verbatim, forming the basis of the documentary analysis.

For several programmes, the learning outcomes of the modules were explicitly linked to one or more of the seven programme outcomes for accreditation. In a few cases, the researcher grouped the learning outcomes that were considered to fall under the programme outcome E, based on similar outcomes set by other modules in connection to this outcome and an interpretation of outcome E rooted in the literature review. This research stage helped determine the main thematic areas used in connection to programme outcome E by modules with a high contribution to programme outcome E, as well as their frequency.

The process of collecting and analysing data underwent several iterations, as follows:

4.6.4.1 Step 1: Limiting scope

In the first stage, the scope of the study was limited to the modules that the participant programmes have deemed to have the highest contribution to meeting programme outcome E. Given the time restraints and the amount of modules offered by the participant programmes, it was not possible to have an in-depth analysis of the ethics coverage of all modules. The rationale for this demarcation was to focus on the modules that are envisioned to provide the strongest input in terms of ethics coverage.

To identify these modules, the study relied on the aforementioned POLO rubric. In the case of the 17 programmes that used the recommended POLO scale of 0-4 or a scale that can be converted to it, the modules that were self-assessed with score 4 have been singled out. It was observed that four of these programmes, offered by institution Uni D, had between 0-3 modules self-assessed with a 4 for programme outcome E. Taking into consideration the overall low self-assessment within this institution for all programme outcomes, additional modules have been including in the analysis. The rationale was to pinpoint the modules that a programme deems to have the strongest contribution toward programme outcome E, and in absence of modules self-assessed with the maximum score, the most revealing for the purpose of our study would be to focus on modules scored with 3.

For two programmes (Uni E2 and Uni F2) that employed a four point colour map, the researcher identified the modules assigned the darkest shade for outcome E, which stands for a "very strong contribution" to the programme outcome.

For three university programmes from institution Uni F (Uni F1, Uni F4 and Uni F5) that used ECTS, the analysis focused on the modules self-assessed as having a contribution of 1 ECTS or more to programme outcome E.

For one university programme (Uni F3), which mapped the contribution of its modules to the programme outcomes in terms of percentage, the analysis included the modules self-assessed as having a contribution to programme outcome E of at least 15%.

At the end of this stage, there was a total of 83 unique modules identified as having a strong contribution to programme outcome E.

4.6.4.2 Step 2: Delineating the pedagogical content purporting to ethics

For the following research stage, the topics and learning outcomes purporting to ethics addressed in these 83 modules were inputted into a table, based on the verbatim information provided by the programmes. This process relied on the following data sources:

- a mandatory rubric present in the documentation submitted for accreditation, which requires programmes to briefly describe how they meet each outcome, including the contribution to outcome E;
- the module descriptors of all 83 modules, made available to the researcher either during participant observation, as an annex to the documentation submitted for accreditation or on the website of the participant programmes;
- the syllabus and additional teaching materials for modules offered by programmes whose accreditation event was observed by the researcher.

For determining what counts as instructional content and learning outcomes purporting to ethics, the study relied initially on the learning outcomes explicitly identified in some module descriptors as contributing to programme outcome E, which were transcribed as such. For the majority of modules, the learning outcomes and topics were determined to contribute to programme outcome E based on the formulation provided by the accrediting body, the standard description of topics falling under outcome E included in accreditation reports and the surveyed literature about the content of engineering ethics education. This allowed the development of a table that brought together the verbatim description of ethical content mentioned in the three aforementioned sources.

4.6.4.3 Step 3: Content analysis

The next research stage was dedicated to analysing the content inputted in the previous stage, following two iteration stages. First, based on the input made in stage 2, a codebook with 28 initial codes was generated, which rendered pedagogical content purporting to ethics, based on the input made in stage 2. To ensure reliability, the original table was shared with a second researcher to generate his own coding based on the raw data. Having ensured the consistency of coding, the researcher proceeded to the second iteration stage, where the initial thematic codes were grouped and subsumed under broader categories. The process led to the identification of 11 major themes of pedagogical content purporting to ethics employed in the participant programmes.

Describing the difference between the two iteration stages, Punch (2014, p.174) notes that "first level coding mainly uses descriptive, low inference codes, which are useful in summarising segments of data and which provide the basis for later higher order coding," while "later codes may be more interpretive, requiring some degree of inference beyond the data. Thus second level coding tends to focus on pattern codes. A pattern code is more inferential, a sort of meta-code." As such, the first iteration stage had the role of making sense of the abundant raw data that was available from the sources employed. During the second iteration stage, the researcher analysed the codes generated in the first stage, rather than the data, aiming to subsume these under unifying themes (Saldaña, 2016, p. 15).

4.6.5 Stage 4: Document analysis of accreditation reports

The document analysis included the accreditation reports issued for 11 participant programmes. This is due to the time delay between the date at which the accreditation events for these programmes took place and the release of these documents by Engineers Ireland. Given that the researcher was present as a participant observer to the accreditation event of 11 of the 12 programmes for which the accreditation report has not been issued, information based on observation notes and draft recommendations has been included to complement this analysis.

The accreditation reports contain information relevant to the objectives of the research study, such as the componence of the panel, previous and current conditions or recommendations, the type of evidence provided in support of each outcome by the programme as well as the panel's comments on the evidence, the evaluation made by the panel of how the programme meets each of the seven programme outcomes, the evaluators' comments on the features and strengths of the programme.

This research stage identified recommendations made by the accreditation panels in regards to ethics education. It also identified the comments of the accreditation panel in regards to the numerical self-assessment of how programmes meet programme outcome E and the supporting evidence. Furthermore, it also determined what accreditation panels deem to be a programmes' strengths and weaknesses in regards to meeting outcome E.

The analysis of the data contained by this type of documents allows the researcher to identify patterns in the evaluation of engineering ethics, but also key aspects related to the education of engineering ethics, such as deficiencies or strong components, according to those responsible for making such evaluations. The recommendations and comments made by evaluators in regards to outcome E are considered significant because they represent the most visible force shaping the engineering curriculum and ethics implementation. It was equally important to identify patterns in these comments and enquire whether they reveal deeper cultural influences about the engineering education. Thus, this research stage was considered to offer a glimpse into what the evaluation panels deem to be a satisfactory engineering education.

4.6.6 Stage 5: Participant observation at accreditation events

Participant observation is a research method that closely examines the activity within a community. Gold (1958) theorizes four stances that can be undertaken for participant observation. The first stance is of the *complete participant*, who is a member of the group and opts for concealing her researcher role to avoid disrupting normal activity. The second stance is of the *participant as observer,* which presupposes that the researcher is already part of the observed group and the group is informed about the research activity. The third stance is that of the *observer as participant*, when the researcher is not a member of the group, but her participation in the group's activities is known and allowed. In this case, the researcher's main role is to collect data, which would be used to provide an enhanced understanding of the group's activities and improve it. The final stance is that of the *complete observer*, allowing the researcher to obtain data completely unnoticed, because either she is hidden from the group's view or she is in a large public setting. For the present study, the stance adopted was that of the observer as participant. This stance is considered to be the most ethical (Kawulich, 2005).

The researcher took into considerations some of the major guidelines for conducting participant observation, such as: being honest about the research without offering too detailed information, taking extensive notes containing comments made but also the interactions that occur, including who talks to whom, whose opinions are respected, and how decisions are made (Kawulich, 2005).

For the process of writing field notes, Silverman (2008) proposes the following guiding questions, in order to establish what the individuals who are under observation are doing, what they want to accomplish and how they go about this, how they characterise and understand what is going on and what assumptions they make.

Participant observation aimed to complement the scarce data available in accreditation reports, as to better capture the process of evaluation of participant programmes. For the purpose of the present study, the researcher observed three accreditation events that evaluated 11 programmes. An accreditation event takes place over two days, in which evaluators receive guidance from the representative of the accrediting body on how to approach this process and get to examine the evidence put at disposal by the programme for all seven programme outcomes. Evaluators discuss among themselves and with the designated representative of EI issues such as their approach to the evidence, their findings, their difficulties as well as the aspects of the programme they are unsatisfied with and that need further exploration and the strengths of the programme. Evaluators also have the occasion to interact with the programme chairs and instructors, in order to ask questions about the programme coverage or the evidence made available. This process offers a rich level of data about the evaluation of an engineering programme in an unmediated manner.

Robson and McCartan (2015, p.320) consider that the direct access to data is an important advantage of observation research, as the researcher does not ask subjects about their views, feelings or attitudes, just “watches what they do and listens to what they say.” This method is also meant to compensate for the discrepancies between what people say and what they do or what they believe (Robson & McCartan, 2015). For example, the researcher encountered discrepancies between the recommendations made during the accreditation and those feeding into the report. As such, during the event several evaluators criticised the way the evidence was presented and how the POLO self-assessment scales were used, but during the final meeting of the accreditation event in which evaluators present the recommendations that will be part of their report, there was no mention either about the evidence, or the POLO scores. A chair evaluator explained the absence from the final accreditation report of a recommendation targeting the display of evidence and the self-assessment scale used, stating that “there were so many comments about this during the event, that they learned and will not repeat it.” It is evident that an accreditation report cannot fully convey aspects purporting to the education and evaluation of engineering ethics, and there might have been a diminished awareness on the emphasis placed by evaluators on the accurate use of POLO self-assessment scales and display of evidence if one is not present in the midst of these discussions.

The participant observation of accreditation events thus complemented the analysis of the accreditation reports and the interviews with evaluators, by taking into consideration the views on ethics, engineering and engineering education verbally expressed by the evaluators, as well as their judgement of how the programmes meet outcome E made throughout the event or in the suggested recommendations. This research stage also gave direct access to the guidelines received by the accreditation panel from the accreditation body in regards to evaluating programme outcome E. The method of participant observation provided a unique insight into the amount of time dedicated to the evaluation of outcome E compared with other outcomes and the discussions generated during the examination of the evidence. This research stage offered the opportunity to observe and take note of the unmediated reaction of the accreditation panel to the POLO scores, the evidence put at their disposal, the implementation and coverage of ethics by the participant programmes. Such detailed information strengthened the patterns identified in the accreditation reports. It also helped identify challenging aspects encountered by members of accreditation panels in their evaluation of outcome E, which could not have been determined otherwise. The data gathered during this research stage provided insights for aspects that need to be explored in more depth in a subsequent research stage, through interviews with evaluators.

For the present research study, participant observation has been limited to three accreditation events that took place from the summer of 2018 to the early spring of 2019. These are the accreditation events for the one programme offered by the institution Uni C, and the five programmes offered by the institutions Uni E and Uni F, respectively. During this selected time period, none of the participant engineering programme offered by institutes of technology underwent accreditation, and so participant observation had to be restricted to university programmes.

4.6.7 Stages 6-7: Interviews with instructors

To complement the extensive analysis of programme documents, module descriptors, accreditation reports and POLO scores, the project also collected data intensively. Besides participant observation of accreditation events, this study also included in-depth interviews with engineering ethics instructors and evaluators. The patterns in engineering ethics education and evaluation revealed by extensive data sources were complemented by an in-depth examination of the views of individual instructors and evaluators on different aspects related to the education of engineering ethics. Interviews were considered to provide an understanding of the experiences and perspectives of the participants (Patton 2002).

Due to the similarity in approach, the two research stages involving interviews with instructors and evaluators are described together.

The interview process unfolded over a series of consecutive steps, as follows:

4.6.7.1 Step 1: Participant selection

For the interview stage, first was determined a criterion for selecting interview participants. Given that the aim of the interviews was to achieve a more in-depth look at the coverage and understanding of ethics, modules with a high emphasis on ethics had been identified. The category of modules chosen was represented by modules of professional formation, which are present in the curriculum of all programmes under investigation. Sixteen of the instructors that were contacted confirmed their participation.

It is important to note that one of the evaluators, E6, is also an instructor of a professional formation module, identified as L13.[20]

[20] When a chapter deals exclusively with data obtained from interviews with instructors, this participant is referred to as instructor L13. Similarly, when a chapter deals exclusively with data obtained from interviews with evaluators, the participant is referred to as evaluator E6. In the situation when a chapter includes data from interviews with both instructors and evaluators, the participant is referred to as instructor L13/evaluator E6.

4.6.7.2 Step 2: Determining interview format and questions

The research followed a semi-structured format for the interviews. This type of interviewing technique is described as employing “a blend of closed- and open-ended questions, often accompanied by follow-up why or how questions.” (Adams 2015, p.493). The closed-ended character of the dialogue follows predefined topics on the researcher’s agenda, but it can also “meander […] rather than adhering slavishly to verbatim questions and may delve into totally unforeseen issues” (Adams 2015, p.493). Thus the questions and themes explored were similar in all interviews, and the semi-structured format allowed the exploration of these themes as they arose.

The method is considered by Adams (2015, p.493) to have a number of advantages that suit the characteristics of the present study, such as its suitability for probing into the independent opinions of each individual and for “examining uncharted territory with potential momentous issues that require maximum latitude” for the researchers to spot useful leads and pursue them.

Stages 1-3 of research helped narrow down the questions to be addressed. In the case of instructors of modules of professional formation, the study has enquired about their motivation for teaching engineering ethics, their views on the role of ethics education in engineering, the topics and methods used in their teaching, their own experience in the classroom, the types of institutional support received or challenges encountered. Interviews with evaluators explored their affiliation, background and motivation for serving in accreditation panels, how they approach the evaluation of programme outcome E and the type of challenges encountered in their evaluation of this outcome, the type of guidance they receive or they would find beneficial as well as how they evaluate evidence in regards to programme outcome E and their expectations on how a programme should cover ethics. The themes and questions that the researcher pursued during the interviews can be consulted in the interview guide, which is available in Appendix 5.

The CR frame helped me focus on connecting these individual perspectives to the broader structure they are embedded into, and posit as generative mechanisms the culturally established conceptions about the profession of engineering and engineering education.

4.6.7.3 Step 3: Conducting the interview

Of the 16 interviews with instructors of modules of professional formation and 5 with evaluators, 3 interviews were conducted online and 18 in person. The interviews had a duration between 23 and 65 minutes and were audio recorded using an electronic device, with the consent of the participants.

4.6.7.4 Step 4: Transcription

The recordings were then transcribed using an online transcription software, whose output was then verified and corrected by the researcher. The protocol of transcription followed a denaturalised method suggested by (Mero-Jaffe, 2011), according to which the transcript eliminated interview "noises," such as pauses in speech, coughs, laughs, involuntary sounds, stutters, grammatical errors. A naturalised transcription method that renders verbatim and in minute detail the description of the speech carries the risk of insulting the interviewees, who might feel that their speech was unrefined (Mero-Jaffe, 2011.). This is due to the fact that the representation of speech as written text is evaluated according to the conventions of written text, despite their differences.

4.6.7.5 Step 5: Analysis

The resulting transcripts were analysed through several rounds of thematic coding. The coding process was iterative and helped refine the themes and explore alternative explanations, according to the guidelines provided by Strauss and Corbin (1998), Dev

(2003) and Saldaña (2015) for open, axial, and selective coding of the interview data. For the first iteration of the coding process, one or more codes have been assigned to each answer to the interview questions. The codes were linked to the experiences and views expressed by the participants interviewed. For the second iteration, the codes have been grouped together under different trees (Olsen, 2012), which then helped generate theoretical concepts at a more abstract level. The coding process helped frame the different and sometimes diverging understandings of ethics in the context of engineering education.

The analysis of the interviews with instructors revealed the background and motivation of instructors of professional formation modules, the views they hold on the goals and scope of engineering ethics education, as well as their experience teaching ethics, including challenges encountered and support received. The analysis of the interviews with evaluators helped reveal the motivation of evaluators for being part of an accreditation panel, their views on the role of engineering education, the introduction and formulation of programme outcome E, their approach to analysing evidence in support of outcome E, as well as challenges experienced and support measures deemed beneficial.

4.7 Validity and reliability of findings

Validity refers to the quality of the research design and of the methods employed of representing accurately the object of the research. The project's aims were to determine how engineering Honours Programmes in Ireland incorporate the programme outcome E set by the accreditation body and also to examine the process of accreditation in regards to it. Given that the research does not cover exhaustively all engineering Honours programmes in Ireland, the question that arose was about ensuring validity of the findings. It was not the intention of the project to include data that is representative of all engineering Honours programmes in Ireland. Instead, the project aimed to identify patterns of coverage of ethics education and evaluation in engineering Honours programmes in Ireland, and to provide explanations about the process by which ethics education is being integrated and evaluated.

The philosophical position underlining CR shaped the research questions pursed, which in turn informed the methods employed. Questions about the validity of the study are closely linked to the concept of causation employed within a CR frame. The use of abductive inference towards the best explanation leads to a view of causation distinct from that of both positivist and interpretivist camps. Following Hume, for positivists causal inferences are reached based on observations about consistent regularities, thus leaving out unobservable structures and mechanisms. However, as Zachariadis *et al. (*2010) point out, CR considers that open systems such as the social world are far too complex to give in to regular connections between causes and effects. The CR researcher aims to provide the best explanation about unobservable mechanisms based on the characteristics and frequency of the phenomena observed. As such, the present research is preoccupied not with establishing causal laws, but with making "analytical or theoretical generalisations" (Robson & McCartan, 2015, p.154), such that the patterns of data and findings can support a theoretical explanation about the underlying mechanisms causing them.

Although an element of subjectivity is involved, both in the numerical self-assessment of programmes of how they meet the seven programme outcomes for accreditation, expressed in POLO scores, as well as in the statements made by participants during interviews and in the notes of the researcher observing the accreditation event, there are patterns present in the opinions expressed. As such, even if individuals can be wrong in their perceptions and the beliefs they hold, there are persistent patterns that need to be explained, which point to structural causes. The research is concerned with tracing down such causes, through explanations that start from the patterns in the opinions registered.

Reliability is concerned with ensuring the consistency of the findings over time and with different observers. To ensure the reliability of the document analysis, a template was developed by the researcher, capturing data about the education and evaluation of engineering ethics, structured according to main themes. This template is common to all programmes and includes data collected from the documents submitted by each programme for accreditation as well as from accreditation reports, and from the module descriptors publicly available on the website of each programme. The notes gathered during the observation of accreditation events include extensive verbatim comments made by the members of the accreditation body, evaluators and academic staff, though without names to ensure anonymity. The interviews with instructors and evaluators were also rendered in a manner that preserves the verbatim comments. Thus, the availability of a well-documented audit trail of materials had been ensured.

4.8 Ethical considerations

The data obtained in this study through participant observation, interviews and document analysis is subject to a nondisclosure agreement with Engineers Ireland, which can be consulted in Appendix 1. The programme documents were made available to the researcher by representatives of the participant programmes, while the accreditation reports have been made available by the accrediting body. The module descriptors were either made available to the researcher as an annex to the programme document, part of the evidence presented during the accreditation event, or accessed online on the webpage of the programme.

The research followed the procedure outlined by the university Research Ethics Committee. As such, ethical approval for conducting the study was sought with the Ethics Committee, in order to analyse the risks of the study and guarantee the participants' rights. This document is available in Appendix 2.

All the data obtained through document analysis was anonymised and codified to avoid recognition of individuals, specific modules or programmes.

During participation observation, programme representatives and evaluators were informed by the presence of a participant observer and the purpose of participation. All identifying details purporting to the names of the individuals present during the accreditation process, as well as the name of modules, were anonymised in order to prevent identification. The comments were transcribed verbatim in order to ensure the accuracy of data. No recording device was used, in order to ensure the privacy of the data and allow participants to express their views openly.

For the interviews, participants received a Consent Form and an Information Sheet describing the scope of the research study, how the data gathered will be used, the measures to safeguard the security and privacy of data, as well as their rights to confidentiality of the data, access to the transcript and retreat from the study. The documents can be consulted in Appendix 3.

In order to ensure the upholding of the principles of transparency and consent, the transcript has been made available to the participants. Participants were thus informed about their right to access the transcript and were asked about the method of transfer they prefer, by email or by post. Participants were also informed of their right to correct, clarify or make additions to the interview. To ensure that the principles of privacy, confidentiality and anonymity were honoured, the transcripts have been edited as to remove any identifying mark, such as the title of the module taught by the instructors interviewed, their institutional affiliation and their name. In addition, the act of sharing the transcripts with any external party, except the research group involved in the current study, was prohibited. For protecting and limiting the access to the transcripts and the electronic recordings, these were stored on a password-encrypted device.

4.9 Limitations

The present research is not without limitations. A first type of limitations refers to the amount of data processed by the researcher. Given the rich amount of data, the study limited the analysis of the topics and coverage of engineering ethics education to mandatory modules self-assessed as having the highest contribution to programme outcome E. Given there are modules that are common for several Engineering programmes belonging to the same institution, only unique modules have been considered to avoid the repetition of identical data. This approach led to a total number of 83 unique mandatory modules, whose content has been analysed based on the description provided in the module descriptors. The downside is that modules that include ethics in a lesser extent have been left out. Specifically, the analysis excluded two category of modules. First, modules which might have included ethics, but self-assessed incorrectly their contribution to outcome E with a lower score were left out. Second, several technical modules which have included ethics in a lesser extent were also omitted from the analysis. The focus of the content analysis only on modules self-assessed as having a high contribution to outcome E was necessary given the time and resources available.

A second limitation was rooted in the choice of methods used. For example, participant observation to accreditation events led in both cases to a sort of reactivity of those observed to the presence of the observer, which McCall (1984) considers a common feature of observational studies. Although the evaluators were made aware of the observer's presence, and attempted interactions by enquiring how to proceed when examining ethics, under the motivation that this is a difficult outcome to evaluate, this by itself is still an important finding that supports the claim about the challenges encountered by evaluators in the US (Le Blanc, 2002). The statistical analysis of POLO score also had its limitations, in the sense that it should not be taken as an absolute representation of the weight given to outcome E, or to any of the other outcomes, by the programmes examined. The POLO scores are rooted in the subjective perception of instructors and programme chairs of how they deem their modules and programme to have met the seven programme outcomes for the purpose of accreditation. That does not exclude a coherent and consistent set of patterns, irrespective of the subjectivity inherent in such a self-assessment.

A third limitation of the examination of curricular content and teaching practices used in engineering ethics education is linked to the reliance on document analysis and interviews, as opposed to direct observation of teaching practices. Observing teaching practices might have offered more reliable insights about the way ethics is taught and the challenges encountered by instructors *in situ*, as well as how students receive modules of an ethical nature. In this regard, this method could have served as a mirror rendering the actual practice of teaching engineering ethics. Nevertheless, the subjective element would still have been present, represented by the researcher's perspective and judgement on how ethics is taught, rather than on how instructors describe and conceptualise their practice and the role of engineering ethics education. The document analysis of module descriptors, combined with interviews, revealed how instructors perceive and articulate the practice of teaching engineering ethics, as well as the scope and goals of this practice.

CHAPTER 5 THE CONCEPTUALIZATION OF ENGINEERING ETHICS EDUCATION

The current chapter addresses the 4th objective of the thesis, and sets to examine how the role and scope of ethics education is understood and articulated by the participants in the study. The chapter begins by describing the research methods employed, before proceeding to a presentation of the main findings, focused on three main aspects: (i) how is engineering ethics defined, (ii) what are the goals used in connection to engineering ethics education and (iii) what type of coverage is considered to fall under the scope of engineering ethics education?

The literature review showed that there are two main theoretical frameworks employed to make sense of the goals and type of coverage employed in engineering ethics education. The first framework is microethical in nature, putting forward the individualistic perspective of an agent faced with a dilemma or situation of crisis (Kline, 2010). The second framework is represented by a macroethical approach that emphasizes the broader context of engineering practice and decision-making, as well as the collective responsibilities of the engineering profession (Conlon & Zandvoort, 2011). Two more recent approaches are value sensitive design, which shifts the focus away from assigning responsibility in situations of crisis to reflection about the values inscribed in technological artefacts at the design stage (Verbeek 2008; 2011), and virtue ethics, whose focus is on character development (Harris, 2008). These four approaches serve as guidance in categorizing how participants understand the discipline of engineering ethics education.

5.1 Method

In order to explore the conceptualisation of ethics in engineering programmes in Ireland, three research methods were employed: (a) interviews with instructors from the participant programmes teaching a professional formation module and evaluators serving on the accreditation panels of Engineering Ireland; (b) a document analysis of a mandatory rubric in the documentation submitted by the participant programmes for accreditation in which the programme goals and graduate learning objectives are described and of the documents of EI describing the scope of the accreditation requirements and (c) participant observation at accreditation events, rendering the observations made by representatives of the accreditation body, evaluation panels and programmes. Each research method has been described in more detail in chapter 4.

5.2 How is engineering ethics education defined?

For the examination of how engineering ethics education is defined, the study considers the conception put forward by the accrediting body, the views on ethics reflected at programme level, and finally, the views of individual instructors and evaluators. In what follows, the articulation of the meaning and scope of engineering ethics education at each of these levels is addressed.

5.2.1 According to the accrediting body

The view of the accrediting body as to what is the meaning of engineering ethics education is conveyed in two documents. One document presents all the programme outcomes required for accreditation and is available to the wider public (Engineers Ireland, 2007). The other document is represented by the accreditation report that needs to be completed by evaluators following the campus visit, and then sent to the each programme stating the official decision regarding its accreditation status. This document contains guiding suggestions on areas to be considered for the evaluation of each programme outcome. The accreditation report is not public, and was received for the purpose of this research study from representatives of the accreditation body.

The formulation of programme outcome E by Engineers Ireland (2007) requires graduates to show "an understanding of the need for high ethical standards in the practice of engineering, including the responsibilities of the engineering profession towards people and the environment." The formulation of outcome E is detailed further, by explaining what abilities fall under this outcome. As such, the description of outcome E is continued by specifying that "graduates should have, inter alia:

> (i) the ability to reflect on social and ethical responsibilities linked to the application of their knowledge and judgements;
> (ii) knowledge and understanding of the social, environmental, ethical, economic, financial, institutional, sustainability and commercial considerations affecting the exercise of their engineering discipline;
> (iii) knowledge and understanding of the health, safety, cultural and legal issues and responsibilities of engineering practice, and the impact of engineering solutions in a societal and environmental context;
> (iv) knowledge and understanding of the importance of the engineer's role in society and the need for the commitment to highest ethical standards of practice;
> (v) knowledge, understanding and commitment to the framework of relevant legal requirements governing engineering activities, including personnel, environmental, health, safety and risk issues.

From the formulation of outcome E, it is visible the aim of combining both microethical concerns related to health, safety, legal compliance and organizational aspects with macroethical concerns linked to the societal and environmental responsibilities and the wider role of engineering. Outcome E also includes financial and commercial considerations. As Polmear *et al. (*2019) note, the formulation of accreditation criteria places a higher emphasis on macroethical areas such as sustainability and environmental welfare in the Non-US Anglo cluster of countries that Ireland is part of, compared to US and Western Europe.

Regarding the evaluation of programme outcome E, the accreditation report advises evaluators to take into consideration aspects such as:

> the importance of plagiarism, late submissions and honesty in work practices; health and safety plans, risk assessments, method statements, laboratory safety plans or

> any other safety issue; the role of the engineering professional in their relevant industries; the role of the engineering professional in society at large; the responsibility of engineering professional to the environment; the relevant legal and professional responsibilities of the engineering professional; the relevant designed standards for the engineering professional; matters of ethical decision-making and finance and management.

When comparing the two documents, there are slight differences related to two key aspects falling under outcome E. First, the microethical issue of plagiarism, which is noted in the accreditation report first on the list of aspects to consider when evaluating how programmes meet outcome E, is missing from the formulation of outcome E of the public document of Engineers Ireland that presents the accreditation criteria. Second, macroethical issues related to cultural aspects and social considerations of engineering practice are present in the formulation of outcome E in the public document, but not mentioned in the guidelines for evaluating outcome E of the accreditation report. During participant observation, while some evaluators were guided by the formulation of the programme outcome in the public document, enquiring about all aspects mentioned in the formulation of outcome E, other evaluators were browsing through the list of issues mentioned in the accreditation report, thus placing an emphasis on plagiarism and health and safety issues.

5.2.2 According to instructors and evaluators

When interviewing instructors and evaluators about their views on engineering ethics education, what is revealed is a variety of –sometimes opposing– conceptions. Several common themes emerge that point to the practical and decision-making character of the discipline, but there are also points of contention as to what exactly engineering ethics education is about. Table 10 renders the main themes used to identify the participants' conception of engineering ethics education.

Table 10. Definition of engineering ethics education (Total=21; Instructors=16; Evaluators=5)

Engineering ethics education is..	Respondents expressing agreement	Respondents expressing disagreement
about decision-making in complex situations	9 (7L ; 2E)	1 (1E)
relevant to engineering practice	6 (5L; 1E)	1 (1E)
socially embedded	4 (4L)	
character shaping	5 (4L; 1E)	1 (1L)
common sense and obvious	1 (1L)	1 (1L)[21]

5.2.2.1 Decision-making in complex situations

The interviews revealed a strong focus on the decision-making character of engineering ethics, according to both instructors and those who serve on accreditation panels. Evaluator E5, who was involved in the discussions surrounding the introduction in Ireland of an accreditation outcome dedicated to ethics, recounted the description of the outcome given by the registrar of Engineers Ireland at that time. The representative of the accreditation body was said to stress to engineering programme chairs that decision-making is at the core of engineering ethics. Accordingly, he stated:

> what falls within the scope of this programme outcome has everything to do with decisions relating to people, to society and to the environment. So even when you are taking technical decisions, you are inevitably also taking decisions which impact on people, your colleagues, society and the environment, and even if those consequences may be very minimal, there are still consequences.

This conception of ethics is shared by 7 of the instructors and 2 of the evaluators interviewed (L2; L4; L5; L7; L8; L12; L13; E1; E5). The nine participants described engineering ethics as involving decision-making. In this sense, ethics is conceived to be about confronting dilemmas and making difficult decisions. As instructor L4 claims, "there is nothing easy about ethics. […] Ethics is not about a simple 'this is right, this is wrong' answer. Ethical

[21] This is the same instructor that agrees that ethics is common sense and obvious, as she expressed these two contrasting opinions during the interview;

questions are complicated. If it is a simple question, if it is a case of something that is obvious, it is not really an ethical question." This view is mirrored by instructor L2, who considers that "ethics always comes in when it is a hard decision to make, a difficult decision. If it is an easy decision, I think ethics just does not come into it."

Ethical decision-making in engineering is described as "complex" and situated in "grey areas." The increasingly challenging character of decisions that engineers have to make means that "the more complex the world becomes, the more important ethics is" (L7). Closely linked to the previous conception, we encounter a vision of engineering ethics concerned with ambiguous situations and uncertainty. Decision-making situated in "grey areas" was explicitly mentioned by six participants (L5; L7; L9; L14; L15; E3). As evaluator E3 says, "engineering is very often about being precise, being black and white, and ethics is about being comfortable with grey." Instructor L5 considers that with ethics, "there is always going to be a grey area and you have to make some kind of decisions," while instructor L14 states that ethics does not deal with "things that are obviously morally wrong, we are talking about very grey areas."

It is important for ethical decision-making to be "value based" (L8) and considerate of a wide range of "satellite effects" (L10; L15), constricting factors (L7; L9; L14) and stakeholders (L8; L11; L15).

Commenting on how the complexity of ethical decision-making is integrated in engineering education, instructor L8 considers that "traditionally and currently, ethics is seen as being something that is just about the right or wrong thing for an individual to do in a non-problematic environment." According to L8, "engineering educators should make explicit not just the individualistic moralistic point of view."

Although the instructors and evaluators interviewed revealed a prevalent view according to which engineering ethics is about making decisions in ambiguous and complex situations, for one respondent "ethics is about life and death situations" and in "engineering the consequences are not so severe" (E1).

5.2.2.2 Close to engineering practice

A second frequent conception expressed by the instructors and evaluators interviewed points to the practical nature of engineering ethics, set in opposition to "philosophical" ethics. According to six respondents, engineering ethics is less theoretical in nature and strongly linked to engineering practice (L4; L8; L9; L10; L11; E3).

This conception is best rendered by instructor L9, a philosopher, who describes the difference between how she would teach ethics in a philosophy classroom setting as opposed to how she would teach in an engineering setting:

> I am not going to talk to you about Kant and Aristotle, that is not going to do anything. The way I understand professional ethics is very close to professional practice. So I need to understand how and what engineers are doing, what kinds of devices they will be developing, how they interact with people, are they working in big companies, are they working individually, in order to have a sense of what are the actual practical challenges.

L9 notes that a "cognitive divorce from practice" exists in engineering ethics education, and is "not sure" if the theory focused ethics instruction would "make engineers more ethical."

The distinction between how ethics is understood and taught in philosophy departments as opposed to engineering departments has been described as an important reason why the instructors themselves and the programmes they are part of do not reach out to philosophy departments to collaborate on the implementation and teaching of ethics. Instructor L4 explains why the collaboration with a philosopher specialised in the ethics of technologies and science has ended, noting that

> partly because his presentation was more aimed at philosophers. There was more obvious ethics, and I wanted to give students a background in ethics, but more focused towards things they are likely to experience in work situations, in college situations […] and trying to make it more practical.

Similarly, instructor L2 explains the lack of collaboration with the philosophy department "because philosophy sometimes can be too.. not practical enough." Instructor L12 also comments on his department's decision to forgo a collaboration with the philosophy department, highlighting the difference between the abstract nature of ethics instruction in philosophy education, as opposed to the practical dimension of ethics encountered in the engineering workplace:

> one option would have been at the extreme end to get our philosophy department to give formal lectures on ethics. We had some very brief discussions about that, but it seemed that they wanted to do a very theoretical sort of ethics, a series of ten lectures and that was it. And we felt that was not the way that it would help our students. […] We have other modules where practitioners from the outside come in and some of them talk about ethics.

Evaluator E3, who is an industry representative, emphasizes the importance for engineering programmes to include the practical dimension of ethics, as opposed to teaching ethics in an abstract way. He thinks that academia and industry "look at ethics completely differently. The academic guys look at ethics very much in the academic sense, referencing, plagiarism, and they talk about responsibility to the environment in kind of abstract terms."

The connection of engineering ethics to practice is traced back to the pervasiveness of ethics (L8, L10, L11, E3). Instructor L8 considers that "there are values in anything we do in our engineering practice, embedded in our practice." Instructor L11 states that ethics is "imbued across all their activities," while evaluator E3 considers that "ethics permeates everything." Instructor L10 explains the pervasiveness of ethics in more detail, stating:

> everything they do has a potentially ethical dimension. They do not have to be a senior manager in Ireland or for a space shuttle to make decisions that have ethical consequences. A very strong example is the medical device industry, where a big

> percentage of our graduates are working. The work they do every day can have a real impact on quality of life for people who use these products.

Not all those interviewed agree with the presence of ethical concerns in engineering practice, with evaluator E1 stating that "unlike pharmacy," engineering is "isolated from ethics" as "the consequences are not so severe."

5.2.2.3 Socially embedded

According to four participants (L1, L9, L11; L14), engineering ethics is about taking into account the perspectives and needs of different stakeholders. The rationale provided is that engineering does not take place *in abstracto*. More so, instructor L9 emphasizes the social dimension of engineering as a key to understanding the practical character of engineering ethics, stating that "ethical practice is part of social dynamics to some extent." Instructor L1 agrees that "a lot of the questioning and the ethics will be looking at something from various sides, from other people's point of view."

5.2.2.4 Character shaping and development of moral virtue

Six of the participants interviewed mentioned the character shaping nature of ethics education (L2; L4; L8; L11; L15; E1). One instructor considers that ethics is not about moralising, while five participants understand engineering ethics education in terms of its character shaping role. As such, instructor L8 admits not to consider "my role as to be moralising or telling students this is right and this is wrong, telling them how to think or what to think." Nevertheless, evaluator E1 disagrees with this view, considering that ethics instructors should be a role model that guides students in their practice through the power of example. According to E1,

> you need to be ethical in every way, the way you deal with the students, as well as how you deal with the topic, and try to encourage them to deal with it. I suppose you have to practice what you say is about.

Instructor L11 considers that engineering ethics education should impact not only the "professional sphere," but also the "personal sphere." According to L11, fostering the development of personal virtues affects how one practices engineering. Virtues such as

> intellectual discipline, intellectual courage and intellectual empathy are woven into everything else that you would do in your professional life in terms of your interactions with all of the stakeholders. I see the building of a certain kind of character as an essential part of what we do.

Instructor L4 agrees that ethics education can have a transformative role, stating that "I cannot control how students are like personality wise," but "by broadening their picture and through the practice of questioning from other people's point of view, you have some influence on them." Instructor L2 emphasizes the role of motives guiding engineering practice. According to L2, engineering ethics implies making decisions based on the right reasons, and that "doing good deeds is not necessarily a good moral behaviour, because you could be doing good deeds for the wrong reason […] and be legally OK, but morally and ethically wrong." Instructor L15 considers that "the purpose of an education is formation, essentially. So you are forming these young people into being really good engineers."

5.2.2.5 Common sense

According to Harris *et al. (*2009, p.8), common morality is one of the three types of ethics and represents "the set of moral beliefs shared by almost everyone." Instructor L1 is the only participant who points to an underlying common sense view of engineering ethics that informs education, according to which ethics is "obvious" and "a given." As L1 explains,

> we know certain things are good and bad. We have a moral compass of our own that we know what is good and bad. […] There is a common sense approach to some of it [..], so ethics seems to be kind of brushed over to a certain degree as a given. […] Probably because some of it is obvious.

Through the course of the interview, while reflecting on some instances of ethical decision-making in engineering practice, L1 starts to casts doubt on the view previously expressed, admitting that "maybe, maybe ethics is not as common sense as I think it is." This change of mind is also reflective of the confusion generated by attempts to define engineering ethics education and what falls under its scope, an issue which we will return to later in the chapter.

5.3 What falls under the scope engineering ethics education?

During the interviews, we have encountered different views towards what counts as engineering ethics education, in some cases marked by confusion and disagreement. In what follows, it is analysed how the coverage of engineering ethics education, as understood by the participants interviewed, could be interpreted as falling under the major theoretical approaches described in the literature review. Only one participant (L8) explicitly placed his pedagogical approach in one of the aforementioned frames, more specifically, the macroethical frame. The views expressed during interviews about what falls under the scope of engineering ethics education are complemented by observations made by members of the accrediting body, panels and programmes during participant observation of three accreditation events.

5.3.1 Extended macroethical scope

Ten participants interviewed (L4; L6; L8; L9; L10; L11; L12; L13/E6; L16; E3) highlight the need to extend the scope of *ethics* coverage in engineering education as to include broader societal considerations and reflection on how to tackle some of the pressing challenges humanity faces. Reflecting on the current educational practices witnessed, instructor L8 considers that this "broader societal understanding of ethics is perhaps slightly deficient or wanting" in engineering education. Instructor L10 emphasizes the role of engineering ethics education in contributing to the betterment of society and addressing the "massive societal challenges ahead," while also stressing the need for "the engineering profession as a whole in stepping up to that." Engineering education has an important role to play in this regard, as L10 considers that preparing engineers to take such responsibilities to heart “begins in education.” According to L10, “ethics is not only about engineers as employees, but as citizens and their responsibilities for far bigger things.”

The broad set of engineering responsibilities that need to be taken into account in engineering ethics education is highlighted by L13/E6, who considers that

> one of the discriminators between scientists and engineers is that the engineer must think broader in their solution of a problem. They just do not come up with a numerical value to solve a problem, they have to consider […] any issues that could have an impact on society in general. Coming into all that focus, then ethics has a huge role to play.

Instructor L12 also emphasizes the need for engineering ethics education to include “a wider picture with a wider group and community that would be affected by the work of engineers.”

Participant observation also reveals the concern expressed by several evaluators with discovering whether the programmes undergoing accreditation understand ethics in a narrow or broader manner. For example, evaluator E7 has asked members of the academic team of Uni F “how do you understand ethics? Just plagiarism, health and safety or something broader?,” before adding that the role of the accreditation panel is “to talk about ethics and how broad it is.” During the first meeting of the evaluation panel, the representative of the accrediting body also prompted evaluators to analyse how broadly ethics is implemented in the programmes undergoing accreditation. According to the representative of Engineers Ireland, “one of the areas that gets overlooked in this discipline is ethics, and most often is understood very narrowly. If you talk to students is plagiarism, but it needs to be more.”

When describing what falls under the extended scope of engineering ethics education, three main areas of coverage are revealed, related to sustainability, the societal dimension of engineering and legislative aspects. These coverage areas can “make explicit not just the individualistic moralistic point of view,” as instructor L8 considers.

5.3.1.1 Sustainability

Sustainability is the topic most often mentioned in connection to the content falling under the scope of engineering ethics education, with ten participants pointing to its inclusion (L3; L4; L6; L8; L10; L11; L13/E6; L15; L16; E2). The significance of this coverage area is explained due to the impact of engineering artefacts on the community and the environment in light of fighting climate change. According to L6, "the responsibility for global sustainability and influencing or not influencing climate change is included in what we do, but it is getting stronger." The sustainable goals are included under this coverage area, having been mentioned by instructors L2, L8 and L16, but also waste disposal and recycling, with evaluator E2 considering that "anything you are disposing of would be under the category of ethics."

While we see a strong focus on sustainability in the participants' interpretation of what type of coverage falls under the scope of engineering ethics education, we also encountered a dissenting opinion. For example, L2 explicitly mentions that she does not consider that ethics is about sustainability, sharing this view also with her students. According to L2, "students do not really understand ethics. I find they get it confused with sustainability or corporate social responsibility and all that kind of things, which is not ethics." The point is reinforced and questioned later on during the interview, hinting to a diminished expertise. When discussing the challenges encountered while teaching ethics, L2 points to the fact that

> the students do not always grasp what ethics is and they get it confused with sustainability or doing the right thing for the environment. It is kind of that, but really it is not. So it is challenging trying to get them to understand what ethics actually is. I do not always understand it myself.

Of a different opinion is instructor L4, who also points to the challenge of making students recognize the wider range of issues falling under ethics, but who considers sustainability to be among these. According to L4, "one of the big problems was the students' ability to categorize something as being ethics, […] and to try and get them to at least see that."

5.3.1.2 Societal impact and social dimension of engineering

Another significant coverage area that falls under the scope engineering ethics education refers to the societal and social dimension of engineering. Eleven participants (L1; L6; L8; L9; L10; L11; L12; L13; L16; L13/E6; E4) consider that ethics coverage should include the responsibilities that engineers have towards society and the impact of engineering practice on different stakeholders. According to L8, this can be understood to "incorporate the broader context of the organizational culture and societal culture." Instructor L11 adds that ethics education needs to comprise "the balance of issues around justice and fairness, harm and prevention of harm," given that "these are significant issues that are going to impact not just the stakeholder who you are working for, but the community where that stakeholder is." For L10, engineering has an impact on the quality of life and growth of society, such that ethics education should address

> the kind of responsibility of engineers to do with that and also look historically at the correlation between the growth of technology and the growth of energy production with standards of living. Not only economics, but quality of life and literacy and all these things, we can see the historical advances over the last 200 years. And to connect that as a positive ethical achievement.

Several instructors pointed to the social and organizational context of engineering practice, noting that ethics education should include considerations about the stakeholders engineers need to engage with in their practice. This is motivated by L14 in light of the characteristics of the tasks and challenges engineers will face. According to L14, students need to be familiarised with the difference in perspectives because "very few are going to spend the rest of their lives in a lab or just in a design role purely, they will all progress into some sort of management role, which means they are dealing with people." Instructor L6 agrees, given that the population holds dissenting opinions on the type of societal challenges that engineers address, such as climate change. Describing the role of ethics education in tackling difference in opinions, instructor L6 considers that

> the debate and the public is becoming more and more polarised. Engineers have to work in that environment, so they have to be aware of it. Even if some of the extreme views are not consistent with the engineers' own beliefs, they have to be aware that they would come across it.

Stakeholder perspective and societal considerations are seen as pivotal areas in engineering ethics education. According to L11, "when you are working in engineering, you have to think about all stakeholders," and ethics education can foster this type of reflection. Instructor L8 agrees that the mission of engineering ethics education is to develop "more fit for purpose engineers who can productively engage with society." Overall, it helps prepare "a more holistic engineer, somebody who is more conscious of their role in society, rather than just solving technical problems," in the words of participant L13/E6.

Not only instructors are concerned with the integration of the societal dimension of engineering, but several evaluators serving on the accreditation panels of Engineers Ireland also consider that societal aspects fall under the scope of outcome E. For example, during the accreditation events observed, three evaluators were explicitly searching for evidence as to how well the respective programmes addressed the societal dimension of engineering.

The emphasis on the societal dimension of engineering by the instructors and evaluators interviewed reflects a similar focus to that identified by van de Poel and Roakkers (2011, p.25), who highlight the role of different actors in influencing "the direction taken by technological development and the relevant social consequences."

5.3.1.3 Regulatory and legislation issues

Five respondents consider that engineering ethics education should include regulatory and legislative issues (L7; L9; L10; L14; L16). Such topics are seen to offer students an "all rounded view of engineering management" (L14).

According to L9, "it would make sense for engineers to know more about protected disclosures and whistle blowing in terms of the legislative part of it." Other topics that engineering students would benefit from are rooted in "the Irish context, which legislation do people want to be covered, for example, and […] how much data protection legislation do they actually need to know." Instructor L9 noticed that within an engineering programme "sometimes you get the law and it is totally separate from the ethics, and I think it needs to be integrated because a lot of the ethical questions are around the edges of the legal questions."

Instructor L10 considers that the inclusion of regulatory and legal issues in engineering ethics education could prompt engineers to take a more active role in policymaking. L10 singles out the medical profession, who "takes a role in advising the governments and in regulating, a much stronger role than the engineering profession has." Given the "massive societal challenges ahead now with climate change," L10 favours the inclusion of regulatory and legal issues in engineering ethics education to prepare "the engineering profession as a whole for stepping up to that. I guess that begins in education." Instructor L6 agrees with the inclusion of regulatory and legal issues in ethics education, such as "environmental directives," the "precautionary principle" and the "polluter pays principle," in order to prepare students to address the problems raised by climate change.

A representative of the accrediting body also mentioned that "ethics is more than plagiarism," advising the evaluation panels for programmes in electronic and electric engineering that "the EU Energy Efficiency Directive is important, but is not well described, so try to see if it surfaces anywhere."

5.3.2 Individualistic microethical scope

Having characterised in the literature review microethical approaches as focusing on the individual perspective of the engineer, the present section aims to explore how the understanding of engineering ethics education, as expressed by participants in the study, falls under this microethical scope.

The interviews with instructors and evaluators revealed three main areas representative the microethical model. These pertain to health and safety, professional codes and ethical theories. In addition to these, one more area has been highlighted during participant observation. Plagiarism has been mentioned by several evaluators and instructors during the accreditation events, although it has not been brought up by any instructor during interviews.

5.3.2.1 Professional codes

Professional codes are the most popular topic understood to fall under engineering ethics education, as twelve instructors introduce them when teaching ethics (L1, L2, L3, L5, L6, L7, L9, L11, L12, L13, L15, L16).

Several instructors emphasized the importance of introducing students to the code of ethics beginning with the first year. Instructor L1 states that “it is worth highlighting to students at an early stage, if they become charter members of Engineers Ireland or members of any of the institution, what they are actually agreeing to do.” Instructor L2 agrees with this approach, noting that “we give them the code of ethics from the Engineers Ireland, even from the first year they get a copy. So we are trying to tell them the criteria for just being a good engineer.”

Although the code of ethics of Engineers Ireland is presented by all 12 instructors, three of them also mention including other professional codes, such as the Code of the American Society of Civil Engineers. Describing his approach, L6 notes that he includes

> codes of practice of ethics. I do the Irish Engineers Ireland code as well as the American Society of Civil Engineers code, just to show that they have a lot in common. There are some differences but they have a lot in common. […] What I have tried to give students is a view on what the situation is in a number of different countries, so they are not exclusively based on the way the codes are formulated in Ireland, because we expect them to be able to work anywhere in the world.

While the motivation named by L6 for introducing students to both an Irish and American code of ethics is cast in terms of the globalization of the engineering workplace, L16 introduces students to various codes in order to frame concrete examples of improper practice and engineering failure. In the words of L16, she introduced

> Engineers Ireland's code of practice and also the eight canons of the American Society of Civil Engineers, and we use these to understand and to discuss things that might be really high profile engineering failures, that might violate two different aspects of the code of ethics or where there was fundamentally a lack of understanding.

For a similar reason to L16, instructor L13 introduces "codes of ethics from various professional bodies and how they pertain to do the work that they are doing."

Instructor L15 addresses the rationale of having a code of ethics to guide engineers' work, stating that he includes "the more pertinent aspects of Engineers Ireland code, and why Engineers Ireland presents what it presents and why it does what it does, why it exists." Instructor L5 is "looking at the Code of ethics from the point of view of money," adding that "it is my view that the Engineers Ireland code of ethics is actually quite weak in this area." Given the weaknesses of the code, students are introduced to L5's "particular version of how ethics applies in this area."

Instructor L9 looks at the Engineers Ireland code of ethics through the lens of "the ethical governance of the profession." The approach described by L9 starts with "the ethics code and this is what your profession says. Those are the things your profession wants you to be aware of and those are their concerns, and that is what it means in practice." The code is also seen as facilitating students' understanding of the "concepts or ideas behind it, such as responsibility or accountability or sustainability and client management and consent and then transparency.

Instructor L3, while including codes of ethics, also noticed that student reception is oftentimes problematic, as codes are regarded as irrelevant. As L3 notes, “I try to bring in the Engineers Ireland code of ethics as well. But the problem is that many of our students are not members, and do not see it as relevant in their careers.”

5.3.2.2 Health and Safety

Six participants consider that health and safety is a topic that should be included in engineering ethics education (L2; L6; L9; L10; L11; L13). Instructor L16 understands this topic in terms of “putting appropriate safety measures in place and risk assessment,” while instructor L11 emphasizes the “focus on issues around safety and design, on quality control.” Instructor L13 introduces the example of the use of robots in agriculture in order to prompt students to consider “what do we need to be aware of in terms of what can happen and what are the safety implications.” One instructor explicitly mentioned that health and safety coverage by itself is insufficient. Instructor L9 considers that ethics is “not all health and safety, there are other things as well.”

The topic of health and safety attracted different opinions on its connection (or lack thereof) to engineering ethics education. While for L10, ethics “of course” includes health and safety considerations, 3 respondents expressed a lack of clarity towards the interpretation of health and safety as falling under the scope of ethics. Instructor L5 admits that until the members of an accreditation panel pointed out that health and safety represents ethical coverage, there was an institutional lack of awareness of this fact. Instructor L5 explains how

> it was pointed out to us by a preliminary review panel that whenever you are talking about safety issues you are addressing ethical matters. Therefore evidence of an example that covers the topic of safety also addresses the issue of ethics because it is tied into it, and we had not appreciated that fact until that point.

One of the evaluators interviewed also expressed doubts whether health and safety coverage falls under ethics. In this regards, evaluator E2 states that "I am not sure exactly if safety may not be under the category of ethics." Instructor L2 views the coverage on health and safety alongside ethics, but nevertheless different from it, considering that ethics "is in there along with communication, teamwork, universal design, health and safety."

The accreditation visits placed a high emphasis on the integration of health and safety issues. First, the campus visit for all three institutions highlighted the health and safety measures and facilities put in place. Second, for all three accreditation events, during the meeting with students, the members of the evaluation panel enquired about the health and safety training received. Third, when asked about ethics coverage in specific modules or in the programme, health and safety was often the topic area brought up by members of the academic teams in all three institutions. For example, when the representative of the accrediting body enquired whether ethics features as a chapter of the final project for the programmes of Uni F, the response of an instructor emphasized that "what immediately comes to mind is health and safety, and we cover this in every lab." In a similar manner, when the chair of the accreditation panel asked the academic team of Uni C how ethics is addressed, the response focused on the coverage of "codes of ethics, health and safety. What students do is not particularly dangerous, but later there is a course where machines could hurt them." During the accreditation event of the programmes offered by Uni E, evaluator E12 pointed out to the academic panel that the presence of outcome E "is very week, especially in the module of professional formation."[22] The response of an instructor showed a similar interpretation of the engineering ethics in terms of health and safety, stating that "outcomes E, F and G

[22] The specific name of the module has been replaced with its general category.

are lightly touched upon, and clearly we will not be hitting health and safety as much as problem solving."

5.3.2.3 Ethical theories

Seven instructors mentioned ethical theories as falling under the scope of engineering ethics education (L1; L2; L4; L6; L7; L11; L15). One instructor mentions explicitly that she doubts the role of this topic in engineering ethics education (L9), stating that "I am not going to talk to you about Kant and Aristotle," because "that is not going to do anything, and there is nothing that is totally universal."

Instructor L6 describes the approach of engineering ethics through ethical theories, noting the inclusion of issues such as

> morality versus ethics. Also environmental ethics, and in relation to environmental ethics, we look at a number of different ways of thinking about it, the Western thinking, but there are also others approaches to looking at it which we explain. […] The extensionist approach, that the moral community includes creatures. […] Then the biocentric view, which includes everything in the Earth's community, recognizing that organisms are interrelated.

Instructor L15 describes the inclusion of

> various theories that have been proposed, both grounded in religion and in philosophy, and how they are applied in various disciplines, but then more specifically within engineering itself, and what the rationale is in applying ethics and ethical behaviour within engineering.

Instructor L2 mentions under the scope of engineering ethics education

> the likes of Aristotle, Kant and the univers..[n.m tries to find the word] what's the one? the universitality and all the universal rules. That is all brought in. And John Locke and the moral frameworks, and Immanuel Kant is there, usually all the different types of ethics, rights ethics, duty ethics, utilitarian ethics, virtue ethics, the different moral frameworks and the pros and cons of each of them. And to say that there is no single framework that can help address all ethical issues, so you need a combination, basically.

Instructor L1 introduces ethical theories by

> talking about the different, I cannot think what the right words were, Ulitarian, that definition of them, what are they again, the types of ethical decisions and that that is not what is important, what is important is actually having that discussion where there is an ethical dilemma.

Instructor L4 notes that while “a small amount on ethical theories” is covered in the module, he considers that “I am not qualified to teach that, there is not enough time to cover it, and also they may not be particularly interested.”

It is notable the challenge in teaching this topic pointed out by instructor L4, rooted in the lack of expertise of faculty with a technical background. L4 is not the only one who admits struggling with the preparation and teaching of ethical theories. Instructor L1 describes struggling in her first year teaching ethical theory, as she “just went with what I was given and it was very much just talking to the students and telling them these are the facts and I have read a few things about them.” Instructor L2 prepares for teaching content related to ethical theories by watching and referring to the TV series The Good Place and videos on ethics posted on Youtube. L12 describes her preparation process, and notes:

> for trying to explain what the theories are, I have used the Good Place, […] and actually somebody in an American University has given very short little videos on the ethics element of the Good Place and how it relates to the different philosophers, Kant and utilitarianism and rights and all the rest. And I found them very useful, because it was somebody, an academic, taking what was in the Good Place and distilling it down into an ethical snippet. So I have used those when I have taught ethics. […] The Good Place helped. So I did not get to read some of the philosophy books. They are a bit heavy going, so I use web resources mainly. The books were a bit too high level for me. […] I try to distil down the theories to students. They just need the edited version.

No other topic falling under engineering ethics education has been described as being particularly challenging to grasp, as is the case with ethical theories. One possible explanation could be related to the demographic characteristics of those interviewed, who were educated during a time when ethics was not a mandatory requirement in the engineering curricula.

5.3.2.4 Plagiarism

Although plagiarism has not been mentioned by any of the instructors interviewed in connection to ethics education, participant observation at accreditation events revealed a strong understanding of ethics in terms of plagiarism. During each of the three accreditation events there were questions asked by the members of the evaluation panels about plagiarism instruction, the detection software used, as well as the measures adopted for preventing and dealing with plagiarism. Evaluators have searched for evidence that plagiarism has been presented to students in connection to outcome E. Evaluator E10, for example, informed the rest of the panel that he "will ask how they deal with plagiarism," as "there is no mention here" in the evidence provided by the programme. The representative of the accreditation body also asked the academic panel whether the "programme has problems with plagiarism." When asked about how ethics is included in capstone projects, a member of the academic team of Uni C1 responded that "plagiarism is a common topic." Members of the academic panel also volunteered information about plagiarism when enquired about ethics education. A representative of Uni F mentioned that "we encourage the ethos of honesty, which can be found in smaller quantity and sprinkled throughout the programme."

5.3.3 Value sensitive design

As mentioned in the previous section, five instructors include in their teaching aspects related to value sensitive design (L3; L4; L8; L10; L15). Value sensitive design is rendered to students in terms of considerations about universal design (L4) and ergonomical design (L3), by inviting students to reflect on values inscribed in the development of engineering artefacts at the design stage. Although L12 admitted he does not teach about value sensitive design, he is aware that "some people bring it into their design work," coming across this approach during his experience as an accreditation evaluator.

5.4 What are the goals of engineering ethics education?

Having examined the views on the coverage that falls under engineering ethics education, I proceed by exploring the goals used in ethics instruction. The analysis focuses first on the goals of engineering ethics education set by instructors, before analysing the goals set at the programme level.

5.4.1 Instruction goals according to instructors

The goals envisioned for engineering ethics education convey a broad spectrum of concerns. There are a multitude of goals mentioned by the instructors interviewed, which cover both the microethical and macroethical approaches, as seen in Table 11.

Table 11. Goals of engineering ethics education (n=16 instructors)

The goal of engineering ethics education is..	**Respondents**
Foster responsibility	14
Enable agency and empowerment	9
Develop broad and (self)critical thinkers	9
Appreciation of the importance of ethics	7
Encourage perspective taking	7
Uphold professional standards	6
Recognize and solve ethical dilemmas	6
Encourage value based design	5
Gain knowledge of formal definitions, ethical theories and vocabulary	4
Appreciation of the broader context of engineering	3
Deal with complexity in a globalized world	3
Knowledge and appreciation of financial aspects in engineering practice	1

5.4.1.1 Foster responsibility

Making students aware of their responsibility towards society and the environment is the prevalent goal set by educators teaching engineering ethics. It is mentioned by fourteen participants (L1; L3; L5; L6; L7; L8; L9; L10; L11; L12; L13; L14; L15; L16). Instructor L6 also includes “other creatures” as part of “the moral community” engineers are responsible for. Responsibility is associated by four instructors (L1, L3, L5, L7, L10, L11, L12) with reflection on the consequences of engineers' decision-making. As instructor L7 explains, "decisions sometimes may affect people or organizations in a negative way, if those decisions not follow the ethical standards."

Professional codes are a popular instructional tool to make students aware of their responsibilities and the importance of meetings them. Nine participants make appeal to professional codes (L1; L3; L5; L6; L7; L9; L10; L12; L16), while one instructor also presents "multiple viewpoints of responsibility for the environment, not just the Western world, [..] Eastern beliefs like Buddhism and Native American Indian beliefs" (L6). The appeal to codes is explained by instructors L1 and L9 as offering legitimacy and "credibility" in front of students to ethical endeavours. As L1 explains, engineers have "an obligation to the society that you do not do cowboy building. And I would have assumed that was obvious, but it is worth having it on paper."

Pointing to disciplinary differences, L13 considers that some engineering disciplines are more prone than others to emphasize to their students the social impact of engineering practice. According to L13, students who

> go to work for any of the utility companies, where the impact of the work in electrical engineering has a direct bearing on public safety, are going to have a higher level of consciousness about ethical approaches to practicing their craft rather than somebody who is for example designing a component that goes into a product where they will never ever see the end product, they are only going to contribute to a minor component.

5.4.1.2 Uphold professional standards

Closely connected to the previous goal of making students aware of their responsibilities as engineers, another goal of ethics education is that of prompting students to uphold the standards of the profession. This goal was mentioned by six instructors (L1, L2, L7; L11; L12; L14). Instructor L2 considers ethics to be "a criterion for being a good engineer […]

because it is part of the requirements to become a chartered engineer.” For L11, it is important that students understand the commitments and role of the profession as a whole. According to L11, "there are a set of professional commitments that have an ethical framework, imbued within them, and you must understand these commitments when you sign up to a profession, whose integrity and values you too must embrace and express.” Instructors L1 and L2 understand this goal as being closely connected to how engineers exercise their profession according to their expertise. L1 explains that “if they become chartered members of Engineers Ireland or of any other institution, what they are actually agreeing to do includes saying that you are not doing work you are not qualified to.” For L12, ethics education should make students “aware that Engineers Ireland have a code of ethics, and that they have to follow that when they go and work in real life.” Instructor L14 talks about the goals of ethics in the context of “re-establishing trust in the profession” following the economic crash, by encouraging students to follow the statements of the Engineers Ireland code of ethics.

5.4.1.3 Enable agency and empowerment

Nine respondents mention as a goal of ethics education empowering students to pursue moral decisions (L1; L3; L8; L9; L10; L11; L13; L14; L16). In this sense, ethics education should prepare students for potential constricting factors rooted in the dynamics and organizational culture of the workplace. This goal is in line with Conlon and Zandvoort (2011), and also with the opinion expressed by participants at a workshop organized by the National Academies of Engineering, according to whom “a major goal of ethics education is to encourage faculty and students to question the decisions, practices, and processes around them so they can make better informed decisions” (National Academies of Engineering 2009, p.11).

For instructor L11, this is an important goal given that an engineer's moral values might be different from their employer's aims. As such, L11 considers that engineering ethics education should make students aware of "the possibility that the intentions of the organizations that we work for may clash with both our professional commitments and our personal commitments." According to L11, students need to be prepared for "engaging in those difficult moments when there are clashes and conflicts," which means being "open and ready to engage in a critical reflection on the kinds of decisions that we want to make and how we want to act."

Instructor L9 frames this goal in terms of enhancing agency and responsibility, stating that the awareness that situations encountered by engineers are "not all black and white, and you have agency and responsibility in those spaces in between […] should be included in the education of our students." The challenge of exercising agency is explained by L11 as due to the fact that in the engineering workplace "there are a set of obstacles in place, there are always obstacles and opportunities when it comes to making the ethical decision, and then actualizing that decision-making in the environment that you are in."

This challenge is compounded by the junior position occupied by recent graduates. Instructor L3 considers that her "main aim" as an ethics instructor is to make students realise that "regardless of how junior they are in an organization, they have moral responsibility within that level, and to get them to think about the effects of their actions and decisions." Instructor L16 shares this opinion, stating that the goal of ethics education is for students "to be able to challenge why things might not be going right or how things could be done better and how they can come up with more sustainable and better solutions even outside of the field of environmental engineering." Instructor L1 also aims to pass on to students the message that they should not be "just saying yes to something because someone has asked you to do it," highlighting also the pressure put on them in situations when they are a junior member of an engineering team. For L11, ethics education should give students the "courage to know that they are in the right and when they are in doubt to speak up," as to pursue their "duty as an engineer to voice concerns about a situation." According to L11, "especially as a young engineer, that is one of the biggest issues."

Referring to the whistleblowing example of the *Challenger* disaster, L9 considers that "everybody said I would not have done it," and ethics education can show "the dynamics behind it, how the reality of doing things in practice can be much more difficult than thinking 'I know what is right', that *de facto* your professional practice is determined by a number of constraints." In connection to considerations made about the constricting force of the context of engineering practice, where students "are going to face companies with all sorts of different cultures," L14 describes the goal of engineering ethics education as leading students to take a proactive stance in addressing it. According to L14,

> rather than just accept what is being dictated, which can often be dictated to them either directly or indirectly, where it is kind of known you do not challenge this or that, we would like them to be stand up as needs be or ideally in a kind of a positive proactive way to say 'look, here is an ethical dilemma. This is something we need to do about it', rather than just accept it.

5.4.1.4 Develop broad and (self)critical thinkers

Nine participants highlight the role of engineering ethics education in developing "broader" thinking and "critical" thinking (L1; L4; L8; L9; L10; L11; L12; L13; L16).

Instructor L12 offers the most detailed explanation about the significance of developing critical thinking in students through engineering ethics instruction. L12 states that the goal of ethics teaching is

> to make people stop and reflect on what are the implications for building a new road or for even putting a new product on the market. How will this device affect some other aspect?. […] To make people aware that there is more to life than just numbers and stress and forces and engineering numbers. That there is a wider picture with a wider group and community that would be affected by the work of engineers.

Similarly, L16 hopes that students will start “thinking about the wider context, which might mean that a good technical solution is not the best solution.” According to L4, engineering ethics education should prompt students “to look at questions, to think about them, to question everything. As an engineer you need to be able to question things. The more they question, the better they are going to be,” adding that “in terms of the ethics, the main thing I would like them to do is to actually question things.” Instructor L8 also aims to “get students think more broadly, develop skills such as critical thinking, so they can look at given situations not just from a utilitarian perspective.” Similarly, L9 considers that “what can be done is to make students think a bit, to make them have a few doubts, potentially doubts about themselves,” while L10 would “like to see something strong that encourages engineering students to be independent thinkers.” Instructor L11 places critical reflection at the core of engineering ethics education, stating that “for me, ethics is always about critical reflection and having the tools to engage in that critical reflection.” Instructor L13 describes the aspirations set for engineering ethics instruction, highlighting that “my hope is that they are broader thinkers, that they do not just think in a narrow way, that they think more widely and more deeply about what they are doing and why they are doing it.” Similarly, L1 considers that ethics education should foster the “critical thinking side of things and being critical of their answers and the implications of 'if you do not look at this and know this and know how to predict how a structure can behave, you are going to have issues on site'.” Nevertheless, L1 considers that critical thinking is “not specifically ethics,” but “that focus was for me a fundamental thing they needed to learn in order to grow into the real world.”

5.4.1.5 Appreciation of the importance of ethics in engineering practice

Seven participants aim for ethics education to give students an appreciation of the importance of ethics in engineering practice (L6; L7; L8; L11; L13; L16). Instructor L13 hopes “to sensitize people to what ethics is,” while L16 aims to enable students “to develop an appetite and an interest in environmental engineering.”

For instructor L7, “my expectation was that the students would realize by the end of the module that ethics is very important,” while L8 wants students “to see that ethics is not just something that is an add-on to an engineering programme, but actually is fundamental to their education as engineers.” Instructor L11 considers that the role of ethics education is that of “convincing an engineering student or a nurse or a doctor that in fact they need to put ethical decision-making and ethics in the armoury of their personal and professional sphere.” Instructor L10 explains that he “would like for them to appreciate that engineering is an ethical activity. It does not exist in isolation from normal human life with all its ethical aspects. So it is an ethical activity for positive or negative outcomes. That it is complicated, that everything they do has a potentially ethical dimension.”

5.4.1.6 Encourage perspective taking

Seven participants consider that one of the aims of engineering ethics education is to encourage students to explore difference in perspective (L1, L4; L6; L8; L9; L11; L16). This goal presupposes taking into consideration the needs and values of different categories of users for the artefacts developed by engineers, interacting with the public and team members holding opposing views. This goal resonates with one of the goals mentioned by Haws (2001) of enhancing the divergent thinking of students, more specifically, understanding situations from other stakeholders’ points of view.

For example, L6 hopes to make students aware of the diversity in views rooted in different cultural backgrounds. L6 aims to place the views of other cultures on the same par with the western centric view. As such, L6 considers that “regardless of the students’ own background they must be able to appreciate that other communities in other parts of the world may have different ways of looking at the relationship between the environment and our own responsibilities to it. There are multiple viewpoints of responsibility for the environment, not just the Western world, that our students should be made aware of it."

Engineering ethics education should prepare students to address different viewpoints, whether within their own team or the community. Instructor L9 aims to make students aware that "there are different values that people hold, and just because I believe in one thing does not mean everybody needs to agree with it." Instructor L1 wants students to "debate what routes different people take and why they take different approaches to the same problem."

Three instructors consider it is important to prompt students to take into account the concerns that members of the community have in regards to the artefacts and projects developed by engineers. Issues such as climate change are considered to be particularly divisive as to what the best solution is. In regards to climate change, L6 highlights that "the debate and the public is becoming more and more polarized. Engineers have to work in that environment, so they have to be aware of it, even if some of the extreme views are not consistent with the engineers' own beliefs." In a similar spirit, L8 wants engineering ethics education to prepare students to be "dealing with the public and to equip them to be able to do that better." This means that students should develop "a toolset and skill set to work with local communities and develop projects from the bottom up, as well as from the top down." Instructor L11 agrees that the goal of engineering ethics education is "to encourage the kind of feedback that you need to get from the community that you are a member of, when that community will have more information than you about how the environment is structured, within which ethical decision-making is possible or not possible or hindered or encouraged."

5.4.1.7 Recognition of ethical dilemmas

Six participants mention the recognition of ethical dilemmas as a goal of engineering ethics education (L1; L2; L3; L6; L10; L14).

Instructor L14 states that the aim is for students "to be conscious of ethics and to be able to make very informed decisions about their own behaviour when they are faced with ethical dilemmas." Instructor L1 considers that "what is important is actually having a discussion where there is a dilemma," which can be facilitated by "having real scenarios where students can see the actual real life dilemma. You do not want to hurt people, you do not want them to lose their job, but then there are the obligations of your industry, and what way is taken." Instructor L6 wants students to think that dilemmas "apply to their practice" and "see how situations can actually happen in their practice that give rise to having to make ethical decisions." Instructor L2 places dilemmas at the core of engineering ethics instruction, stating that "the horns of the dilemma was the origin of ethics. It is very difficult, no matter which one you pick, you are in trouble." The main dilemma used by L2 when teaching ethics relates to whistleblowing, which is seen to be "kind of linked to ethics," and is meant to familiarise students with reasoning "in an engineering situation where they come across something that is not quite right. Should they report it or they should not? And that is an ethical decision." Instructor L3 wants to expose students to "the more obscure types of ethical dilemmas that they might face," such as "conflict of interests or influencing a tender."

5.4.1.8 Encourage value sensitive design

Five participants mention that the goal of ethics education is to encourage students to think ethically during the design stage (L3; L4; L8; L10; L15). Instructor L3 hopes that engineering students come to realize that

> designing for manufacture is actually, in part, an ethical consideration, because they are saving on materials or saving on time, saving on wastage. Using recyclable

> materials is actually an ethical decision. The ergonomics of how a product is used is an ethical decision, because you are looking after the welfare of users.

Instructor L15 considers that "by thinking ethically and responsibly," students can "focus the design down to a smaller subset of designs, because you would reject some certain designs or solutions because they do not fit into your mode of thinking as an ethical engineer, or as somebody who is concerned with safety or responsible engineering."

The goal is addressed through lectures and report assignments, rather than in projects. As such, instructor L10 presents the characteristics of universal design, while L8 brings the example of self-driving cars in order to make students aware that "a value based decision prevails" when engineers "incorporate new technologies, and […] if there is a basically foreseeable risk, we would reduce risk."

5.4.1.9 Gain knowledge of formal definitions, ethical theories and vocabulary

Four respondents consider that the goal of ethics education is for students to gain knowledge of formal definitions, ethical theories and vocabulary. (L2; L8; L9; L12)

In this regard, instructor L12 "would like to get them some formal consideration of issues, formal definitions," while instructor L9 "would have hoped that they understand the vocabulary, as understood by the profession." Instructor L8 wants students "to be able to take some of the things that they are exposed to and then to try to put an ethical framework on different situations and look at the broader macro ethical issues particularly, which relate to both the professional practice, bodies, and also practice within organizations and within society." Instructor L2 aims to familiarize students with the different ethical frameworks, but also convey the message "that there is no single framework that can help address all ethical issues, so you need a combination."

5.4.1.10 Appreciation of the broader context of engineering

Three participants aim for ethics education to offer students an appreciation of the broader context of engineering practice (L8, L10, L12). In this regard, L8 wants students to "gain an appreciation of what ethics is in the broad sense, something that goes beyond the microethical moralistic approach." Instructor L10 "would like for them to appreciate that engineering is an ethical activity. It does not exist in isolation from normal human life with all its ethical aspects. Instructor L12 hopes to convey to students that "there is a wider picture with a wider group and community that would be affected by the work of engineers."

5.4.1.11 Deal with complexity of today's world

Two participants consider that the role of ethics education is to enable students to deal with complexity of today's world (L; L7; L9). L9 states that the aim is for students "to have some sense of the real complexities" of engineering practice. For instructors L6 and L7, complexity is understood as one of the ramifications of globalization. Instructor L7 gives the example of expanding networks for global supply chains that presuppose "complicated relations" and "many different rules and legislation." According to L7, "this is where ethics come into place, when regulations policies and the law are complex." For instructor L6, globalization means that students have to learn how adapt to the values of different cultures. This means to be "aware of ethical situations, [..] on what the situation is in a number of different countries, so they are not exclusively based on the way the codes are formulated in Ireland because we expect them to be able to work anywhere in the world."

5.4.1.12 Knowledge and appreciation of role of financial aspects in engineering practice

One instructor described the approach to ethics solely through the prism of the financial considerations involved in engineering. As such, for L5, the goal of ethics education is to make students aware that "everything they do has a financial value. Secondly that they have an ethical responsibility to minimise their consumption of resources and that the responsibility still exists even if they own the business due to the potential consequences for employees, customers and suppliers."

5.4.2 Institutional goals related to engineering ethics education

After analysing the main goals related to ethics set by individual instructors, we are now turning the attention to the goals set at institutional level, according to the description provided in the documentation submitted for accreditation. These goals are seen to capture the educational mission of an engineering programme, given their direct influence on the curriculum and the core educational values pursued (Bielefeldt *et al.,* 2019). The analysis is conducted at institutional rather than at programme level, given that programmes within the same institution formulate their goals broadly in similar terms, and some institutions participate in the study with only one programme and other institutions with more than four programmes. If the analysis would have been conducted at programme level, calculating goals per programme might have led to a misleading picture.

Table 12 shows that there are two main institutional goals set in connection to engineering ethics education that the majority of participants agree on, two goals shared by two institutions, and four goals set only by one institution.

Table 12. Institutional aims related to engineering ethics education (n= 6 institutions)

Programme goals	**Institutions**
Awareness of impact of engineering practice	Iot A; Iot B; Uni C; Uni D; Uni E; Uni F
Uphold professional standards	Iot A; Iot B; Uni C; Uni D; Uni F
Knowledge of the regulation and organization of the profession	Iot B; Uni C
Develop a holistic engineer	Iot A; Uni C
Customer and user orientation	Iot B
Compliance with existing legislation	Iot B
Personal development	Uni F

5.4.2.1 Develop awareness of impact of ethics in engineering practice

All institutions have explicitly included the goal of making students aware of the societal and environmental impact of engineering practice. Iot A aims to deliver graduates with a "discernment of the impact of engineering on society and the environment." Iot B wants its graduates to be "competent and proactive in the areas of safety, health and the environment," as well as to "have an appreciation of the necessity of national and global sustainable development." Additionally, Iot B aims for its graduates to "have a high awareness of the position of professional engineers in society and of the social and environmental implications of technological decisions." According to Uni C, its graduates should be "critically aware of the impact of technological developments on society." For Uni D, graduates should be "environmentally aware," while for Uni E, graduates should "become aware of social and ethical implications in their professional work." Uni E states among its goals that graduates show "an appreciation of professional and ethical responsibility" and to "develop an understanding of the professional responsibilities of engineers, such as ethical standards, health and safety, risk management, environmental and societal impact."

5.4.2.2 Uphold professional standards

The second most popular goal, stated by all but one participant institution, is fostering the adoption of professional standards. This is understood by Iot A as "knowledge and respect of ethics and ethical standards." Iot B aims for its graduates to "develop and maintain high ethical standards" and "to engage in personal development to meet the responsibilities required as members of Engineers Ireland and other professional learned bodies." Uni C states as its programme goal that graduates should "embody the professional qualities of discipline, discrimination and application." Uni D states that

> we subscribe fully to the code of ethics of Engineers Ireland and ensure that the education we provide is based on these and in particular: in dealing with others behave with integrity, objectivity and respect their dignity, carry out work with due care, skill and diligence, strive to develop their professional knowledge, skill and expertise throughout their careers.

The goal of programme Uni F is to "promote the adoption of high ethical standards in the practice of engineering, including the notion of community service and volunteerism."

5.4.2.3 Knowledge of the regulation and organization of the profession

Two institutions state a goal related to raising awareness of how the profession of engineering is regulated and organized. As such, Uni C states that graduates should "understand the structure and organisation of industry," while Iot B aims for its graduates to "have a high awareness of the position of professional engineers in society" and to "understand the critical role of management structures, finance and industrial relations within organisations.

5.4.2.4 Foster holistic engineers

Developing holistic engineers is the goal set by two institutions. For Iot A, this goal means to "focus on the holistic engineer, where being socially, globally, economically and environmentally aware complements solid mechanical foundations and analytical skills" and to "educate students in the multidisciplinary nature of engineering practice, including the interaction between the technological, business, and management functions." More so, the graduates of institution Iot A should develop a social and cultural outlook, by showing "an appreciation of the philosophical and social contexts of a discipline." The institution Uni C interprets this goal as producing graduates "who are technically competent, environmentally aware, and ethical, professional engineers."

5.4.2.5 Compliance with existing legislation

One institution states explicitly as a programme goal developing graduates that comply with existing legislation. Institution Iot B aims for its graduates to "recognise the need for engineers to comply with Codes of Ethics, safety policies and EU directives, in order allow them engage in engineering activities in such a way that contributes to sustainable development."

5.4.2.6 Customer and user orientation

In the document submitted for accreditation, the institution Iot B mentioned explicitly in connection to outcome E the goal of developing graduates that are aware of the characteristics and needs of customers. According to Iot B, its graduates should "apply appropriate software tools and basic design methodologies, to design customer focused product and processes" as well as to "apply World Class production system methodologies and managerial strategies to support the effective development, planning and continuous improvement of lean, agile and customer focused manufacturing enterprises."

5.4.2.7 Personal development

One institution mentions personal development among its graduate programme outcomes. As such, institution Uni F aims to develop a "focus on personal development, embedded in modules across all five years, in ethics, social responsibility, communication."

5.5 Key findings

The literature survey revealed a diversity of goals and a wide set of topics used in engineering ethics education. These are representative of the microethical and macroethical approaches, as well as virtue ethics and value sensitive design. According to Hess and Fore (2018), there are multiple definitions of ethics in engineering education literature, and no consensus as to how engineering ethics should be conceptualized.

The study confirms the existence of a varied and uneven understanding of engineering ethics education both at the individual and programme level, in terms of defining engineering ethics education, as well as setting the goals and scope of instruction.

The study found that engineering ethics is preponderantly defined through its connection to engineering practice, rather than in its theoretical dimension. As Godfrey and Parker (2010, p.10) remark, “abstract, philosophical concepts, such as ethics and sustainability were unacceptable to both faculty and students unless taught in a practical, relevant context.” Participants reported a low engagement with ethical theories, with learning goals seldom targeting the development of theoretical knowledge about ethics in the form of knowledge of formal definitions, ethical theories and vocabulary, supporting the findings of Hess and Fore (2018; 2020).

According to participants, engineering ethics is considered to come into play when decision-making in complex situations is required. The emphasis on the embeddedness of ethical decision-making in contexts of practice that require careful deliberation and critical reflection points to the importance of developing the intellectual virtue of *phronesis*, as suggested by virtue ethics theories (Davis, 2012, Schmidt, 2014; Nair & Bulleit, 2020). In line with the precepts of virtue ethics, character development has been revealed in the present study as an important goal of engineering ethics education. Besides *phronesis*, other virtues that instructors aim to foster through engineering ethics education are discipline, courage and empathy.

The study found a diverse range of goals set in engineering ethics education. While instructors emphasize goals related to fostering responsibility, enabling agency and developing broad and critical thinkers, programmes highlight developing awareness of the impact of engineering practice and upholding professional standards. The goals set by the instructors can be characterised as being directed at the engineer herself, while the goals most common at programme level regard the engineer as an employee and member of a professional organization or institution. There is a marked preference for using professional codes in order to meet the goals associated with fostering responsibility and upholding professional standards.

The goals formulated by instructors point to a macroethical concern with broadening the scope of ethics education within engineering programmes, in order to encompass societal considerations and reflection on how to tackle some of the pressing contemporary challenges. Similar to the observations made by Herkert (2006) and Conlon and Zandvoort (2011), the instructors interviewed consider that sustainability could provide a focus for broadening the engineering curriculum and integrating ethics and STS.

The study also showed that while instructors aim to familiarize students with value based design, it has lesser prominence compared to other aspects deemed to fall under outcome E. This finding can be explained in light of the nature of the category of modules taught by the instructors interviewed, given that design and experimental projects rarely feature in modules of professional formation. Self-driving cars are a popular topic employed to encourage students to reflect on the values inscribed in technological artefacts at the design stage. Other theoretical aspects presented to students through the lens of value based design are related to the importance of considering universal and ergonomic design features in engineering projects.

Finally, it is notable that the study encountered disagreement and confusion as to what counts as engineering ethics education. Educators have expressed conflicting views and lack of clarity in regards to whether topics such as sustainability and safety fall under the scope of engineering ethics education. Reed *et al.* (2004) have similarly encountered situations when ethics has been incorporated without the awareness that ethical content has been touched upon.

Having established the theoretical conceptualisation of engineering ethics, as well as the main goals set for engineering ethics education, the enquiry will now focus on their translation at the level of practice. As such, while the focus of the current chapter was on aspirational matters regarding the delivery of ethics, the following chapters aim to explore its actual delivery. As such, Chapter 6 examines the implementation of ethics in the engineering curriculum, while Chapters 7 and 8 present the prevalent teaching method and topics used for conveying ethical content.

CHAPTER 6 THE IMPLEMENTATION OF ETHICS IN ENGINEERING PROGRAMMES IN IRELAND

This chapter contributes to objectives 5 and 6 described in the research design chapter. After describing the research methods employed, the weight given to ethics in the curriculum of engineering Honours programmes in Ireland is examined, followed by an analysis of the methods for implementing ethics in the engineering curricula.

6.1 Methods

Three research methods have been employed to achieve the aims that are the subject of the present chapter. First, a simple statistical analysis was employed. The statistical analysis was based on a rubric present in each document submitted for accreditation, whereby the participant programmes are required to self-assess how the learning outcomes for each of their modules meet the seven programme outcomes required for accreditation. Only mandatory modules have been considered. Second, a document analysis of the documents submitted for accreditation was undertaken. It was based on a rubric where programmes describe how they aim to implement the seven programme outcomes. Third, interviews explored the instructors and evaluators' views on the presence of ethics in the engineering curricula.

The use of mixed methods allowed an examination on the implementation of ethics from two perspectives. On one hand, there is the programmes' perspective on how it considers to implement outcome E, rendered in the programme documents and the POLO rubric. On the other hand, there is an external reflection on how the programmes implement ethics, based on the views expressed by instructors who are familiar with the academic practices within the respective programmes, as well as the views of the members of accreditation panels.

As stated in Chapter 4, an important tool that allowed to determine the weight given to ethics is the self-assessment rubric present in the documentation submitted by the programmes for accreditation. The rubric recommended by the accrediting body contains a 5 point scale, with scores ranging from 0 to 4. These are known as POLO scores and their meaning was previously described in Table 8. The role of the rubric is for the programmes to self-assess how they meet the seven programme outcomes for accreditation presented in Table 9, by assigning a score to their modules based on the learning outcomes achieved. Besides the recommended self-assessment scale of 0-4, which was employed by 13 programmes, other four different scales have been employed by the remaining 10 programmes for the purpose of self-assessment. Table 13 presents the type of self-assessment scales adopted by each participant programme.

As revealed in Table 13, two programmes mapped their contribution to the programme outcomes by using a four point scale consisting of different colour shades. Each shade represents how much a module contributes to the programme outcome, but there is no shade corresponding to a module having no contribution to the programme outcome. For these programmes, the conversion to the 0-4 scale is not possible because of the absence of point 0. Three university programmes mapped the contribution to the programme outcomes in terms of ECTS. As such, each module's contribution to the seven programme outcomes was capped at the number of ECTS required, which was then divided among the different programme outcomes. In a similar manner, one programme mapped the contribution to the programme outcome in terms of percentage, and distributed the equivalent of 100%.

Table 13. Types of self-assessment scales employed by participant programmes (n=23)

Self-assessment scale	Programmes	Can be converted to 0-4 scale
0-4 scale	Iot A1; Iot A2; Iot A3; Iot B1; Iot B2; Iot B3; Iot B4; Iot B5; Uni C1	Yes
0-22 scale	Uni D1; Uni D2; Uni D3; Uni D4	Yes
4 colour map	Uni E2; Uni F2	No (only the conversion to 3-4 is accurate)
ECTS contribution	Uni F1; Uni F4; Uni F5	No
Percentage contribution	Uni F3	No

In addition to the rubric meant to self-assess the contribution of the modules to the programme outcomes, 9 programmes that did not use the recommended 0-4 POLO scale provided a self-assessment of their programme's yearly or overall contribution to the outcomes in terms of percentages. Table 14 shows that nine programmes presented their contribution to the programme outcomes in terms of percentage.

For the remaining 14 programmes, the percentage contribution to each programme outcome had to be calculated based on the scores provided by the programmes. As such, the percentage contribution was calculated by considering the self-assessment score provided by the programmes for each outcome against the sum of all seven programme outcome scores, for each of the 14 programmes. The outcome of this process is a self-assessment measure common to all 23 participant programmes, as seen in Table 14.[23]

[23] The consultation with the expert statistician in our research group ensured that this method of converting the self-assessment scores to percentage contribution allows for a comparison across all participant programmes.

Table 14. Rubrics of self-assessment of learning outcomes provided by the programmes

Programme	Programme used the 0-4 POLO scale	Programme used a self-assessment scale that can be converted to 0-4	Programme provided % contribution to LOs	The programmes' % contribution to LOs can be calculated by the researcher
Iot A1	YES		NO	YES
Iot A2	YES		NO	YES
Iot A3	YES		NO	YES
Iot B1	YES		NO	YES
Iot B2	YES		NO	YES
Iot B3	YES		NO	YES
Iot B4	YES		NO	YES
Iot B5	YES		NO	YES
Uni C1	YES		NO	YES
Uni D1	NO	YES	YES	
Uni D2	NO	YES	NO	YES
Uni D3	NO	YES	YES	
Uni D4	NO	YES	YES	
Uni E1	YES		NO	YES
Uni E2	NO	NO	YES	
Uni E3	YES		NO	YES
Uni E4	YES		NO	YES
Uni E5	YES		NO	YES
Uni F1	NO	NO	YES	
Uni F2	NO	NO	YES	
Uni F3	NO	NO	YES	
Uni F4	NO	NO	YES	
Uni F5	NO	NO	YES	

6.2 What is the weight given to ethics?

The average weight given to ethics in engineering programmes is determined according to the programmes' own assessment, by analysing the average POLO scores for the seven programme outcomes across all participant programmes, as well as the percentage contribution to each programme outcome.

Given that the variety of self-assessment scales employed by the participant programmes prohibits the unanimous conversion to the 0-4 scale, six programmes are excluded from the analysis of the POLO scores. These programmes are Uni E2, as well as all five programmes offered by institution Uni F. Therefore, the average POLO scores for the seven programme outcomes can be calculated based on the data provided by 17 programmes, which are revealed in Table 14.

A major finding reveals the low weight given to ethics in the curriculum of participant programmes, based on their own assessment. According to the numerical analysis of the average POLO scores of the 17 programmes, Table 15 shows that the average score for outcome E is 1.56, on a scale from 0-4. Compared to the average scores of the other programme outcomes, the average for outcome E is the lowest. More so, the overall average for outcome E (1.56) is more than twice lower than the overall average for outcomes A (3.18), representing mathematical, scientific and technical knowledge, and outcome B (3.12), representing problem solving.

Programme outcome E is consistently self-assessed with a low score. In fact, it is the lowest of all programme outcomes for 14 programmes under investigation, while for the other three programmes, the average for outcome E is at a small difference from the lowest scoring outcome, of 0.01, 0.06 and 0.14 respectively. For 11 programmes, the average of outcome E is more than two times lower than the average of programme outcome A. Three of these programmes are offered by institutes of technology (Iot A3, Iot B1, Iot B5) and eight by universities (Uni D1, Uni D2, Uni D3, Uni D4, Uni E1, Uni E3, Uni E4, Uni E5). For one programme offered by a university (Uni C1), the average for outcome E is more than three times lower than the average for outcome *A*.

Considering the top and bottom averages of all outcomes recorded by the participant programmes, Table 15 shows that outcome E has the lowest average considering both the bottom averages and top averages. As such, the top average for programme E is 2.41, while the bottom average is 0.88. This is much lower than the highest scoring outcome, outcome A, which has a top average of 3.74 and a bottom average of 2.06.

Table 15. Bottom and top average recorded for each outcome by programmes (n=17)

Outcome	Average	Bottom Average	Top Average
A (technical and scientific knowledge)	3.18	2.06 (Uni D2)	3.74 (Uni E4)
B (problem-solving)	3.12	1.95 (Uni D2)	3.68 (Uni E4)
C (design)	2.34	1.74 (Uni D2)	2.86 (Uni E3),
D (experimental work)	2.06	0.94 (Uni D4)	2.98 (Uni E3),
E (ethics)	1.56	0.88 (Uni C1)	2.41 (Iot A2)
F (teamwork)	1.94	1.18 (Uni D3)	3.11 (Iot A1),
G (communication)	1.96	1.15 (Uni D4)	2.9 (Iot A1)

Although other accrediting bodies do not use the self-assessment scale recommended by Engineers Ireland, to allow a direct comparison, one Canadian institution has developed a similar instrument with the aim of exploring how much students of the University of Toronto are taught about "contextual" issues, such as "the influence technology has on human life, society and the natural ecology" (Vanderburg & Kahn, 1994). For this, the University of Toronto used a five-point assessment scale to self-assess modules with a score from 0 ("no reference to context issues") to 5 ("substantial reference to context"). Given that the coverage of what Vanderburg and Kahn (1994) call contextual issues would fall under the scope of outcome E set by Engineers Ireland, and a similar scale has been employed to determine its weight in the curriculum of University of Toronto, it is possible to make a comparison.

As in the case of the present study, Vanderburg and Kahn (1994, pp.359-60) found that contextual issues have a low weight in the curriculum of the University of Toronto. As such, the average score for the 50 courses analysed was 0.8, meaning that "most of the courses are contextless, with fewer and fewer courses showing more and more context." The findings led Vanderburg and Kahn (1994, p.360) to conclude that "the overall picture was not reassuring."

The low priority given to ethics in the engineering curriculum was also acknowledged by the instructors and evaluators interviewed. According to instructor L7, "how ethics is addressed is weak, one of the weakest points of every programme." As evaluator E2 confirms, "ethics is way down the priority list" of engineering programmes, with "most subjects probably not covering it." Evaluator E1 strengthens this view, suggesting that ethics "might appear like it is tagged on a bit at the end," and that "the amount of module content dedicated to it would be minimal." Based on personal experience, evaluator E1 concludes that ethics "is not quite an afterthought, but it is probably not given as much importance as maybe it should."

Participant observation revealed that during the accreditation events, evaluators commented on the low weight given to ethics. After analysing evidence in support of ethics for programme Uni F3 for 40 minutes, evaluator E8 concluded that "ethics is quite thin. According to the scores, it should be in the third year, and yet here it is very thin." Commenting on the weight given to ethics within programme Uni C1, E2 tells the other members of the evaluation panel that only two modules cover ethics, and otherwise there is "mostly low scoring." The response of E6 confirms that a low weight given to ethics is common, stating that "this is mostly the case everywhere." During the accreditation event of the programmes of institution Uni E, E11 notes that "outcome E is very weak," while E5 declares that he is "a bit disappointed with how little coverage is in year four."

Having an accreditation criterion dedicated to ethics is considered to have led to an enhanced presence of ethics in engineering programmes. This was considered by evaluator E1 to have represented a "big change," as "we definitely are more considerate of that in our own programme." This opinion is reinforced by instructor L12, who served as an evaluator for 20 years and was on the board of the accrediting body during the introduction of ethics as an accreditation criterion. According to L12, ethics "went from zero. There is no question, it was zero. It was virtually nothing about ethics prior to the year those guidelines came in." Evaluator E6 considers that in the last decade since ethics has been first introduced as a requirement for accreditation, "universities become a lot better at implementing it." Evaluator E3 agrees that this process "is moving slowly," with instructor L14 also holding the view that "there is an increased consciousness by a lot of the colleagues." Instructor L4 describes the increased weight given to ethics in his own institution as a

> direct response to a previous Engineers Ireland review many years ago, when ethics had become the big topic in Engineers Ireland, and no colleges were addressing it directly. So it became an issue at accreditations, and we had to respond.

L4 adds that the change in the education of engineering ethics was the result of "a push from Engineers Ireland. The first two accreditations of a number of programs, which was quite a few years now, 15 years ago, recommended to improve the teaching of ethics throughout the programmes."

While the power exercised by the accrediting body on shaping the engineering curriculum has been credited as a source for the increased weight given to ethics in the past decade, societal characteristics are seen as a force for change when evaluators consider the future of engineering ethics education. An enhanced future emphasis on ethics in the engineering curriculum is seen as a response to growing societal needs in areas such as cybersecurity and data protection (E3; E5) or tackling climate change (E5). The interplay between these two forces for change has been best described by evaluator E5, who declares optimism about the systematic implementation of ethics

> simply because in today's world the ethics programme outcome is more important and it is growing in importance, so I think the educational institutions are just going to have to address this in a more structured way. I honestly do not think it is much more Engineers Ireland can do. And I do not think they should really, because they have taken the lead, but there is no point in overplaying the card. The issue is really so important, particularly with all that is going on in computing and security, that it is just going to have to happen anyway.

Although evaluators agree that the introduction of programme outcome E increased the weight of ethics in the engineering curriculum, there were several opinions suggesting that this increase was not organic. As evaluator E2 considers, ethics is present in the curricula of engineering programmes “mainly just to cover the requirements of Engineers Ireland.” Instructor L8, reflecting on his familiarity with other programmes and personal experience as an evaluator, considers that “a lot of engineering programmes go 'well, we need to do something', so they do something, but it is seen as an add-on.” Evaluator E1 further adds that preparing for an accreditation event is “often the first time we think 'we really need to take ethics seriously, they are coming to evaluate us and we are a bit short’.” More so, L9 adds, ethics is perceived as “kind of an add-on that the professional association wants us to do.” Pointing to the piecemeal implementation of ethics, evaluator E5 highlights the lack of a systematic integration, stating that

> most programmes actually do not deliver it as well as they could deliver it. I think that many institutions still regard it as a sort of just a troublesome programme outcome and they have to go looking 'is there anything that we are doing that actually meets it?', rather than really building it in the design of the programme.

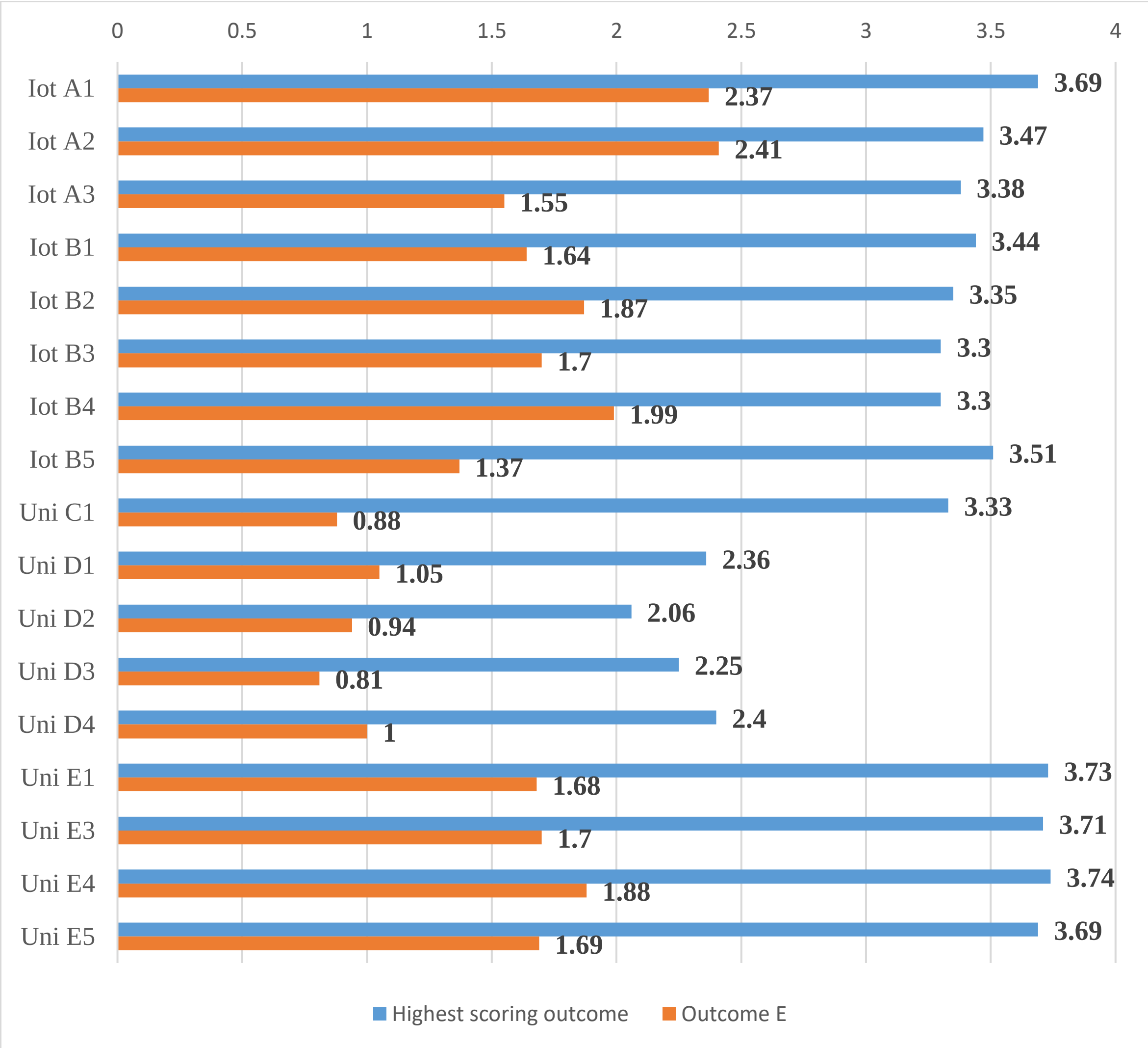
From the perspective of the instructor, L9 reflects that ethics “is very difficult to integrate” in the engineering curriculum “because ethics is often seen as a burden and something just annoying, that a programme has to tick the box, but it does not really matter.” The point raised by L9 reinforces the unsystematic manner in which ethics is being implemented. According to L9, “we are always the ethics work package” which can develop a “general ethics module that you can plug it in everywhere.”

Although the accrediting body had an important role in enhancing the weight given to ethics with the introduction of programme outcome E, ethics does not appear to be yet at the stage where it is implemented in a systematic manner. As instructor L8 remarks,

> Engineering Ireland's defining of outcomes requires that ethics is incorporated in engineering education and that is a good start, but then that has to be defined and elucidated and developed as to what it actually means.

Another notable finding points to the variation in the weight given to programme E in the curriculum of the 17 participant programmes. As shown in Figure 2, the average POLO scores for programme outcome E vary among programmes between a lowest average of 0.88 (Uni C1) and a highest average of 2.41 (Iot A2). The variation among programmes is also manifest when considering the difference between the highest scoring outcome and outcome E. For nine programmes, the difference between the outcome with the biggest weight in the curriculum and outcome E is less than 1.50, while for five programmes, this

Figure 2. Difference between POLO average of highest scoring outcome and outcome E



difference is higher than 2 points on the 1-4 scale. According to Figure 2, the average difference between outcome E and the highest scoring outcome in a programme is 1.58, ranging from 1.06 (Iot A2) to 2.45 (Uni C1). More so, Figure 2 also reveals institutional differences in the weight given to outcome E compared to highest scoring outcomes. While institution Uni D records low self-assessment scores for all outcomes, it also marks a low difference between the highest scoring outcome and outcome E, which falls between 1.12 and 1.40. On the opposite end, institution Uni E has the highest self-assessment scores, and a difference between the highest scoring outcome and outcome E that ranges between 1.86 and 2.05. This seems to suggest that the variation in the implementation of ethics is rooted at institutional level.

The variation between how institutions implement ethics has been noted also by the participants interviewed. Instructor L9, who has experience as an evaluator, has observed that there are “universities where ethics is taken really seriously and universities where it is just a box to tick, where you may have one session covering ethics, and that is all.” Instructor L6, who served as an evaluator at 3 accreditation events, remarked that the programme offered by the home institution was “the only one I have come across that looks at the global aspect of ethics.” Instructor L12, who served as an evaluator “once a year for the last 20 years,” also remarked on the disparity between institutions, with some that “had problems at outcome E.” During the accreditation event of the programmes of institution Uni E, evaluator E12 stated that “every university in Ireland will look differently in terms of covering outcome E.”

There have also been recorded differences when analysing the weight given to ethics in the curricula of programmes belonging to different core branches of engineering. The four core branches of engineering are represented by Civil Engineering, Mechanical Engineering, Electrical and Electronic Engineering and Chemical Engineering (Culligan and Feniosky, 2010; National Academy of Engineering, 2013, p.19; Habash, 2017, p.26). The specializations offered by the participant programmes have been grouped under these main branches and are rendered in Table 16. These disciplinary groupings are based on the subdisciplines considered to fall under each branch and also the specializations offered by the programmes, taking into account that some programmes offer joint specialisations that would not allow to distinguish between the two or three disciplines offered. As such, the disciplinary label “Mechanical Engineering” is represented by seven programmes, offering the specialization Mechanical Engineering, Energy Engineering, Energy Systems Engineering and Manufacturing and Design Engineering. The disciplinary label “Civil Engineering” is represented by five programmes which offer the specialization Civil Engineering, Structural Engineering, Civil, Structural and Environmental Engineering. The disciplinary label “Electrical and Electronic Engineering” is represented by eight programmes offering the specializations Electronic Engineering, Electrical and Electronic Engineering, Electrical Engineering, Electronic and Computer Science Engineering, Electronic and Computer Engineering and Computer Science and Information Technology. The core branch of “Chemical Engineering” is excluded from the analysis given that there is only one representative programme. One programme offering the specialization Biomedical Engineering and one programme offering the specialization Building Services engineering are also excluded given their multidisciplinary nature.

Table 16. Disciplinary averages for programme outcome E

Engineering discipline	**Programmes**	**Avg POLO E**
Mechanical (n=7)	6	1.80
Civil (n=5)	3	1.40
Electrical and Electronic (n=8)	5	1.36

Table 16 shows the average POLO scores for the three core branches of engineering. The lowest overall score averages for programme outcome E are registered for the disciplines of electric and electronic engineering, with an average score of 1.36 for the five programmes that used a self-assessment rubric convertible to the 0-4 POLO scale. This is closely followed by programmes from the discipline of civil engineering, which recorded an average self-assessment score of 1.40. Programmes of Mechanical Engineering have a higher average self-assessment score, of 1.80. The data suggests that the weight of ethics education varies among disciplines, with some discipline more prone to integrate curricular content related to ethics education.

Having looked at the weight given to ethics in the curricula of engineering programmes, the attention is now moved towards the manner in which ethics is being implemented.

6.3 How is ethics implemented?

For the examination of how ethics is being implemented by the participant programmes, the study relies on the analysis of two rubrics present in the documentation submitted for accreditation. One rubric contains the POLO scores and another rubric describes how the programmes meet the accreditation outcomes.

6.3.1 The implementation of engineering ethics education according to the programmes

The analysis of the self-assessment scales provided by the participant programmes focuses on the distribution of each POLO score assigned to outcome E across all programmes. Only mandatory modules offered by the programmes that included a self-assessment rubric convertible to the 0-4 scale have been considered. Table 17 breaks down the number of modules that received the score of 0 to 4 for meeting outcome E as well as how they are distributed across the programmes.

Table 17. Number of mandatory modules with a POLO scores of 0-4 for outcome E and the percentage distribution across programme (n=17)

Programme	Mandatory modules	POLO 0	% distribution	POLO 1	% distribution	POLO 2	% distribution	POLO 3	% distribution	POLO 4	% distribution
Iot A1	46	7	15%	5	11%	12	26%	8	17%	14	30%
Iot A2	48	7	14%	6	13%	9	19%	12	25%	14	29%
Iot A3	47	0	0%	30	64%	9	19%	6	13%	2	4%
Iot B1	45	4	9%	21	47%	11	24%	5	11%	4	9%
Iot B2	45	11	24%	8	18%	10	22%	9	20%	7	16%
Iot B3	45	5	11%	15	33%	17	38%	5	11%	3	7%
Iot B4	43	12	28%	7	16%	5	12%	9	21%	10	23%
Iot B5	44	16	36%	9	20%	10	23%	5	11%	4	9%
Uni C1	39	18	46%	13	33%	4	10%	1	3%	3	8%
Uni D1	43	19	40%	10	28%	10	23%	3	8%	1	2%
Uni D2	38	22	58%	9	24%	3	8%	3	8%	1	3%
Uni D3	38	21	55%	12	32%	3	8%	2	5%	0	0%
Uni D4	43	20	47%	12	28%	5	12%	5	12%	1	2%
Uni E1	35	9	26%	8	23%	8	23%	5	14%	5	14%
Uni E3	34	12	35%	4	12%	8	24%	4	12%	6	18%
Uni E4	35	8	23%	8	23%	8	23%	4	11%	7	20%
Uni E5	30	10	33%	5	17%	4	13%	5	17%	6	20%
TOTAL	**698**	**201**	**29%**	**182**	**26%**	**136**	**19%**	**91**	**13%**	**88**	**13%**

According to Table 17, the percentage of total number of modules within a programme that self-assessed their contribution to programme outcome E with 0, as “not contributing to the programme outcome,” ranges from 0% to 58%. The percentage of total number of modules that self-assessed their contribution to programme outcome E with 4, as making a “fairly strong contribution, with significant assessment relating to the programme outcome,” ranges from 0% to 30%. This dispersed distribution of percentages for modules scoring 0 and, respectively, 4 for meeting programme outcome E points to an uneven implementation of ethics across participant programmes.

To exemplify the disparity between programmes in the delivery of outcome E, programmes offered by Uni C and D can be compared against programmes offered by Iot A and Iot B. As such, on one hand there are two programmes from institution Uni D reporting no contribution to outcome E for more than half of their modules, followed closely by three programmes from institutions Uni D and Uni C, for which more than 40% of their modules received the score 0 for their contribution to outcome E. On the other hand, there are five programmes from institutions Iot A and Iot B for which less than 20% of the modules are deemed to have no contribution to outcome E.

Based on the self-assessment carried by the participant programmes, the variation regarding the percentage of modules with no contribution to outcome E appears to be institutional. It is notable that the programmes scoring 0 on outcome E for more than 40% of modules consisted of all the participant programmes of institutions Uni C and Uni D. Similarly, all participant programmes of institution Iot A assigned a score of 0 for meeting outcome E for less than 15% of their modules.

Reinforcing the institutional variation based on the POLO scores presented in Table 17, Table 18 brings in data about the four programmes of institution Uni F that employed a self-assessment scale of their modules' contribution to programme outcomes in terms of ECTS (Uni F1, Uni F4, Uni F5) or percentage (Uni F3). As mentioned previously, the self-assessment scale employed by programmes Uni F1, Uni F3, Uni F4 and Uni F5 did not allow a conversion to the 0-4 scale due to the fact that the distributed weight is capped at the number of ECTS or 100%, and thus the meaning of a score would vary depending on how many outcomes a module contributes to. The only constant score is 0 ECTS or 0%, for modules with no contribution to a programme outcome. Table 18 thus presents the number of modules offered by the programmes Uni F1, Uni 3, Uni F4 and Uni F5 which self-assessed meeting outcome E by a contribution of 0 ECTS or 0%. In the case of the four programmes offered by institution Uni F, the percentage of modules deemed to have no contribution to outcome E ranges from 47% to 80%, with a median value of 51%.

Table 18. Modules with no contribution to outcome E for institution Uni F (n=4)

Programme	Mandatory modules	Modules with 0 ECTS or 0% to outcome E	Percentage distribution outcome E
Uni F1	37	20	54%
Uni F3	43	20	47%
Uni F4	43	21	49%
Uni F5	30	24	80%

After analysing the distribution of modules with no contribution to outcome E across programmes, the attention is now turned to modules deemed to have a strong contribution to outcome E.

Table 17 shows that 9 programmes recorded a strong contribution to programme outcome E for less than 10% of their modules. Three programmes recorded a strong contribution to outcome E for 10-19% of their modules, while five programmes recorded a strong contribution to outcome E for more than 20% of their modules. The distribution of modules deemed to have a strong contribution to outcome E ranges from 0% (Uni D3) to a maximum of 30% (Iot A1) of the total mandatory modules offered by participant programmes.

The distribution of the POLO scores for outcome E within a programme, across all participant programmes, points to an institutional variation. This variation is higher for the percentage of modules deemed to have no contribution to outcome E. As Table 19 shows, the average percentage of modules self-assessed with 0 for outcome E ranges between 10%, for programmes offered by Iot A, and 58%, for the programmes offered by institution Uni F, with a standard deviation of 18.44%. The two institute of technology programmes appear to have a lower percentage of modules with no contribution to outcome E than university programmes. This institutional distinction can be explained through the findings of Klassen's (n.d.) study, according to which more prestigious and higher ranked higher education institutions show a tendency to resist the pressure of curricular change exercised by accrediting bodies. The system of engineering education in Ireland is marked by a distinction in prestige between universities and institutes of technology (Walsh, 2018).

Table 19. Distribution of POLO scores for outcome E by institution

Institution	**Percentage distribution 0**	**Percentage distribution 1**	**Percentage distribution 2**	**Percentage distribution 3**	**Percentage distribution 4**
Iot A	10%	29%	21%	18%	21%
Iot B	22%	27%	24%	15%	13%
Uni C	46%	33%	10%	3%	8%
Uni D	50%	28%	13%	8%	2%
Uni E	29%	19%	21%	14%	18%
Uni F	58%	n.a.	n.a.	n.a	n.a.
Standard Deviation	**18%**	**13%**	**7%**	**5%**	**9%**

Turning the focus on how participant programmes describe the way in which ethics is integrated in their curriculum, a mandatory rubric of the documentation submitted for accreditation is considered. In this rubric, programmes are required to describe how they meet each of the seven programme outcomes for the purpose of accreditation. Ten of the 23 participant programmes mention explicitly in this rubric that they aim to deliver ethics across the curriculum (Iot B1, Iot B3, Iot B4, Uni C1, Uni E1, Uni E3, Uni E5, Uni F1, Uni F2 and Uni F5). Programmes of institution Iot B state that ethics is "embedded into our programme at all stages, commencing with the stage 1 module of professional formation,"[24] adding that "ethical criteria and considerations in the context of Engineering decisions are incorporated into all other modules also including being formally considered across all stages of the final year project module." The programme of institution Uni C states that outcome E is

> addressed using a combination of (i) key modules, incorporating assessments that explicitly address ethical practice, and (ii) a distributed treatment throughout the programme where ethical issues are dealt with as they naturally arise within individual modules. This approach ensures [..] that ethics is embedded, relevant and context-sensitive.

The programmes of institution Uni E note that

> a few modules in the early stages contribute to this programme outcome, whenever relevant issues arise. Most of the strong contributions are in the later stages, where students might be expected to have a better appreciation of the responsibilities of a professional engineer.

The programmes of institution Uni F state that

> ethical, social and professional understanding is developed by including relevant, topical and modern examples directly into the syllabus of engineering modules throughout all years.

Institutions Iot A and Uni D make no explicit mention on how ethics is being implemented in their programme.

Despite proclaiming the preference for the implementation of ethics across the curriculum, for some programmes this narrative is contradicted by the high percentage of the modules

[24] The name of the module was modified to a generic topic category to protect anonymity.

deemed to have no contribution to outcome E. An example is programme Uni C1, which explicitly mentions an integration of ethics across the curriculum, while 46% of its modules are self-assessed with 0 and 33% with 1 for this outcome. This is the case also for programme Uni F5, which has a percentage of 80% modules deemed to have no contribution to outcome E, but states that "an understanding of the need for high ethical standards and the social and other responsibilities of practicing engineers is fostered throughout the degree programme."

Placing existing findings in the context of theoretical models regarding the implementation of ethics in the engineering curriculum explored in the literature review, it can be said that a programme with a high percentage of modules self-assessing outcome E with the score 0 suggests that the respective programme does not implement ethics across the curriculum. A more balanced distribution of percentages for each 5 scores would suggest an implementation approach across the curriculum.

6.3.2 The implementation of engineering ethics education according to members of evaluation panels

According to members of evaluation panels, the preferred method of implementing ethics is across the engineering curriculum. The preference for this implementation approach appears to have been influenced by the stance put forward by the accrediting body. For example, the representative of the accrediting body highlighted the desirability of an approach across the curriculum during the accreditation event of the five programmes of institution Uni F, pointing out that "ethics is not a subject to be compartmentalised, but manifest within the programme." Instructor L4 also notes that his institution acknowledges this implementation approach, as "something that came from Engineers Ireland, in the first place, that there is no point to having one module covering ethics and that it needed to be throughout."

The implementation of ethics across the engineering curriculum is considered to foster the development of holistic engineering graduates that do not divorce ethics from the technical solutions they pursue. As evaluator E6 states, implementing ethics across the curriculum "is the way to go if we want to produce engineers that consider ethics as part of their direct logical reasoning." Evaluator E1 argues that ethics "has to be across," noting that "during accreditation, we do not just want to see it in the professional development modules, we would like to see some mention of it in other modules as well." E1 justifies the preference for this approach, considering that "you cannot be ethical just in one module, there should be an element of it everywhere." Evaluator E4 agrees that ethics "has to be everywhere, maybe not to the same extent everywhere, but I think it is not possible to just have one module delivering on this outcome." This opinion is shared by evaluator E2, who considers that "ethics possibly should be brought into more modules as opposed to just being covered in a module." The reasoning behind this preference is that having ethics addressed in a dedicated module could contribute to the perception of the topic as an add-on, "just to get it in the course," and thus minimizing its importance in the engineering curriculum. According to evaluator E3, it is key to show that "ethics permeates everything" rather than being singled out as a distinct topic

While two instructors consider having a dedicated module on ethics unsuitable (L2, L6), three instructors state their preference for a hybrid approach that aims to integrate ethics both in dedicated modules and technical modules (L3, L4; L12). Arguing in favour of the former view, instructor L2 doubts that "you could have more ethics *per se*, a whole module on ethics" and that "having ethics embedded would be much better." In the opinion of L2, "if ethics is always there in everything students do, as an embedded not separate thing, then that becomes mainstream. They do not even have to do it as a separate issue." Similarly, instructor L6 considers that "rather than having a specific course on ethics, it is important to integrate ethics into some of the other courses, not in all."

Representative of the later view, L12 describes the approach within own programme, where ethics is not confined to a dedicated module, but "we also ensure that we have ethical issues that are addressed elsewhere in our program, so it is not all just one assignment in third year. We want to bring ethics into other parts of the program and we do that." L4 describes a similar approach adopted by the programme, considering that

> it is good to have ethics in multiple modules where possible […] in the four years. We try to hit on it somewhere every year, but the main places will be on a first year module and then third year and then fourth year in the project.

L4 explains that ethics has to be integrated "in situations where the students can understand why it is there and they can see that it is connected to other things, […] where the question is arising technically and they are seeing it in relation to that." Instructor L16 considers that by integrating ethical concerns alongside technical considerations, students can "understand the calculation, but also the context and wider relevance of that in society and the environment."

The preference towards implementing ethics across the curriculum expressed by instructors and evaluators alike is in line with calls witnessed in recent years for adopting this approach (Cruz & Frey, 2003; Newberry, 2004; Drake *et al.,* 2005; Ocone, 2013). The advantages mentioned in connection to teaching and assessing ethics in several modules throughout an engineering programme resemble the views put forward in existing research. It is considered that by providing a holistic and interdisciplinary approach which "mirrors the ways in which ethical issues arise in day-to-day engineering practice" (Cruz & Frey, 2003, p.545) students get "to see ethics in action" (Ocone, 2013 p.e114). The integration of ethics across the curriculum is also seen as helping students become aware of the intrinsic connection between ethical concerns and technical content, by rectifying the preconception that ethics is just an "add-on material" (Newberry 2004, p.346). As such, it is argued that this approach can be more effective in improving engineering students' moral reasoning and sensitivity to ethical issues than solely having dedicated modules on ethics (Drake *et al.*2005, p.223).

Nevertheless, the evaluators interviewed consider that engineering programmes are not yet at the stage of implementing ethics across the curriculum. "It is not quite there yet. I do not see any programmes where it is permeating throughout," states evaluator E6. Evaluator E 6 stresses the variation between programmes in their method of implementing ethics, remarking that while "some programmes will have dedicated modules to try and address program outcome E specifically, others I would regard as more rounded programs would have aspects of different modules where they would incorporate ethical questions."

Of the 11 programmes for which the accreditation report was available for analysis, only two programmes were commanded for the delivery of ethics across the curriculum. The accreditation report of programme Iot B2 highlights "the manner in which ethics permeates many of the modules in the programme," while the accreditation report of programme Uni D1 notes that "an awareness of the principles of sustainability is embedded throughout the programme." Three programmes have been reprimanded for not integrating ethics across the curriculum of the four years of studies. As such, the accreditation report of programme Uni D2 recommends a "greater integration of ethics content into the broader curriculum," while the accreditation report of programme Uni D4 mentions that "the panel feels that many opportunities for assessment of PO(e) are missed or not explicitly specified throughout the programme." The accreditation report of programme Iot A1 notes that ethics is covered mainly in the final year, and that the "evidence of achievement in earlier semesters is less clear."

Evaluator E2 considers that “most modules do not cover ethics. In any module that has a high technical content, probably ethics is not covered there.” According to evaluators, ethics tends to be covered in dedicated first year modules or yearlong projects (E2, E6), and that “typically an institution will have identified one person which has done a good job on incorporating it to their modules” (E5). Instructor L4 is an example of one such person overseeing ethics education in his own institution. L4 explains why his name is still mentioned in the most recent accreditation document, despite not having taught in the previous academic, because “I was still the person to talk about it.”

Participant observation highlighted a similar opinion held by evaluators on the implementation of ethics. During the accreditation event of Uni E, evaluator E5 probed students whether a module of professional practice deemed to have a high contribution to outcome E is “carrying the whole weight or is the thread of ethics present in other modules,” with answers stating that “there is not other module that particularly tackles it.” Reinforcing the view that ethics is not yet at the stage of being integrated in a systematic manner across the engineering curriculum, evaluator E9 remarked during the accreditation event of institution Uni F that the modules that the programme deems to have the highest contribution to outcome E are delivered online, in parallel to the work placement. The impression that evaluator E9 has on how ethics is implemented in the programmes of Uni F is that “they just created these modules and threw in some ethics to show they support the programme outcome.”

When it comes to the implementation of ethics across the curriculum, a challenging aspect mentioned by evaluators E4 and E6 is that it is unclear how ethics can be integrated in most modules. Evaluator E4 considers that “not every module can deliver in full under this learning outcome ,” an opinion shared by E6 who states that “for some modules it is going to be hard to bring ethics into light.” This point is expanded by E6, who sees the root of this difficulty in the technically focused education received by engineering lectures. According to E6, integrating ethics "is very difficult because of the way the existing crop of academics were taught engineering, in a very different way to the way we are teaching engineering now." This is seen to lead to a "slow process of getting people to think more holistically in their approach to engineering education." There is an agreement among evaluators for the need for more guidance on how to implement ethics more effectively, especially in the case of technical modules (E1, E2, E4). This issue has been highlighted also during the observed accreditation events, with representatives of the academic teams highlighting the challenges of implementing ethics and the need for more guidance. One such challenge mentioned by the programme chair of Uni C1 is linked to the technical expertise of current faculty. The chair considers that "for ethics we make a particularly effort, because is not something that would be addressed naturally. For example, for an entrepreneurship module[25] we bring people with a background in social sciences and entrepreneurship education to teach."

6.4 Key findings

This chapter was focused on examining the weight given to ethics in the engineering curriculum and its method of implementation. As Wicklein (1997, p.74) remarks, it is important to enquire "to what degree should the curriculum be devoted to technical skill training," given that "historically, educators within technology education have given an exorbitant amount of instructional time to this area while slighting many of the other facets of the curriculum." According to Wicklein (1997, p.74), the key to a healthy engineering curriculum is finding the "appropriate balance of tool skills with other curriculum areas."

This study found that outcome E is the outcome that has the lowest weight in the engineering curriculum of participant programmes, compared to all outcomes required for accreditation.

[25] Module name omitted to avoid identification, and replaced with a generic module type.

Although the low presence of ethics in the engineering curriculum has been previously highlighted (Colby & Sullivan, 2008; Barry & Ohland, 2012; Ocone, 2013; Monteiro *et al.,* 2016), the study succeeds in revealing the weight of ethics in comparison with other outcomes, using the programmes' own assessment that is undertaken for the purpose of accreditation. While a process of self-assessment based on the instructors and programme chairs' perception of how they deem to have met the accreditation requirements is inherently subjective, a coherent and consistent set of patterns still emerges. Thus the study reveals that ethics has a lower curricular presence not only when compared with technical outcomes, but also with other nontechnical outcomes, such as communication and teamwork.

Furthermore, similar to studies conducted in US (Barry & Ohland, 2012; Volkwein *et al.,* 2004; Lattuca *et al.,* 2006), UK (Ocone, 2013) or Australia (Johnston *et al.,* 2000; Skinner *et al.,* 2007), the curricular presence of ethics is perceived to have increased since the introduction of a dedicated accreditation outcome. This finding reinforces the role played by national accrediting bodies in supporting engineering ethics education, through the formulation of accreditation requirements targeting ethics.

A third finding shows variation and lack of uniformity in the weight and implementation of ethics, confirming Colby and Sullivan (2008)'s findings. The uneven implementation of ethics is manifested most markedly at institutional level, with a higher percentage of modules deemed to have no contribution to outcome E in the programmes offered by some participant institutions than others. It is important to note that the implementation of ethics is considered to be carried in an unsystematic manner, mostly as a "box-ticking" exercise for being granted accreditation. This finding supports the intuition expressed by Flynn and Barry (2010, p.2), according to which "one can take (and is often tempted to take) a 'tick box' approach to the teaching of ethical issues within the Engineering curriculum."

While there is an expressed preference by evaluators and instructors alike towards the implementation of ethics across the curriculum, evaluators consider that few programmes manage to do so, while for the majority of programmes ethics is confined to a dedicated first year module and the capstone project. As Mitcham (2014) points out, humanities and social science requirements are often limited to "little more than a semester's worth, spread over an eight-semester degree program crammed with science and engineering."

CHAPTER 7 INSTRUCTION IN ENGINEERING ETHICS EDUCATION

The present chapter addresses objective 7 described in the research design, and is dedicated to examining the teaching methods used in connection with engineering ethics education.

According to research carried in US, case studies have been found to be the prevalent method employed for teaching ethics in engineering colleges in US (Herkert, 2000a; Colby & Sullivan, 2008; Haws 2001). Considerable variations have been noted in regards to the type of content employed in case instruction and the way in which cases are implemented, marked by a lack of consensus as to which approach is more effective and towards which goals (Davis, 1999; Gorman *et al.*, 2000; Herkert, 2000a; Haws, 2001; Harris *et al.*, 2009; Jonassen & Hernandez-Serrano, 2002; Herreid, 2006; Abaté, 2011; Martin *et al.*, 2019). Instructors in Canadian engineering programmes were found to employ a "very diverse" set of overall teaching goals, but "the goals and practices did not always align" (Romkey, 2015, p.25). We encounter a prevalent microethical approach to case studies used in engineering ethics education, presenting individual dilemmas set in scenarios of crisis (Haws, 2001), with less focus on macroethical aspects such as public policy and the broader social mission of engineering (Colby & Sullivan, 2008; Lynch & Kline, 2010; Bielefeldt *et al.*, 2016).

The current chapter aims to address the need for empirical research on engineering ethics case instruction (Yadav & Barry, 2009), by interviewing instructors in more depth about their use of case studies, as well as their aspirations and challenges encountered, in order to reveal patterns in the design, application and goals of case instruction.

7.1 Methods

Initially, approach intended for addressing the aforementioned objective was to rely on the descriptors of the 83 modules deemed to have a high contribution to outcome E and the documentation submitted for accreditation by the participant programmes. Given that the accreditation process is outcome based, the documentation mentions the assessment methods employed in a module, while containing scarce data about the teaching methods used. The output of a documentary analysis would have been thus incomplete and unreliable. As such, the decision was to suspend the overview of the teaching methods employed in engineering ethics instruction based on the documentary analysis. Instead, the interviews which initially were meant to add depth to the data gathered through documentary analysis became the main source of data. The views of 16 instructors teaching modules of professional formation were explored with the aim of identifying the most frequent teaching methods employed, their specific application, as well as their preferred way of teaching ethics. This data represents the core of the analysis that is the subject of the present chapter. The result is an exploration of a prevalent method for teaching ethics, rather than a broad overview of all teaching methods employed.

7.2 What is the prevalent method for teaching engineering ethics?

As in the case of the research conducted in the US (Herkert, 2000a; Colby & Sullivan, 2008; Haws, 2001), a popular method for teaching engineering ethics in professional formation modules in Ireland are case studies. Of the 16 instructors interviewed, only one instructor did not employ case studies for conveying ethical content. The 15 instructors who employ this teaching method admit to including between one and “half a dozen” (L14) different cases in their module. One advantage of using case studies highlighted by an instructor is that it facilitates the inclusion of ethical considerations into technical content. One instructor explained her preference for case instruction, considering it “the easiest way to integrate ethics into a programme, […] through picking a case that is large enough to have different components within it that will link to the technical aspects of the course” (L16). This view is shared by another instructor, who considers that “it is the only way to teach ethics for engineers, by putting it in a scenario. Then they have to do their calculations based on some ethical decision as well" (L2, F).

7.3 How are case studies selected?

As seen in Table 20, engineering ethics case instruction in professional practice modules shows a close balance between the uses of existing case studies, cases that are adapted based on newspaper reports or existing cases and developing original cases.

Table 20. Types of sources employed in engineering ethics case instruction

	Source	Example
Imported case studies	Online repositories (4 mentions) University websites (1 mention) Colleagues (3 mentions) Conference presentations and workshops (1 mention)	Cutting roadside trees Killer robots
Adapted case studies	News features (9 mentions) Online repositories (1 mention)	*Challenger* shuttle explosion (3 mentions) *Volkswagen* emissions scandal (3 mentions) The wall between US and Mexico (1 mention) Hurricane Katrina (1 mention) The Christchurch Earthquake (1 mention)
Original case studies	Developed by the instructor (6 mentions) Developed by students (1 mention)	Hypothetical workplace situations (2 mentions) Using governmental data such as policy reports, environmental impact assessment, court case reports (2 mentions) Inspired by local issues (1 mention) Inspired by technical issues reported in academic journals (1 mention)

The use of imported case studies has received ten mentions from 9 of the instructors interviewed. Two popular sources for case studies stand out. Online sources, such as repositories of case studies and university websites, have received 5 mentions. Case studies obtained from colleagues or peers met during academic events received 4 mentions. This highlights the importance of online resources and dedicated events in supporting engineering ethics instructors with information, examples of best practice and teaching materials. As one instructor puts it, peer dialogue helped him improve the way he teaches ethics through case studies:

> I was teaching this 10-20 years ago, but I was not really happy with it. I just felt that the case studies were very shallow. And then I came across [n.m. censored peer's name] work, and it made more sense to me. I think networks can help people who are interested in these things to see that there is a link between ethics and maybe the environment and society, and then put that into our programmes (L10).

The use of cases studies adapted from news reports has received 10 mentions by 7 instructors. High-profile cases such as the *Challenger* shuttle explosion (L7; L12; L13; L15) or the *Volkswagen* emissions scandal (L2; L11; L15) appear to be the most popular scenarios. Natural disasters have been included by one instructor L16, who mentioned using case studies about the Hurricane Katrina and the Christchurch Earthquake. One justification given for adapting rather than importing case studies is to better fit "the context of our students" (L14).

Three instructors responded that they include original case studies, either developed by them (L6; L16) or by asking students to create a scenario (L7). The instructors developing their own scenario rely on their professional experience, their academic expertise or local concerns. To achieve this, they either draw up hypothetical workplace situations or expose students to local or contemporary issues by integrating real data such as policy reports, environmental impact assessments or public court case reports.

7.4 What are the goals used for case instruction?

There have been several goals linked to the use of case studies. Several instructors have highlighted the epistemic character of ethical decision-making that students are exposed to by using case studies. Other instructors emphasized how case instruction helps convey certain values that need to be cultivated by engineers. A fewer number of instructors focused on exposing students to the broader context of engineering practice and on conveying to students problematic issues in regards to individual engineers exercising their agency.

7.4.1 Epistemic

The majority of instructors employed case studies presenting ethical dilemmas. By being exposed to “wicked problems” (L10) and “grey areas” (L7; L8; L9; L12), students are expected to become acquainted with scenarios that lack a win-win outcome similar to those they might encounter in the workplace. Ambiguity is seen as an important feature of ethics coming into play in engineering decision-making. In the words of one of the instructors interviewed, “when you work as an engineer, you are exposed to grey areas far more than most” (L8). The importance of using case studies that render wicked scenarios is reinforced by instructor L4, who considers that

> in the ethics of all those engineering decisions a lot of it is compromise, and a lot of it is about how do I weigh the different things. There is nothing easy about that, and I want to get students used to that, that ethics is not about a simple 'this is right, this is wrong', it is about the things that are complicated. If it is a simple question, if it is a case of something that is obvious, it is not really an ethical question.

A third instructor opts for wicked problems due to their lack of a predetermined approach, which allows students “to look at different framings of the problem” (L10), and to analyse an ethical issue “from multiple perspectives” (L12). This view is shared by instructor L12, who considers that cases featuring ethical dilemmas show students the “complex grey areas and the sense that there are different values that people hold”.

7.4.2 Value driven

Instructors who employed high-profile cases such as the *Volkswagen* emissions scandal or the *Challenger* shuttle explosion aimed to highlight to students the importance of fostering values such as “moral responsibility,” “care” or “conscientiousness.” The focus is on reflection about the effects that an engineering decision might have, as well as on the decision-making process preceding it.

7.4.3 Broader context

The interviews also showed a concern for making students aware of the broader societal context of engineering practice and the “satellite effects” (L8) of their decisions. Several instructors described the role of case studies in allowing students to “think about those wider contexts, which might mean that a technically sound solution is not the best solution. That is where the ethical responsibility is” (L16). Another instructor shared a similar goal of making students aware that addressing an immediate problem “might not solve the broader problem, so to get them to think more broadly” (L10).

7.4.4 Agency

Two instructors mentioned agency related aspects as one of the goals of using case studies. One instructor achieved this by focusing on junior level engineering roles, aiming to make students aware that “regardless of how junior they are in an organization, they have moral responsibility within that level” (L3). Another instructor aims at developing “awareness that it is not all black and white, and you have agency and responsibility in those spaces in between” (L12). According to the instructors, raising awareness about the engineers’ responsibility to act should be taught alongside legal mechanisms of protection for whistleblowers, such as protective disclosures. The rationale offered is that “a lot of the ethical questions are around the edges of the legal questions” (L12).

7.5 What is the nature of the scenarios employed in case instruction?

Our analysis encountered both a micro and macroethical application of cases, with a preponderance of microethical cases. Twelve of the instructors interviewed included solely microethical cases, 2 instructors have included solely macroethical cases, while 2 instructors have used both micro and macroethical cases.

7.5.1 Microethical cases

The microethical approach to the use of case study has been described by Martin *et al.* *(*2019) as "individualistic," with resolutions being rooted in the precepts of code of ethics and ethical theories. Based on the description of the case studies employed by the instructors interviewed, we notice a strong focus on the individual engineer facing a moral dilemma or situation of crisis. Our study confirms that dilemmas raised by cases which promote an individualist perspective are often "referred back to" (L3) or "expanded through various ethical theories" (L8) or reference to professional codes (L7). The prevalent scenarios include ethical dilemmas that can be encountered in day to day practice, such as conflict of interest or reacting to improper practices, but also high-profile events such as the *Volkswagen* emissions scandal and the *Challenger* Disaster. The study finds a similar thematic focus to the case studies used in engineering ethics instruction in the US (Haws, 2001, p.226; Herkert, 2005, pp.306-7; Freyne & Hale, 2009, p.8; Harris *et al.*2009, pp.12-3). As Huff and Frey (2005, p.401) found, there is a "tendency […] to have only bad news cases, cases in which some bad outcome occurs because of poor choices."

The appeal of disaster scenarios rooted in real life events is described by the instructors interviewed as precautionary. Cases featuring high-profile failings can make students aware of the negative and often catastrophic outcomes of unethical decision-making, as they actually occurred. As one of the interviewed instructors states, "it is important that some of the case studies discussed with students are real world case studies, that show that when people ignore the ethics, things can go horribly wrong" (L6). The individualist approach to high profile disaster cases is also described by L11, who focuses on questions about

> the thought process that an engineer goes through in doing something like that. Students have to think about what they would do in that situation. How would they behave, was the observed behaviour correct, how would they modify their behaviour if it is not correct, what did they expect the outcome to be if they had behaved differently, would they hold on to their job, would they lose their job?

Similarly, instructor L2 employs a case of an engineering development that can be weaponised, asks students to consider "if you were given that problem how would you approach it? Have you thought of this effect? Would you do it again?"

Among the more mundane workplace dilemmas, the ones most often mentioned by instructors refer to prioritizing conflicting values, roles and potential outcomes, loyalty and conflict of interest, tendering procedures, issues around safety and design, quality control and whistleblowing. To exemplify, one instructor who explored the dilemmas faced by an engineer who might be tasked with building a wall at the border between the US and Mexico describes students' internal "conflict between wanting to retain a sense of professional propriety and all the existential concerns that go with having a job and loving your job, looking after your family, looking after your career, and then you come up against something which is very rewarding from a financial perspective" (L8). The "problem of wearing two hats at once, a managerial hat and the engineering hat" (L13) was also mentioned as a dilemma faced by students. Dilemmas surrounding tendering procedures and quality control have been included by one instructor through case studies "on reporting observations where practices are not what they should be in an engineering environment" (L3).

7.5.2 Macroethical cases

Macroethical instruction cultivates questions about the collective responsibility of the engineering profession and societal decisions about technology (Herkert, 2001b, p. 404). Our study found that four of the interviewed instructors employed case studies with a macroethical outlook, as suggested by the examples given by L6, L10, L12 and L16. These cases are preponderantly developed by instructors themselves and can include policy aspects, local and global issues and the perspectives of different agents.

Two main aims have been mentioned in connection to the use of macroethical case studies. A first aim is to encourage students to consider the broader context of engineering practice. This includes considerations about the social dimension of engineering practice as well as the structural issues affecting an engineer's agency. For example, in connection to the latter, instructor L12 mentioned how whistleblowing was explored in the context of a high profile scenario, in order to make students aware of the tension between recognizing what is morally right to do and the organizational constraints that might impede this. In her words,

> whistleblowing has been an example in the *Challenger* disaster, and everybody said 'I would not have done it'. But then, to think of the dynamics, to see how the reality of doing things in practice can be much more difficult than thinking 'Yes, I know what is right'. To see how ethical practice is part of social dynamics to some extent, and to make that a little bit more experiential, that they have a little bit of the question 'what would I have done? Probably not what I should have done' (L12).

Exposing students to the social dimension of engineering has also been highlighted by instructors L10 and L12, who emphasize the importance of using scenarios that require students to consider different perspectives. To achieve this, L12 integrated the role-play of a case of killer robots for

> a unit on responsibility. Each person in the group had to fulfil one role and they had to come to a decision on who was actually responsible for the death of a person when a robot malfunctioned, such that there were all kinds of distributed responsibility. […] I love the killer robot case because it made them think about 'how do I think about responsibility?' There are so many different levels of responsibility […] but there are also the interpretations I make and the public-facing interaction issues. […] It is really the vocabulary and complexity and the sense that there are different values that people hold, and just because I believe in one thing does not mean everybody needs to agree with it.

A second aim noted in connection to macroethical approaches is that of exposing students to the broader societal mission of engineering to address local and global concerns (L6; L10; L16). The cases include public court cases, as well as open data and policy documents issued by the Environmental Protection Agency, Met Eireann, the European Commission, local councils or the Smart Dublin initiative. L16 describes two of the case studies she employs, which asks students to reflect on the development of wastewater solutions benefitting the wider community in order to familiarise them with their “responsibility towards the environment”:

> In some of the case studies I used this semester, we were looking at the Greater Dublin Strategic Drainage Study where you access online all the data and the entire environmental impact assessment, which allows a discussion around that. Another thing I incorporated is the applications of physical processes, which is where you're looking at how material contaminant pollutants might be transported, so looking at air quality based on Dublin's urban publicly available sensor data. […] This is an example in which you have a technology that is treating the wastewater to a certain standard and being discharged to the environment, but maybe it is not meeting the legal concerns that it needs to. Students need to then understand many different elements to see whether this technology is functioning to a certain level, but maybe a different technology could be better. And then what are the implications of that, in terms also of the cost of putting any technology, or the legal costs of not meeting the environmental standards or of the actual quality around data collection.

Macroethical case studies are considered more engaging and effective in making students reflect on their wider responsibilities. L10 explains his pedagogical change from using “case studies of right or wrong things to do” to macroethical cases, due to the former “kind of washing over.”

Having seen a prevalence of case studies presenting hypothetical individualistic scenarios over case studies featuring real data or realistic settings, an important aspect is to examine the alignment of the methods used for teaching ethics through case studies, as described by the instructors interviewed, with their preferred or ideal way of teaching.

7.6 What is the preferred way of employing case studies?

The interviews revealed a set of desirable characteristics of engineering ethics case studies. According to the instructors interviewed, case studies should be realistic, more experiential, relevant, engaging, provocative, facilitated properly, including various stakeholders, integrating ethical alongside technical or legal considerations, based on real life data and documentation.

There is an overarching emphasis on immersive case studies that expose students to real or realistic contexts of practice. Relevance is one of the preferred characteristics of engineering ethics case studies, as described by 4 instructors (L3; L12; L14; L16). Four instructors mentioned their preference for case studies that are "realistic" or anchored in "real life," (L1; L6; L9), "close to practice" (L12) or "experiential" (L12). L1 considers that "having real scenarios where they can see the actual real life dilemma" is "the best approach," while L9 thinks that dilemmas about health and safety work best when the theoretical aspects are combined with practice and "fused in real life situations." L12 explains that she would like to use more "experiential" cases, as these would allow "to see how ethical practice is part of social dynamics to some extent." All the instructors who expressed their preference for immersive ethics case studies have professional experience outside the academia, preponderantly in the private sector, but also in policymaking or healthcare.

One way of anchoring case studies in real contexts of practice identified by instructors is through the involvement of external stakeholders. L16 states that she "hopes that in the future years I can bring in different stakeholders, […] to bring in a more practical element." A second way is through inviting stakeholders to the classroom (L1; L7), and a third way is through employing actual data and documentation (L6; L10; L16). The role of stakeholder involvement has been previously highlighted by Corple *et al.* (2020, p. 268) as conducive to ethical reflection

A second group of desirable case characteristics focus on student experience. According to the instructors interviewed, case studies should be "provocative" as to give rise to debates and discussions that allow students to "think about the deeper ethical issues that might be in play in a certain circumstance or certain context that you as an engineer might face" (L13).

It is important that students “resonate” and “engage” with the scenarios presented (L3; L7; L12).

A third group of desirable characteristics points to the content of case studies. Several instructors mentioned combining ethical concerns alongside technical issues (L2; L15; L16) or legal matters (L8; L12). This approach is best explained by L16, who emphasizes the role of addressing technical questions alongside ethical questions in order to make students aware of the wider context and implications of their work:

> students can understand the cost benefit of different solutions, and that is a technical thing that they are considering, and then they can think about the downstream impact of one solution over another solution. I think the best way to teach that is through understanding different case studies and understanding which bits of the technical component within that can impact the ethical downstream side of that. […] This ties together how things can go wrong and how that can have implications for public well-being and the safety of individuals but also for the environment and the sustainability of resources within that environment, based on understanding the technical knowledge, but the context around that as well. […] There is no point being able to technically deliver something if that solution is not a good solution and that is where the ethical responsibility is. Is it safe? Is it going to affect public welfare? Is it going to affect the environment? Thinking about those wider contexts might mean that a good technical solution is not the best solution. I think a really important part of their decision-making is to understand the implications of the technical content they have learnt.

Instructors encounter several obstacles for employing case studies in a manner that more closely aligns to their preferred teaching approach. These challenges include the impact of big student cohorts on interactive teaching interventions (L3; L10; L15), a crowded syllabus (L2; L15), available classroom space as well as classroom design, such as the allocation of tiered seating rooms (L1; L3), involving or developing stakeholder contacts (L1; L16), lack of best practice case study examples (L6, L10), timetabling issues (L16), the module format, such as the online delivery of the module (L13), and insufficient resources allocated for modules with ethical content (L15).

The opinions expressed by instructors seem to suggest the need for, on one hand, a greater institutional or departmental support for modules of professional formation, and on the other hand. for guidance on improving case study instruction.

The institutional support can be translated either as an investment of institutional resources, additional instructors, timetabling or room repartition. This institutional effort is not sufficient by itself. Two instructors (L1; L10; L15) have highlighted the role of accreditation bodies in offering support in liaising with external contacts or providing expertise about best practices. L1 gave as example how she "initially went to Engineers Ireland, because they have the code of ethics, to ask if they have anyone who would come and […] give some examples that they have dealt with in practice, maybe litigation," to be given the contact of an instructor within her own institution, who "had case studies, and we went through them and he helped me." The need for the accreditation body to offer informational support is also highlighted by L15, who "would like to see Engineers Ireland providing support and really help deliver an ethics programme outcome and how to embed it, and to provide some case studies or best practice examples." Furthermore, L10 suggests that "an evolution of the accreditation requirement could be helpful to explain what is required and then people would have to go look up the literature on case studies, and so on, to see what this actually means." These opinions seem to suggest a growing need of ethics case studies and of a repository where they can be consulted. As L6 states,

> I think the challenge is actually finding good case studies and finding the documentation to support it, because very often some of the information is not made publicly available. […] There are books and books and books on the principles and you can look at codes of ethics anywhere, but it is actually to bring it into the students' consciousness. It has to be made very concrete with examples.

There are ample online repositories of engineering ethics case studies developed as a US initiative, such as The Online Ethics Center for Engineering and Research, maintained by the Center for Engineering, Ethics and Society of the National Academy of Engineering.

Several higher education institutions also host examples of case studies on their institutional website. Nevertheless, there is a real lack of cases rooted in the Irish context and of an online platform presenting their content and suggestions for application that can serve as inspiration for instructors using engineering ethics case studies.

7.7 Key findings

The main findings of the present chapter reveal that case studies are the prevalent method used by the participant instructors in engineering ethics instruction, supporting empirical research conducted in the U.S (Colby & Sullivan, 2008; Haws, 2001; Herkert, 2000).

In terms of how cases are framed, it is notable the use of individualistic hypothetical scenarios containing dilemmas set in scenarios of crisis that can be addressed through appeal to ethical theories or professional codes over case studies exploring the wider mission of the engineering profession. The study thus finds an alignment between the use of case studies and the conceptualization of ethics in practical terms explored in Chapter 5. The study finds a marked understanding of ethics as decision-making in complex situations and embedded in engineering practice, reflected in the method of instruction.

Instructors have also highlighted the need to move away from hypothetical scenarios towards more immersive case studies set in real/realistic settings. As Bairaktarova and Woodcock (2017) found, "taking an ethics class did not increase students' ethical awareness," supporting a teaching approach "with more real-life scenarios and open-ended questions" in order to "provide students with a more complete exposure to engineering ethics." One approach for implementing immersive scenarios suggested by the participants is through the involvement of stakeholders and external guests. This preference mirrors incipient initiatives for developing and employing case studies that would more closely replicate the context of engineering practice (Kalamas Hedden *et al.*, 2017; Holgaard &

Kolmos, 2018; Bombaerts *et al.*, 2018; Mattasoglio Neto *et al.*, 2019). A second approach favoured by the participants makes use of real data and documentation, such as environmental data and recordings, policy documents or court reports made publicly available by governmental organizations or community initiatives.

An important aspect highlighted by the participants interviewed is the need for institutional support, teaching resources and the development of communities of research and practice to assist and enhance engineering ethics instruction. Participants deplored the lack of cases rooted in the Irish context and of an online platform presenting their content and suggestions for application that can serve as inspiration for instructors using engineering ethics case studies. Although there are ample online repositories of engineering ethics case studies developed in the US, such as The Online Ethics Center for Engineering and Research, maintained by the Center for Engineering, Ethics and Society of the National Academy of Engineering, there is none at European or Irish level.

CHAPTER 8 CURRICULAR CONTENT OF ENGINEERING ETHICS EDUCATION

The current chapter addresses the 8th objective of the thesis, and it aims to determine the main curricular themes employed in engineering ethics instruction. In the use of the term ‘curricular content,” the study is guided by an understanding of curriculum in terms of the syllabus content of a specific discipline or set of units taught to students (Lattuca & Stark, 2009). The chapter proceeds by describing the methods employed for this purpose, followed by a presentation of the main findings that will then lead to a discussion of what they might reveal about the ethics content of the engineering curriculum in Ireland.

8.1 Methods

In order to examine the curricular content employed in engineering ethics education by the participant programmes, two research methods have been employed: (a) document analysis of the documentation which was either prepared by the programmes for accreditation or is available on the website of all participant programmes and (b) interviews with instructors and evaluators.

Documents are a stable and non-reactive source of data, which can offer a broad picture of the type of ethical content offered by the participant institution (Bowen, 2009, p.31). Nevertheless, document can have an insufficient in-depth detail to address the research questions set, by virtue of having been developed independent of a research agenda (Bowen, 2009, p.31). The description of ethical content provided in the documentation submitted for accreditation and in the module descriptors is uneven, with some modules offering more detail, while others offering very scarce information. By focusing on a sample number of modules, the interviews can complement the data obtained from the documentation in order to pursue in more depth questions about the content and instruction methods used in engineering ethics. In addition, interviews can also serve to confirm the accuracy of the documentary analysis, by comparing the description of the coverage of ethical issues in the interviews with the themes generated by the researcher following the document analysis.

For the documentary analysis, three main sources have been used. A first source of data was the self-assessment POLO rubric present in all documents submitted for accreditation by all participant programmes. Secondly, 17 programmes have provided the description of their modules, either as an annex to the documentation submitted for accreditation (6 programmes) or part of the evidence presented during the accreditation events observed by the researcher (11 programmes). A third source of documentary data consists of the syllabus and the description of modules posted on the website of all participant programmes.

The process of collecting and analysing data underwent several iterations, as described in the research design chapter, until it generated a first codebook containing 28 topics employed for meeting outcome E by the 83 unique modules identified to have a high contribution to outcome E. During the second iteration stage, the initial thematic codes have been grouped and subsumed under broader categories, which led to the identification of 11 major thematic categories of curriculum content purporting to engineering ethics education. Table 21 mentions what type of curricular content is comprised by each of the 11 thematic categories identified, based on module descriptors containing learning outcomes and topics and the rubric in the accreditation document in which programmes describes how their modules address outcome E.

Having established the major themes employed in engineering ethics education by the participant Engineering programmes, the study proceeded to an in-depth exploration of curricular content through a series of interviews. As in the case of the documentary analysis, this process developed over a series of research stages, which were described in chapter 4.

Table 21. Coding process for determining content of Engineering Ethics education

THEMATIC CATEGORY	CONTENT
Sustainability	Referring to the principles of sustainable development, environmental impact and protection, climate change, carbon management, energy efficiency, renewable energy, life cycle analysis, waste management, sustainable economic growth, eliminating poverty traps
Health and Safety	Referring to health, workplace safety, accident prevention, environmental and societal hazard prevention, prediction and risk assessment
Legislative	Referring to national and international standards, directives, regulations, and legislation, CE marking, product liability, contract documents and planning requirements, policy making, intellectual property and patent law, security, privacy and GDPR
Professional ethics	Referring to Codes of Ethics, organization and regulation of the profession, professional and public bodies
Business studies	Referring to management, business, finance, cost effectiveness, organizational culture
Societal context	Referring to the cultural, economic and socio political dimension of engineering, science and technology studies, globalization and international context, diversity, implications of robotics, AI, automated and autonomous systems
Responsibility	Referring to responsibility towards society and the ecosystem, corporate social responsibility
Value design	Referring to value design, universal design, design centred on user needs and characteristics
Plagiarism	Referring to referencing, plagiarism and academic honesty
Ethical theories	Referring to ethical theories, ethical dilemmas, ethical reasoning and decision-making, computer ethics, cyber ethics, environmental ethics
Humanitarian engineering and community engagement	Referring to humanitarian engineering, social commitment and community engagement

8.2 What are the main themes of curricular content in engineering ethics education?

The present section aims to determine the main themes used to teach engineering ethics and the distribution of each theme across module types.

During the coding stage, eleven broad thematic categories have been identified as being addressed in engineering ethics instruction. These curricular themes are Sustainability, Health and Safety, Legislation, Business Studies, Responsibility, Professional Ethics, Societal context, Value design, Plagiarism, Ethical theories, and Humanitarian engineering and community engagement.

Table 22 shows that three main themes dominate the engineering ethics curricula, being present in more than half of the modules self-assessed as having a strong contribution to programme outcome E. These themes are related to sustainability coverage (present in 59% of modules), health and safety coverage (present in 58% of modules) and legislation (present in 54% of modules). These themes are also present in a wide variety of module types, such as technical modules, design modules, professional formation modules, capstone projects, legal studies modules, business studies modules, as well as for work placement. The distribution of sustainability, health and safety and legislation topics seems to suggest that these are the preferred topics for integrating ethics across the engineering curriculum.

With a presence amounting to approximatively a quarter of the modules with a strong contribution to programme outcome E, curricular content related to professional ethics (25%) business studies (25%) and societal context (24%) represent three popular themes used in engineering ethics instruction. Professional ethics, including coverage related to the codes of ethics and the organization and regulation of the engineering profession, is addressed in 92% of the modules of professional formation, but has a weak presence in other type of modules. Business studies are present in modules dedicated to this topic, as well as in 67% of the professional formation modules. Societal context is most often covered in modules of professional formation, where is present in 50% of this type of modules, and in technical modules, where is present in 22% of the modules. Although the societal dimension of engineering has been found by evaluators to be present in the teaching materials, it is less prominent in assignments. In this regard, evaluator E8 notes that after going through the

Table 22. The distribution of ethics coverage across module types (n=83)

Thematic category	Technical Modules (n=36)	Design modules (n=15)	Professional formation modules (n=12)	Capstone Projects (n=8)	Work Placement (n=2)	Business studies modules (n=6)	Legal studies modules (n=3)	Personal Development module (n=1)	TOTAL (n= 83)	% OF TOTAL
Sustainability	19	10	8	5	1	4	2	0	**49**	**59%**
Health and Safety	19	8	10	5	2	1	1	0	**48**	**58%**
Legislation	13	10	8	5	2	4	3	0	**45**	**54%**
Professional ethics	1	2	11	2	1	2	1	1	**21**	**25%**
Business studies	2	4	8	0	0	6	1	0	**21**	**25%**
Societal context	8	1	6	1	0	2	1	1	**20**	**24%**
Responsibility	2	1	9	2	1	1	2	1	**19**	**21%**
Value sensitive design	6	6	1	1	0	0	0	0	**14**	**17%**
Plagiarism	0	1	3	8	0	0	0	1	**13**	**16%**
Ethical theories	4	0	6	1	0	2	0	0	**13**	**16%**
Humanitarian engineering and community engagement	0	1	0	0	0	0	0	0	1	1%

evidence, he noticed the absence "in projects and assignments" of an "aspect that is important, about the effects on society."

Responsibility is addressed in 21% of the modules self-assessed as having a strong contribution to programme outcome E. This theme features most extensively in modules of professional formation. Responsibility is present in 75% of the modules of professional formation. The high frequency of this theme in modules of professional formation can be understood in light of the modules' role of fostering an understanding of the norms, standards and values of the engineering profession. The *Code of Ethics* set by Engineers Ireland (2018) represents a mirror of such standards, and places the concept of professional responsibility at its core.

Value design is included in 17% of the modules self-assessed as having a strong contribution to programme outcome E. It has the highest occurrence in design modules, being present in 40% of modules of this type, followed by technical modules, being present in 17% of modules of this type.

Plagiarism is included in 16% of the modules self-assessed as having a strong contribution to programme outcome E. Capstone projects have a high emphasis on this type of curricular content, as it is present in all modules of this type. Plagiarism is also present in 25% of professional formation modules. As capstone projects are taking place in the final year of studies, and professional formation modules are typically a common first year module, it can be said that students are introduced to this curricular area early in their studies. It is important to note the conflation encountered between, on one hand, the understanding of plagiarism in terms of academic integrity and honesty (O'Rourke & McAvinia, 2014), and on the other hand, issues pertaining to giving due credit to someone else's work included in engineering professional codes. Plagiarism is present in article 1.3 of Engineers Ireland's (2018) *Code of Ethics*, which states that "members shall ensure, so far as they are able, that other engineers receive credit for their professional achievements and receive whatever rewards to which they are entitled". The *Code of Ethics for Engineers* issued by the National Society of Professional Engineers (2019) also states under article 3.c that "engineers may prepare articles for the lay or technical press, but such articles shall not imply credit to the author for work performed by others," which is considered to be an act that "deceives the public." The document analysis and participant observation revealed that instructors rarely refer to professional codes of ethics when addressing plagiarism issues deemed to fall under outcome E. As such, the study encounters that the theme is preponderantly addressed as a standalone issue that is more closely linked to academic ethics. The study also encountered an omission of discussions about plagiarism, in an instance when the understanding of the topic as academic dishonesty legitimately overlaps with its formulation by professional codes[26]. A relevant example is that of computing and programming modules offered by the participant programmes. These type of modules are considered to register a high frequency of academic dishonesty cases (Culwin *et al*., 2001), due to students' use of copied source code (Marsan, 2010; Kermek & Novak, 2016). Yet the study found little focus on discussing the ethics of using source code and what constitutes plagiarism in computing and ICT disciplines. A possible explanation could be linked to the confusion as to what counts as plagiarism in these disciplines (Cosma & Joy, 2008; Baugh *et al.,* 2012, Simon *et al.,* 2014, Simon *et al.,* 2016).

[26] In the US, according to the *Code of Ethics and Professional Conduct* developed by the Association for Computing Machinery (2018), computing professionals should therefore credit the creators of ideas, inventions, work, and artifacts, and respect copyrights, patents, trade secrets, license agreements, and other methods of protecting authors' works," while the *Code of Ethics* of the IEEE Computer Society (1999) states that software engineering professionals are expected to "credit fully the work of others and refrain from taking undue credit".

Ethical theories, dilemmas and reasoning is included in 16% of the modules self-assessed as having a strong contribution to programme outcome E. It is present in 50% of the modules of professional formation, and also in 11% of technical modules.

Humanitarian engineering and community engagement is the theme which is the least represented in the engineering ethics curricula, being present in only 1% of modules. It is worth noting that this theme is present in extracurricular activities offered by the participant programmes, under the form of the competition *Where there is no engineer* organized by Engineers without Borders Ireland. The initiative aims to encourage engineering students to "design creative solutions to development challenges globally" and "improve resilience within communities." Among the projects designed by students are a solar powered battery bank, low cost heaters and a menstrual pad washing system for women living in refugee camps (McCarton & O'Hógáin, 2018).

In examining the content of the modules in terms of the debates presented in the literature review, a surprising finding is the extent of coverage of what the literature labels as macroethical issues. Sustainability, legislative and societal related coverage are the most common themes used in engineering ethics education. The strong presence of macroethical curricular content is consistent with the findings about ethics coverage revealed by the study conducted by Polmear *et al.* (2019). Polmear *et al.* (2019)'s investigation points to the prevalence in Western European Engineering programmes, compared to US programmes, of topics related to sustainability, the societal impact of technology and professional practice issues. This seems to suggest that compared to the US, the coverage of ethics by the participant programmes in Ireland is more geared towards macroethical topics.

Considering topics associated with the microethical approach, while safety is indeed the second most popular theme used to convey curricular content pertaining to ethics, receiving 60 mentions in 43 modules, the themes of plagiarism and ethical theories, which are traditionally associated with microethical approaches, are among the three least used themes. Curriculum content pertaining to ethics education does not bear as heavy emphasis on plagiarism in participant engineering programmes in Ireland as it does in the UK and Portugal, according to studies conducted by Atesh *et al.* (2017) and Monteiro *et al.* (2017). Ethical theories also have a low presence in the curricula of participant engineering programmes in Ireland, unlike the emphasis reported in studies conducted in US Engineering programmes (Colby & Sullivan, 2009).

Another notable finding points to the attempt to encompass several themes in one module deemed to have a high contribution to outcome E. There is an average of 3 themes addressed in each of the modules analysed. Several modules describe the attempt to address ethics from both a micro and macroethical perspective. As Devon and van de Poel (2004) argue, the "social [macro] ethics approach and individual [micro] ethics approach do not exclude each other," and this is visible in many teaching interventions that were analysed.

In what follows, the chapter will proceed with an examination of the three most popular themes are examined in more detail in order to determine specific instances of curricular content present in the teaching and assessment methods employed by the participant programmes.

8.3 Sustainability related coverage in the engineering curricula

When analysing how ethics is being integrated in the curricula of the participant Engineering programmes, we found that sustainability is the most popular theme employed in connection with meeting programme outcome E. Table 22 shows that 49 (59%) modules deemed to have a high contribution to outcome E include sustainability related topics. The topics mentioned in connection to the teaching and assessment of the theme of sustainability are the principles of sustainable development, environmental impact and protection, climate change, carbon management, energy efficiency, renewable energy, life cycle analysis, waste management, sustainable economic growth and eliminating poverty traps. There is a higher emphasis on the environmental dimension of sustainability than on its social and economic dimension. The environmental dimension of sustainability has a cumulated 75 mentions across all 83 modules, while the socio-economic dimension has a cumulated 21 mentions across all modules.

The theme of sustainability is covered in a wide variety of module types, such as technical modules, design modules, professional formation modules, capstone projects, work placement programmes, business studies modules as well as legal studies modules. An exception, considered insignificant, is for the only module categorised as a personal development module, which does not offer coverage related to sustainability. More so, as seen in Table 22, sustainability related coverage is present in more than half of the modules with a strong contribution to outcome E from each module type. This suggests that sustainability is present as a focus for implementing ethics across the curriculum. More so, an evaluation panel commended a programme for its implementation of outcome E across the curriculum through sustainability topics. As such, the accreditation report of programme Uni D1 notes that "an awareness of the principles of sustainability is embedded throughout the programme."

From the perspective of instructors, sustainability has the advantage of being a theme that suits the technical expertise of engineering faculty members. As one instructor states, sustainability coverage has "the potential" to be integrated in technical modules. According to her, ethical questions about energy efficiency and waste production "did resonate because people could see how they might be involved in something that could be problematic." Sustainability is also found to be appealing to students, who were found to show "a real interest." Reflecting on her classroom experience, one instructor noticed a real focus on the

Sustainable Development Goals, with students commenting "this was something they really enjoyed."

These observations seem to address two common challenges highlighted by current research on engineering ethics instruction. One such challenge is the engineering faculty' lack of familiarity with the topic, which that hinders the linkage of ethical concerns with technical subject matters (Sinha *et al.,* 2007; Harding *et al.,* 2009; Walczak *et al.,* 2010; Romkey, 2015; Monteiro, 2016; Polmear *et al.,* 2018). A second challenge is the students' negative reception and engagement with nontechnical content (Harding *et al.,* 2009; Romkey, 2015; Polmear *et al.,* 2018).

Sustainability is present in the curricula of the participant programmes both in taught components and assessments. In what follows, we describe some of the evidence of sustainability coverage in both these components.

8.3.1 Teaching methods used for sustainability related coverage

Table 23 shows that the participating programmes include sustainability topics through various taught components, such as lectures, case studies, community service, online polling systems and documentaries.

The case studies used by the instructors interviewed aim to foster students' reflection on the implications of developing technologies that fail to meet environmental standards. For example, a case study about wastewater treatment explores the "certainty of knowing" that the discharge from the respective technology is "actually polluting the environment or was it just that we took one sample and that sample is inaccurate?" Students are exposed to the various type of ethical concerns that arise, such as "the rigor and integrity of their data collection and management, the cost benefit of different solutions, and the impact of one solution over another solution."

Table 23. Teaching methods addressing sustainability issues

Type	Example of content
Lectures	Principles of sustainable development The relationship between a country's CDP and associated energy use Wealth inequality Local and/or international environmental policies Environmental ethics in different traditions of thought
Case studies	Ethical dilemmas about waste water treatment technologies
Community service	Developing environmentally-friendly and/or socially-conscious solution based on needs identified through direct interaction with a non-profit entity or community group
Online polling systems	Inputting the moral decisions students make for tackling climate change
Films and documentaries	Surviving Progress

Community engagement has been mentioned in connection to designing "socially-conscious building retrofits that are student initiated and with clear relevance to societal contribution and community awareness." While an example of documentary shown in class addresses "what is progress from a critical perspective, looking at various aspects of sustainability and how they are interlinked." Online polling systems have been used by one instructor to ask students to input the moral decisions they make in their daily lives for tackling climate change.

The integration of various teaching approaches led to addressing all three pillars of environmental protection, economic viability and social equity of the topic of sustainability. This seems to suggest that a hybrid approach undertaken by each programme to include sustainability in the engineering curriculum is needed in order to offer students a more rounded understanding of the topic.

8.3.2 Assessment methods used for sustainability related coverage

In order for ethics instruction to be successful, it was argued that the inclusion of ethics in taught components is insufficient by itself if it is not accompanied by an assessment of the ethical components of technical modules (Bairaktarova & Woodcock 2017, p.1132).

Furthermore, Cech (2014a) also emphasizes introducing ethical considerations in assessment, considering that "if even 10% of homework and exam questions required students to reflect on the social ramifications of research and results, scientists and engineers could reverse the slide into disengagement."

In what follows, several examples will be introduced highlighting the integration of sustainability issues in the assessment methods employed by the participant programmes. As seen in Table 24, sustainability was found to be included in exam question, reports, presentations, research projects, design projects and capstone projects.

Table 24. Assessment methods addressing sustainability issues

Type	Example of content
Exam questions	discuss the ethics of landfilling determine knowledge of sustainability principles
Research projects (reports, posters and presentations)	about the sustainable development goals about the state of energy legislation in Ireland and the EU
Design projects	projects that require the design for environment approach
Capstone project	mandatory rubric discussing the ethical implications and issues arising in the final year project

Exam questions were found to assess students' knowledge of the principles of sustainable development, or to reflect critically on the integration of sustainability concerns in various engineering practices. An example was offered by instructor L16, who described asking students about the ethics around landfilling, and "whether it is a problem or an opportunity, whether you can generate energy and actually recover things from it and turn it into a positive, or whether the negatives do outweigh that."

Research projects are a popular method of including sustainability topics in assessment. Some of the examples mentioned by the lectures interviewed revolve around asking students to present or write a report on the sustainable development goals. An instructor described how their report assignment is asking students "to put the context of why the chosen goal was a challenge, and then to discuss what progress had been made so far and to critique that, whether that was sufficient progress, whether they were on a good trajectory, and then what environmental engineers could do in the next decade in order to be able to meet that 2030 target." Another example of a research project asks students to analyse energy policies across a number of countries, with a focus on their impact of the adoption of bio-energy technologies "that could lead to sustainable, cyclic energy systems."

The majority of capstone projects include a mandatory rubric that requires students to include a section in their thesis where they reflect at the ethical implications and issues arising in their projects. This rubric is found to explicitly mention sustainability as one of the implications to be considered. For the programmes that do not yet have this requirement for the final year project, evaluators mentioned its absence and suggested the introduction of an ethics section.

8.4 Health and safety related coverage in the engineering curricula

Health and safety related coverage is the second most popular theme of curricular content employed in engineering ethics education, present in 58% of the modules deemed to have a strong contribution to outcome E. Considering the modules with a strong contribution to outcome E, the theme of health and safety is most often addressed in technical modules, where is present in 50% of the modules of this type, in design modules (present in 53% of this type of modules), as well as professional formation modules (present in 83% of this type of modules) and capstone projects (present in all modules of this type). The study also found that 12 technical modules included only one thematic area, of Health and Safety related coverage, although the average number of themes employed in engineering ethics instruction by a module is 3. The theme of health and safety thus appears to be suitable to be integrated in technical modules and design modules.

There are two main topics grouped under the theme of Health and Safety. First, we have topics related to ensuring workplace safety, such as health and accident prevention, which are mentioned in 24 unique modules with a strong contribution to outcome E. Second, we have considerations about the safety of the outputs of engineering work, such as environmental and societal hazard prevention, as well as prediction and risk assessment, which are present in 36 unique modules with a strong contribution to outcome E.

Curricular content purporting to health and safety is the theme that evaluators made the most comments when evaluating outcome E, both during accreditation events and in accreditation reports. The accreditation reports of 3 programmes, from the 11 accreditation reports available, comment either positively or negatively on the integration of curricular content purporting to health and safety. No other theme has been mentioned as frequently in accreditation reports.

The study also found that the theme of Health and Safety is the theme most prone to misinterpretation by instructors in regards to its contribution to outcome E. For example, there are 6 modules offered by Uni E that claimed to have a high contribution to programme outcome E by virtue of addressing aspects related to safety, but the ethical component is not present in the description of the learning outcome of the respective modules, nor is supported by the evidence made available during the accreditation event. In these six modules, safety considerations are not integrated through the prism of ethics, as the justification for their contribution to programme outcome E was framed through the prism of technical and mathematical related content. To illustrate this misinterpretation, an example is offered by a technical module, which provided in the documentation made available during the accreditation event a justification for the scores assigned for all seven programme outcomes. As such, the justification provided by the module for self-assessing the contribution to outcome E with the score 4 is described in virtue of preparing students to

> efficiently numerically solve a system of first order differential equations subject to given initial conditions. Be able to use this ability to determine the actual performance of a significant class of engineering systems. Again appreciate the approximation involved, the problems which can occur how to identify them and what to do if they arise.

The evidence offered by this module during the accreditation event to support the contribution of this specific learning outcome to programme outcome E was an assessment exercise involving an inverted pendulum. The misinterpretation of the contribution of technical modules to outcome E through safety topics has been also highlighted by evaluators during the accreditation event of Uni E. Evaluator E5 pointed out to the academic team of Uni E that, given the evidence provided, this module should not have been assigned the score 4:

> Evaluator E5: The module had a 4 given that stability is important. It seemed a bit tedious to link stability of the inverted pendulum with ethics and safety. It is not sufficient for ethics.
>
> Instructor 7 Uni E3: I think you are probably right
>
> Instructor 8 Uni E3: I am a stabilist and I am with the instructor on this one. It is about the ability to certify that issues are safe
>
> Evaluator E5: I would rate it as a 2 rather than a 4
>
> Instructor 8 Uni E3: Even after I explained?
>
> Evaluator E5: Yes, it is just an exercise about stability
>
> Instructor 8 Uni E3: I disagree. It could not be an inverted pendulum, it can be an airplane.

The conflation of technical content focused on calculations with ethical considerations was found present only for the theme of Health and Safety. Nevertheless, the opposite situation was also encountered, in which the academic team of Iot A3 was unaware that curricular content related to health and safety falls under the scope of outcome E. As instructor L5 admitted, until the members of an accreditation panel pointed out that Health and Safety represents ethical coverage, there was an institutional lack of awareness of this fact. Instructor L5 explains that

> it was pointed out to us by a preliminary review panel that whenever you are talking about safety issues you are addressing ethical matters. Therefore evidence of an example that covers the topic of safety also addresses the issue of ethics because it is tied into it, and we had not appreciated that fact until that point.

One of the evaluators interviewed also expressed doubts whether Health and Safety coverage falls under the scope of outcome E. In this regards, evaluator E2 states that “I am not sure exactly if safety may not be under the category of ethics.”

In what follows, we describe how the evidence of health and safety curricular content has been integrated in the teaching and assessment component of the participant programmes.

8.4.1 Teaching methods used for health and safety related coverage

The theme is integrated through taught components such as lectures, lab demonstrations and case studies, as seen in Table 25.

Table 25. Teaching methods addressing legislative issues

Type	**Example of content**
Lectures (including guest lectures)	Safety standards and legislation; Industrial safety; risk assessment and hazard categories; Safety systems (earthing system; residual current device, miniature circuit breaker); Safety strategies for automated systems; Road safety engineering techniques and auditing; Product safety; User safety
Lab demonstrations	Health, Safety and Welfare at Work Regulations, National Rules for Electrical Installations (ETCI Regulations), European directive on operating machinery Maintenance, installation and fault finding of electrical or fluid power systems
Videos	Safety measures, notable accidents and disasters
Case studies	Accident and disasters (*Piper Alpha*, Texas BP explosion, *Challenger* shuttle explosion)

Lectures include topics such as safety standards, testing and strategies in different disciplines of engineering, as well as considerations regarding product safety and user safety. Lab demonstrations are focused on conducting engineering practice in a safe manner as to avoid workplace accidents, according to national and European guidelines. We also encountered an example of a module that included a guest lecture given by the safety officer of a national institute. Lab demonstrations are a popular teaching method for conveying content purporting to Health and Safety. This method provided direct exemplifications of the various directives and regulations targeting workplace safety and accident prevention. We also encountered case studies containing historical accidents and disasters used to convey the importance of adhering to safety standards. Historical accidents and disasters offer students the possibility to think retrospectively of the missteps leading to them, as well as on how to ensure safety and prevent future hazards.

8.4.2 Assessment methods used for Health and Safety related coverage

For assessing Health and Safety curricular content, the methods employed include exam questions, laboratory assignments, risk and impact assessments, research projects, design projects and capstone projects, as seen in Table 26.

Table 26. Assessment methods addressing health and safety issues

Type	Example
Exam questions	Describe the hierarchy of standards used to ensure compliance with safety legislation Identify safety issues in the context of system failures, equipment design and human factors. Explain the use and operation of safety systems
Laboratory	Health and safety practices on site
Risk and impact assessment	Identify hazards as per the international standards Conduct a risk assessment of a product or process Write standard operating procedures for experimental work Generate a structured safety statement for a work area in the college.
Research projects (report; poster, presentation)	Identify societal risks and hazards of new technologies Analyse human consequences of accidents and how these accidents could have been avoided Outline the theory and the application of safety management to a historical case study (Piper Alpha tragedy, Texas BP explosion)
Design projects	Ensure compliance with safety requirements based on existing standards and regulations Include safety strategies in the design of automated equipment
Capstone projects	Include risk assessment rubric.

Exam questions are used to test students' knowledge of standards and legislation purporting to safety, to identify safety issues or explain the use and operation of safety systems. Laboratories offer the possibility to verify the practical application of health and safety considerations on site. Conducting a risk and impact assessment is a popular assessment method, which asks students to identify safety hazards according to national and international guidelines in respect of a specific engineering process or product. An example of risk assessment required from students is to develop a safety statement by considering a specific work area in their college building. All capstone project modules analysed include safety considerations in the form of a mandatory rubric of risk assessment. Design projects also require risk assessment prior to implementation, as well as the inclusion of safety strategies. Research projects have been used in assessment for targeting students' understanding not only of workplace safety but also of societal hazard prevention. New technologies are seen as an avenue for enquiry regarding their prospective risks, while historical accidents and disasters can be used to assess students' application of safety management measures to concrete examples. Instructor L13 introduces safety considerations in assessment by asking students to "produce a poster where they are looking at the introduction of robots in agriculture, and as part of that they have to write a section on the ethics or the ethical reasoning about it," which includes an analysis of "the complications and what we need to be aware of in terms of what can happen, what are the safety implications."

8.5. Legislative related coverage in the engineering curricula

As seen in Table 22, legislative related coverage is another popular thematic area, present in 45 (54%) of the participant modules with a high contribution to outcome E. The topics mentioned in connection to the teaching and assessment of the legislative theme are national and international standards, directives, regulations, and legislation, CE marking, product liability, contract documents and planning requirements, policy making, intellectual property and patent law, security, privacy and GDPR. Of these topics, the highest emphasis is placed on national and international standards, regulation and legislation, present in 36 unique module, followed by policy considerations, which are present in 6 unique modules, and intellectual property and patent law, which are present in 5 unique modules.

The inclusion of legislation related issues in engineering ethics education is seen as prompting engineers to take a more active role in policymaking. As such, instructor L10 singles out the medical profession, who "takes a role in advising the governments and in regulating, a much stronger role than the engineering profession has." L10 mentions the "massive societal challenges ahead now with climate change" as the reason for opting for the inclusion of regulatory and legal issues in engineering ethics education to prepare "the engineering profession as a whole for stepping up to that. I guess that begins in education." This viewpoint is shared by instructor L6, who agrees with the inclusion of regulatory and legal issues in ethics education, such as "environmental directives," the "precautionary principle" and the "polluter pays principle," in order to prepare students to address the problems raised by climate change. Instructor L9 supports the inclusion of legislative issues, stating that "it needs to be integrated because a lot of the ethical questions are around the edges of legal questions," while another considers that "when regulations, policies and the law are complex, and there are many grey areas, this is where ethics is very important."

Nevertheless, participant observation revealed confusion encountered at programme level whether legislative issues such as intellectual property or the development of invention disclosures fall under the scope of outcome E. As such, a module on Innovation and

Entrepreneurship[27], offered by institution Uni F, which featured among its learning goals "evaluating and understanding intellectual property," and "creating an invention disclosure" was self-assessed as having no contribution to outcome E. This is also the case with an introductory module dedicated to regulatory issues. The justification provided by this instructor regarding the self-assessment of the module's contribution to outcome E is that "the module does not explicitly feature the word 'ethics', and that is why I do not mention it or consider it for scoring outcome E."

8.5.1 Teaching methods used for legislative related coverage

The theme is incorporated through taught components such as lectures, lab demonstrations and case studies, as seen in Table 27.

Table 27. Teaching methods addressing legislative issues

Type	Example of content
Lectures	National and international standards, directives, regulations, policies and legislation. CE marking. Product liability. Contract documents and planning requirements. Intellectual property and patent law. GDPR
Lab demonstrations	Health, Safety and Welfare at Work Regulations, National Rules for Electrical Installations (ETCI Regulations), European directive on operating machinery
Case studies	Whistleblowing in the context of legal requirements and protection

Some of the frequent topics included in lectures revolve around standards such as ISO2600 on social responsibility, safety standards and quality assurance standards such as ISO9000. Intellectual property is another frequent thematic topic mentioned in lectures across all disciplines. Discipline specific issues are addressing contract documents and planning requirements in Civil Engineering, GDPR in Computer Engineering, Environmental directives in Environmental and Energy Engineering programmes. Lab demonstrations have been used to teach students about conducting engineering practice in a safe manner as

[27] Specific name of the module replaced with a general module category, to ensure anonymity;

to avoid workplace accidents, based on the guidelines set in the Safety, Health and Welfare at Work Act, operating machinery at work set in the 2006/42/EC Directive or for operating electrical panels stated in the National Rules for Electrical Installations. Dilemmas related to whistleblowing has been a popular topic in the case studies employed, giving rise to discussions related to the protective measures and legislation needed.

8.5.2 Assessment methods used for legislative related coverage

For assessing legislative related coverage, the methods employed include exam questions, research projects, design projects and capstone projects, as seen in Table 28.

Table 28. Assessment methods addressing legislative issues

Type	Example
Exam questions	Describe the hierarchy of standards used to ensure compliance with safety legislation Reflect on a specific policy Recall measures for protecting intellectual property
Risk and impact Assessment	Identify hazards as per the international standards Conduct a risk assessment of a product or process Write standard operating procedures for experimental work
Research projects (reports, presentations, posters)	Evaluate policies Prepare SEA/EIA projects in complying with statutory and public hearings Develop an invention disclosure
Design projects	Define core issues relating to intellectual property within a device design Integrate requirements based on existing standards and regulations
Capstone projects	Includes risk assessment rubric. Legislative considerations can be included in a contextual section.

A key issue emphasised by several instructors is the importance of having assessment that encourage students to “apply legislation and standards to real life examples.” This can obtained by conducting a risk assessment of a specific product or process, preparing an invention disclosure or a SEA/EIA project in compliance with statutory and public hearings, as well as by integrating legislative requirements in the design of a product. It is also considered important to assess knowledge of various legislative stipulations, by asking students to recall their formulation in exam reports. Critical reflection is encouraged by adopting assessment methods that encourage students to evaluate a specific policy or formulation.

8.6 Key findings

In examining the curricular content of the modules deemed to have a strong contribution to outcome E, the study noted a particular emphasis on the inclusion of sustainability, health and safety and legislation across the engineering curricula, as these topics are present in a variety type of modules.

There are two major characteristics of the prevalence of addressing ethics through the prism of sustainability, legislation and safety. First, compared with other thematic areas, these themes have a particular strong presence in technical modules. Second, these themes are closely linked to the conceptualisation of ethics in practical terms described in Chapter 5 and the instruction through realistic case studies reflecting the context of engineering practice. It can be argued that while the development of propositional and theoretical technical knowledge is the locus of concern when exposing students to the technical dimension of engineering (Radcliffe, 2006, p.263), in engineering ethics education the emphasis is on the practical application and situational responses enabled through *phronesis*.

Reflecting on the integration of ethics through sustainability, it has been argued that higher education institutions are "far from reorienting themselves towards sustainability" and that sustainability appears to be "integrated in a piece-meal fashion" (Lambrechts *et al*., 2013, p.64). While it cannot be said that the implementation of sustainability is carried in a systematic and even manner in the programmes in the study, what does emerge is a desire to address ethical issues through the prism of sustainability. A foundation in ethics relating to sustainability is seen by Biedenweg et al. (2013, p. 7) as a critical component in the education of engineers because it provides “a structure for understanding the moral basis for decisions about which technique or strategy to employ.” Sustainability indeed appears to be the most popular topic used to meet programme outcome E. An advantage is that sustainability is a thematic area that can be tailored to the expertise of engineering faculty and is appealing to engineering students. The downside of this is that sustainability becomes associated with its environmental dimension and less with the social and economic dimension. Following Jamison’s (2013, p. 39) observation that in Denmark “many engineers […] learned how to build wind energy plans and connect the electricity into the power grid, but very few of them have learned how to make Denmark sustainable”, it is important to enquire how a sustainability focus in engineering ethics education can contribute to the transformation of society into a more sustainable direction. As Jamison (2013, p. 39) further notes, engineering students “have learned to solve problems with technical solutions, (n.m. but) they have not learned much about the problems that need to be solved.” An issue then is how we can use this desire to focus on the coverage of ethics through sustainability and legislation as a mechanism for broadening engineering education and more fully integrate the technical, the social, and the environmental dimensions of engineering in one comprehensive form of education, as proposed by Nicolaou *et al.* (2018) and Schank *et al.* (2019).

Another key finding is the extent to which what might be considered macroethical issues are included. For example, if we combine items related to sustainability, legislative aspects, the societal dimension of engineering, responsibility and community engagement, we can see that these themes associated with the macroethical approach outnumber themes associated with the microethical approach, such as health and safety, professional ethics, ethical theories and plagiarism. Existing research points out that a focus on sustainability and policy may facilitate the broadening of engineering ethics education beyond a micro ethical approach (Herkert, 2000b; Gorman *et al.*, 2000; Conlon & Zandvoort, 2011; Byrne *et al.*, 2013; Bekker & Bombaerts, 2017). The integration of these thematic areas through a macroethical lens is considered to empower students to address the pressing socio-political, socio-economic and biophysical aspects of environmental problems (Warburton, 2003; Bender, 2012).

In examining the curricular content of the modules deemed to have a strong contribution to outcome E in terms of the debates explored in the literature review, the study notes a similar low engagement with philosophical theories as pointed out by Hess and Fore (2018). While professional ethics aspects such as rules and codes are often touched upon, these do not represent the main focus for the integration of ethics, confirming the findings of Hess and Fore (2018).

The study also brings to light the existing confusion as to what counts as ethical content. The theme of Health and Safety, for example, revealed itself to lead to problematic understandings regarding whether its coverage falls under the scope of outcome E or not. While some instructors were unaware that curricular content related to Health and Safety falls under the scope of ethics, other instructors interpreted this contribution to outcome E solely through the lens of its mathematical and technical application, with no discussion of the safety considerations involved by these calculations. A similar challenge was remarked in connection with the coverage of legislative issues such as intellectual property and protected disclosures, with some instructors unaware that these fall under the scope of ethics education. The confusion as to what counts as engineering ethics education has been previously pointed out by Reed *et al. (*2004, p. 169), especially in connection to topics such as "copyright, building codes and other similar concepts covered in technology education." The study also encountered confusion in the understanding of plagiarism as an engineering ethics issue, when this theme was in fact presented to students as an issue regarding academic honesty and integrity. The study also found that in the case of computing and programming modules, plagiarism understood as use of copied source code was rarely addressed. This topic is one in which the understanding of plagiarism in engineering ethics terms overlaps with its understanding as an issue of academic ethics. This finding reminds of the confusion as to what counts as plagiarism in ICT engineering (Cosma & Joy, 2008; Baugh *et al.*, 2012, Simon *et al.*, 2014, Simon *et al.*, 2016).

CHAPTER 9 THE PROCESS OF EVALUATION OF PROGRAMME OUTCOME E FOR ACCREDITATION

This chapter contributes to objective 9 described in chapter 4, aiming to identify patterns in the response of the accreditation panels to the documentation, evidence and self-assessment scores put at disposal by the participant programmes in connection to outcome E. While the emphasis is placed on aspects of the accreditation process specific to outcome E, other aspects described in this chapter are valid for all programme outcomes.

After describing the methods employed, the chapter proceeds by examining the response of the evaluation panel to the self-assessment scales employed by the programme, the organization of evidence, the consistency between self-assessment scores, supporting evidence and the reality of teaching practices, and to the weight given to programme outcome E by the participant programmes.

9.1. Methods

Three research methods have been employed in the analysis that is the subject of the present chapter. One of the research methods employed is documentary analysis of the accreditation reports of 11 programmes offered by institutions Iot A, Iot B and Uni D. The accreditation report of programmes offered by Uni C, Uni E and Uni F, as well as Iot A3, are excluded from the analysis on grounds that the documents were not issued by the end of 2019. The second method is represented by participant observation at three accreditation events, of 11 programmes offered by institutions Uni C, Uni E and Uni F, during June 2018-March 2019. During the accreditation events, preliminary recommendations have been formulated that will be integrated in the accreditation report. The document analysis is based on rubrics present in each accreditation report, such as notable features of the programme, judgement on how the programme meets outcome E and recommendations targeted at outcome E.

During participant observation, a verbatim transcription was undertaken, which included statements made by the academic team of the participant programmes, evaluator panels and the representatives of accrediting body, employers, students and graduates of the programme. Notes have been made about the evidence put at disposal by the programmes in the form of module descriptors and student assignments. Finally, the research study also employed interviews with evaluators, which would allow for an in-depth exploration of initial findings revealed through participant observation and documentary analysis.

9.2 Response to the self-assessment rubrics employed by the programmes

The documents submitted by the 23 participant programmes for accreditation point to an uneven process of self-assessment of outcome E and of documenting this self-assessment. As Table 13 showed, there were 5 types of self-assessment scales employed by the 23 participant programmes to convey the contribution of their modules to the seven programme outcomes required for accreditation. The usage of different types of self-assessment rubrics comes despite the recommendation of the accrediting body for programmes to POLO scores of 0-4 (Engineers Ireland, 2015).

This divergence is acknowledged in a statement made by a representative of Engineers Ireland during an accreditation event, who remarked that “no two places are doing it (n.m. the self-assessment process) the same from what I’ve seen. It is the human condition.” During interviews, evaluators agreed with having encountered different ways of self-assessing the programmes’ contribution to these outcomes. While the existence of a self-assessment rubric is considered by evaluator E3 “a starting point” for analysing evidence in support of each programme outcome, he adds that the result of this self-assessment process is “chaotic,” and that

> every college does it differently. I would say every accreditation visit I have been on, the panel has to spend a good bit of time understanding how that college applied

> that rubric. I cannot provide a better solution. So is it good? It is better than nothing. But I would describe it currently as chaotic.

During the participant observation of institution Uni F, evaluators expressed dissatisfaction with the scoring rubrics used, stating several times that they cannot follow the scoring system employed by the programme for self-assessing the attainment of the programme outcomes. The rubric has been characterised by evaluator E10 as “messy.” Institution Uni F was the institution with the most varied type of self-assessment rubrics employed, and the only institution which did not employ the 0-4 scale for the self-assessment of any of its programmes undergoing accreditation.

This confusion about the development of self-assessment rubrics can be perpetuated by the contrasting comments made by different members of accreditations panels to the programme teams responsible for the preparation of the accreditation process. For example, evaluator E5 for the programme Uni E3 was an evaluator for the prior accreditation event underwent by programme Uni F3. During the accreditation of programme Uni E3, E5 expressed dissatisfaction with the use of the 0-4 scale for self-assessment, suggesting that a self-assessment in terms of splitting the overall contribution of a module between programme outcomes would be more beneficial in rendering the profile of the graduates. E5 made the following comments to the programme chair of Uni E3 during the accreditation visit:

> Evaluator E5: Weighted averages have little variation. The profile of your graduate engineer has a 3.6, next 3.5 on outcomes A and B. This is little variation. The lowest score is on outcome E. This is not really telling me what the profile of your graduate is like. I am curious what were the discussions about the weights.
>
> Programme representative of Uni E3: We explained to individual instructors what is asked, what 4 means, what 3 means. There is variation in meaning. We had less control outside our own area. We will be with you to find evidence. Or we can even recalculate the numbers
>
> Evaluator E5: Did you mess with those numbers, try see what it leads to?
>
> Pr. Repr. Uni E3: No, we left the raw data.

> Evaluator E5: Another anomaly: a Physics module on semester I scores 0 for outcome G, but in the second semester it scores similar for all outcomes, until outcome G, when it scores 4. Is there really such a difference between semester I and II in terms of communication? Did you guys dig into that?
>
> Pr. Repr. Uni E3: No, maybe there is an element of continuous assessment. We believe in academic integrity and trust our team.
>
> Evaluator E5: One adjustment would be to make weighted averages by year, rather than total.
>
> Pr. Repr. Uni E3: If you take outcomes A, B, C, D people know what these are. But E, F, G, if you are a scientist, an engineer, you might not even know what those mean. Someone might give a 4, other a 1. Those are hard ones.
>
> Evaluator E5: Maybe give them a number and it is up to them to divide it across outcomes.

During the same accreditation event, at another session bringing evaluators together with faculty members, E5 made similar comments about the self-assessment rubrics employed by the programmes:

> Evaluator E5: Now the agenda is to refer back to the anomalies in weighing the heatmaps ...
>
> Instructor 7 (Uni E instructor, interrupting): You get burned in columns A and B (n.m. the columns for outcome A science and technical skills and knowledge and outcome B problem-solving).
>
> Evaluator E5: Some programmes do not even have scores, only shades of green. These are anomalies. I recommend moderating the data you get from colleagues and consider a normalization process, to ensure that the weighted averages carry a statistical significance. A need for 4s to be 4s. And sometimes there are 0s who are not 0s. An example, I could not believe this one, is this Mathematics module[28] which gives 0 for problem solving.
>
> Instructor 7 (Uni E instructor): It (n.m. outcome B) says ability to solve engineering problems, and they might think math problems are not engineering problems.
>
> […]
>
> Evaluator E5: Do not jump off your skin if you see a recommendation about normalizing and moderating the scores.

The final session of the accreditation event for the five programmes offered by institution Uni E has indeed revealed among the preliminary set of recommendations voiced by E5 a

[28] The name of the module was modified to a generic topic category to protect anonymity

“strong need to moderate the data in the heat map and consider the option of normalizing it.”

During the accreditation event, the programme chair of Uni E3 provided a tentative new scoring to the evaluation team, prompted by the dissatisfaction of the evaluator with the (n.m. recommended) 0-4 scale employed. It is notable that the approach suggested by E5 for dividing a fixed number across the programme outcomes is exactly the approach used for the current accreditation process by the Uni F3 programme, to which E5 served previously as an evaluator. The programme chair of Uni F3 justified their usage of the self-assessment scales because they “thought we have given the panel what is needed.”

This seems to suggest that programme teams tend to adopt the self-assessment process suggested by accreditation evaluators, and the evaluators’ suggestions have an important role in this regard. It is thus important for evaluators to communicate to programme teams a coherent and cohesive message about the self-assessment process and scales to be employed during accreditation events. Notwithstanding, during the three accreditation events observed by the researcher, several evaluators as well as the representative of Engineers Ireland made numerous explanatory comments to the programme representatives that the expected self-assessment scale is the 0-4 scale described in Table 8.

The document analysis of accreditation reports also showed comments about the self-assessment scales employed by the programmes. In the case of programme Uni D4, the panel notes that “heat maps were created indicating how each programme outcome was achieved: a number of iterations of these heat maps were presented.”

Based on the response of the evaluation panels to the self-assessment rubrics employed by the programmes, it seems that evaluators have strong responses to what they perceive to be an improper development of this rubric. It can also be noted that the programme teams made attempts to show that they tried to address and correct the shortcomings perceived by the evaluation panels in this regard, by providing new calculations during the event or by adopting the suggested scale for the next accreditation event. Nevertheless, evaluators have expressed contrasting messages about which type of self-assessment rubric is preferable, having recommended other approaches besides the 0-4 scale recommended by the accrediting body. This suggests the importance of evaluators passing on a correct and unitary message to the programme teams about which self-assessment rubric style to adopt, given the programmes' tendency to adopt it.

9.3 Response to the organization and display of evidence

The first joint session of the accreditation event for the programmes of Uni E was opened by a representative of the accrediting body, who offered advice on how evaluators should relate to evidence. The representative stressed the importance of clear evidence, prompting the evaluators to "ask the academic team to show the evidence if it is not clear. Do not go searching through all the room. The evidence should be clear."

Participant observation has revealed that there were several issues highlighted by evaluators in regards to how the programmes displayed and stored evidence. Evaluator E7 described the evidence put at disposal by Uni F1 as "appallingly displayed and presented, […] in boxes by year and not by module. We received the evidence for all modules of a year in one box." Evaluator E5 also commented about how the evidence was displayed by Uni E3, suggesting that

> Evaluator E5: Maybe present it by outcome, instead of module. It would make it easier.
>
> Evaluator E16: More online documents, and an easier access online.

> Instructor 1 Uni E3: Last time we did by outcome and a representative of Engineers Ireland[29] told us to do it by module next time.
>
> Evaluator E5: In a previous visit at our institution, the panel was very angry that we did it by module, during the representative of Engineers Ireland's predecessor. In my view, arranging it table by table is good.

From the suggestions made by the two evaluators E5 and E7, we can see that programme representatives can be exposed to contrasting recommendations. While E7 and the representative of Engineers Ireland suggested that evidence should be displayed by module, evaluator E5 recommends displaying the evidence by outcome. Notable is also the comment made by the evaluators' panel in the accreditation report issued to programme Iot B2. The programme was commended for how the evidence was displayed by programme outcome, with the panel commenting that "the evidence in the evidence room was set out by Programme Outcome and this facilitated the Panel's efforts to find the evidence for the achievement of each Programme Outcome." The positive comments about the way in which the programme Iot B2 displayed the evidence by outcome is contrary to the comments made by the representative of the accrediting body and the majority of the evaluators during the accreditation events observed by the researcher, who recommended the display by module.

These contrasting suggestions can be responsible for fostering confusion among programme teams about which approach to the process of self-assessment is best and should be followed for the next accreditation event, and could explain the discrepancies encountered. Notable is that evaluator E5 is the one who also suggested the adoption of a self-assessment scale that is not the scale recommended by the accrediting body for programmes Uni E3 and in the past for Uni F3.

[29] Name was changed with affiliation to protect anonymity

The document analysis of accreditation reports also revealed comments made by evaluators in regards to the display and organization of evidence. On a positive note, programme Iot B4 was commended for the preparation of the accreditation documents and evidence, the evaluators having noted that "the accreditation report was very well written and structured. The evidence was complete and well organized and demonstrated." About programme Iot B3, the panel noted that it was "satisfied with the quality of the documentation, sample work, data etc. presented" and that "information was well presented." The evidence displayed by programme Iot B5 was also positively highlighted by the evaluators' panel, due to the fact that "the material was very well laid out and it was relatively easy to track the outcomes down to individual assessments." The panel noted about programme Uni D4 that "the evidence room was organised by year, with boxes created for each module."

The accreditation reports also feature negative comments about the programmes' display and organization of evidence. In the case of one programme, Uni D2, the accreditation panel notes in the accreditation report that upon "reviewing the submitted documentation," the accreditation visit was postponed to a later date due to "a lack of clarity regarding the delivery of the seven programme outcomes and their linkage to the various modules," which "made it more difficult to assess the outcomes and to confirm that they were being achieved.."

The interviews conducted with evaluators highlighted the variation between programmes in the display of evidence. Evaluator E6 considers that "there is great variability in how the different sites prepare their evidence room." Evaluator E5 is of a similar opinion, according to which evidence preparation

> varies enormously. It really does. Some places do put in a big effort, there is no doubt about it, and some places put in an absolutely minimal effort. […] So I have been in some very difficult situations, I must say, where there were multiple

> problems. The problems being that the documentation we got was bad and the evidence was very scant.

Instructor L12, who served as the chair of the evaluation panel for the accreditation of programme Uni D4 as well as “at least 10-15 accreditation events,” agrees with the variation in how programmes prepare evidence. Describing programme Uni D4, L12 mentions that the evaluation panel encountered “big problems with some aspects of their self-assessment, that they had made some big claims about some things. But we looked and felt that they were not there.” L12 noticed an improvement in the last decade regarding the organization of supporting evidence, but also notes that “in the last couple of years I have been on an accreditation that has not been successful for various reasons (n.m. of programme Uni D4), so not everybody still gets it right.”

From the response of the evaluation panels to how the programmes opt to organize and display evidence in support of the outcomes, it is evident the confusion and lack of clarity as to which approach should be followed. This confusion is present both at programme level and at the evaluators’ level. We can see that programmes have opted to display the evidence in various ways: by module, by programme outcome, but also by year. Although the latter approach has been unanimously deemed confusing, for the other two approaches the programmes received contrasting feedback as to their suitability. This seems to suggest that evaluators do not show a unitary front in the suggestions and recommendations they put forth in regards to the organization and display of evidence.

9.4 Response to the consistency between self-assessment scores, supporting evidence and teaching practices

Besides the different self-assessment scales employed by the participant programmes, there are also discrepancies in the interpretation of the scores. The first common theme that emerges from the analysis of accreditation reports and participant observation is the discrepancy between self-assessment scores, the evidence put at disposal by the programmes and the 'actual' teaching practices, as perceived by the evaluators.

During the first day of the accreditation of programmes offered by institution Uni E, when the panels convened for the lunch break, the following discussion ensued from a comment made by the representative of the accrediting body

> Representative EI: When we return, look at evidence, as there are many 4s out there.
>
> Evaluator E5: We already grilled them. They let their instructors choose their score.
>
> Evaluator E17: I guess no one will want to say their module contributes 0.
>
> Evaluator Chair (retired instructor): There is nowhere written that each module should contribute 4s to all outcomes.
>
> Representative EI: You would get your diploma after three modules.

The issue of uneven scoring was highlighted again during a joint session that brought together the evaluator panels and the academic teams to discuss the evidence and scoring:

> Evaluator Chair (retired instructor): "Another issue is about the tables with various contributions of modules to outcomes. Some seem realistic, other really enthusiastic. Some modules hit a 4 on all programme outcomes. Any comments about that from evaluators?"
>
> Evaluator E13: At any point during the process did the whole team come together and work at scores and challenge each other, why each score?
>
> Programme representative Uni E3: We trust each other as professionals, in areas specific to our discipline. But some modules are outside of our control: Chemistry, Physics. We did not try to think what they meant by this score.
>
> [discussion continues about the scoring for MA programmes undergoing accreditation, before it switches back to the BA programmes]
>
> Evaluator Chair (retired instructor): Looking at evidence, in some cases, you will not find it. Try to look for it yourselves. What does this module contribute to: environmental issues, ethics, how does it contribute to that?

After analysing the evidence, the panels stated in a private meeting the following conclusion regarding the mismatch between scores and evidence:

> Evaluator E14: Some modules claim less, as 2 what should be a 4; others claim 4 for what should be 2.

> Evaluator E13: They need training in how to deal with scoring.

> Evaluator E15: The description of the scores was vague, but it was the only guidance for which modules focus strongly on what.

The statements made by evaluators E13 and E15 point to one possible root of the mismatch between self-assessment scores, evidence and practice, related to the vagueness of the scores and the lack of guidance for their interpretation. In addition, the self-assessment process is also a subjective one, as highlighted by evaluator E4. These remarks highlight the need for more detailed guidance and training sessions about how the programmes should carry out the self-assessment process.

The issue of the mismatch between scores and evidence offered by the programmes of institution Uni E was expressed strongly for several modules related to different programme outcomes. During a session bringing together evaluators and academic teams, E5 mentioned what he considered to be an “anomaly,” a mathematics module which scored 0 for problem-solving. Another two “anomalies in the heat map” pointed out by E5 in connection to outcome E were two technical modules.[30] One module was assigned a 2 and the other a 4 for outcome E, based on an assignment with an inverted pendulum:

> Evaluator E5: It had a 4 given that stability is important. It seemed a bit tedious to link stability of the inverted pendulum with ethics and safety. It is not sufficient for ethics.

> Instructor 7 Uni E3: I think you are probably right.

> Instructor 8 Uni E3: I am a stabilist and I am with the instructor on this one. It is about the ability to certify that issues are safe.

> Evaluator E5: I would rate it as a 2 rather than a 4.

> Instructor 8 Uni E3: Even after I explained?

[30] The name of the modules were omitted, being replaced with a generic topic category, to protect anonymity.

Evaluator E5: Yes, it is just an exercise about stability.

Instructor 8 Uni E3: I disagree. It could not be an inverted pendulum, it can be an airplane.

The mismatch was further emphasized in regards to outcome E during the accreditation event of the programmes of Uni F. After analysing for 40 minutes the evidence for outcome E prepared by programme Uni F3, evaluator E8 states:

ethics is quite thin. According to the scores, it should be covered in year 3, and yet here it is very thin. I do not think the scores reflect the evidence. In this design module[31] which scored higher there is no mention of ethics.

To this statement, the representative of the accrediting body adds that "there is a mention of utilitarian ethics, but there is nothing in the evidence." Later, at the same accreditation event, the discussion between evaluators E8, E10 and a representative of the accrediting body continued in a similar manner in regards to the lack of evidence for meeting outcome E:

Representative EI: Are people happy outcomes have been achieved?

Evaluator E8: In general yes, but not much evidence about ethics. More about regulations rather than the effect on society.

EI: What about work placement reports?

Evaluator E8: No, not even where you would expect, in reports that deal with self-driving cars for example.

Evaluator E10: The reports were extremely thin, some were two pages where they say they did this, they did that.

EI: Maybe final year reports should have a chapter on ethics. Some programmes require it.

The mismatch between evidence and scores has been noted also by the researcher during participant observation. While analysing in detail the module descriptors and evidence provided by the programme Uni F3, in conjunction with the POLO scores for outcome E, the researcher identified several discrepancies. Four modules offered by the programme Uni

[31] The actual name of the module has been replaced by the researcher for avoiding identification.

F3 recorded a lower self-assessment score and three modules recorded a higher score than suggested by the evidence put at disposal during the accreditation event. For example, a module that addressed intellectual property scored 0 and did not count this coverage as pertaining to outcome E, while another module offered by the same programme that addressed intellectual property considered this topic for meeting outcome E. A first year professional formation module that addressed several topics in connection to outcome E was self-assessed with 0 for this outcome, considering that this category of modules typically has one of the strongest contribution to meeting outcome E and are self-assessed the highest by engineering programmes. A low self-assessment score for a professional formation module was also encountered in the case of the programmes of Uni D. A community based course offered by Uni F2 which was described as aiming "to fulfil a real need in the community by providing a means of connecting students' academic study with community and society, with the explicit intention of promoting active and responsible citizenship" was not assessed with the highest score for outcome E, despite the significant evidence purporting to ethics.

The issue of how, in some cases, the evidence fails to match the reality of practice was brought up by representatives of Engineers Ireland and evaluators during the accreditation events of programmes in all three institutions observed, Uni C, Uni E and Uni F. The representative of the accrediting body made a remark in regards to scoring and how the evidence put at the disposal by the programmes of institution Uni F match the teaching practice, noting that "there are no deficits on programme outcomes, the problem is with the evidence. Ethics should be referenced explicitly in projects." At a later time during the event, when the panels of all five programmes of institution F grouped to discuss their preliminary findings, the representative of the accrediting body spoke on behalf of the Uni F3 panel that he joined throughout the day, noting that "the way the evidence was mapped out made it difficult to assess." This observation was strengthened by the statements made by the panel evaluating the programme Uni F2, according to whom "the scoring was also something we were not happy with. It was colour coded (n.m. shows the self-assessment rubric in the programme document) and divided and focused on learning across programmes outcomes, with projects in final year." The panel evaluating programme Uni F1 also commented on the evidence and scoring:

> evidence was appallingly displayed and presented. Evidence was put in boxes by year and not by module. We received the evidence for all modules of a year in one box. Did not use scale 0-4, did the scoring on credits. It does not reflect if the modules contribute to the programme outcomes and some 0.3 and 0.4 ECTS modules were some of the strongest contributors to a programme outcome. Ethics had little visibility through evidence, but it was acknowledged by students and employers.

A similar sentiment was described during the accreditation event of institution Uni E, with evaluator E5 noting in regards to all programme outcomes that "the major issues were the weighing, but it is not to say that the programme does not deliver on the learning outcomes. It made it more difficult to assess."

In regards to the scores, evaluator E10 mentioned several times that the scores provided by the programmes of institution Uni F were "uneven." This is the case with other outcomes, as one evaluator points out about outcome G that "the breakdown for communication does not correspond to the state of affairs. It is either less or the evidence does not capture it well." Evaluator E2 made a similar comment about the programme Uni E1, noting that in the case of outcome E, "some 4s should be 2s, some 2s should be 4s."

The interviews conducted with evaluators have revealed a strong impression left by the lack of allignment between self-assessment scores, supporting evidence and the reality of teaching practice. Evaluator E6 gives the most detailed description of this situation. In his words:

> I think that the programmes that understand the matrices [n.m. the self-assessment rubrics] best, would have very bright stickers on everything that they wanted to emphasize, and they would emphasize the evidence that is usually hard to find. I think programme outcome E is the most difficult of the outcomes to find sufficient evidence to back up that this programme outcome is being met. And so programmes are trying to flag this everywhere. Quite often, what we will find is that the panel members will have to extract more explicitly the information from the programme teams by questioning, because usually we find it very difficult to find the physical evidence. It is always there, but it is never properly identified. But when you question the academic team, we tend to find that there are plenty of examples of where the students are exposed to the concepts of ethics and ethical reasoning.

Turning to the analysis of accreditation reports, the study encounters several references targeting the correspondence (or lack thereof) between POLO scores, supporting evidence and the reality of teaching practices. The evaluation panels of four programmes made remarks that the self-assessed scores did not accurately represent the evidence and the reality of teaching practice, either as an over-estimation or under-estimation of the contribution to outcome E.

There are several negative comments about how the evidence fails to capture the delivery of outcome E. This is the case with the programme Iot A1, which had the second highest POLO score for outcome E, with the panel noting in the accreditation report that "evidence of achievement in earlier semesters is less clear." This was also the case for programme Uni D4, of which the panel notes that

> ethical issues, as distinct learning outcomes, were not, however, clearly (nor immediately) identifiable within all of the material presented for consideration. The panel feels that many opportunities for assessment of PO(e) are missed or not explicitly specified throughout the programme.

In regards to the self-assessment scores presented by the programme Uni D3, the accreditation report notes that

> while the programme team provided guidance on the most important modules that contribute to particular programme outcomes, it was also clear that some "overestimation" and "underestimation" of contribution was made in some cases (most likely due to differences in interpretation of "strength of contribution"

> between different module owners). The Programme Team should attempt to instil greater rigour, consistency and objectivity in the estimation of contribution.

Programme Uni D1, which had one of the lowest POLO score for outcome E, prompted the panel to remark that

> documentation and module descriptors are not capturing all of the features, learning achievements and teaching techniques that are happening 'on the ground," and further, that "for programme outcomes E, F and G sufficient credit has not been attributed in Table 5.5 (n.m. the table containing the POLO scores) of the accreditation documentation, to all the evidence that is available.

On the other hand, we have the programmes Iot B2 and Uni D3, which received a positive mention in their accreditation reports about the evidence presented to the evaluation panels. The evidence provided by Iot B2 in support of outcome E was commended for being "dispersed throughout the four years of the degree." On a more general note, the evidence presented by the programme Uni D3 in support of all outcomes made the evaluation panel affirm that it "was satisfied that the academic level being attained by students on the programme is of a high standard and this was demonstrated by the evidence viewed during the visit." Considering the 11 programmes observed by the researcher, only one programme was praised for the choice of evidence and how it supports the outcomes. In this case, the evaluators commented that they are "satisfied with the documentation and the programme" offered by Uni C1.

The reason for the discrepancies between self-assessment scores, evidence and teaching practices is explained by the evaluators interviewed as being due to the ambiguous description of what type of contribution falls under each score (E2; E5), as well as to the subjective nature of interpretation (E1; E3; E4; E6). As evaluator E2 states, for the self-assessment scores encountered during evaluation, "I could just come up with a completely different one," admitting that self-assessment is "one area of contention that a lot of people that I have spoken to complain, that it is very much open to interpretation." According to evaluator E1, the "ambiguous" nature of the self-assessment process is encountered on both sides, "the side of the panel and from the people giving the evidence."

The data obtained through participant observation of accreditation events, interviews with evaluators and document analysis of accreditation reports shows that evaluators and representatives of the accreditation body react to the self-assessment scales used by programmes, on the choice and display of evidence and on how the evidence matches the self-assessment scores. Evaluators were found to make suggestions to the programmes undergoing accreditation on what type of rubric to employ for the purpose of self-assessment and how to present evidence. With the exception of one evaluator, evaluators stress the use of the 0-4 scale for the self-assessment of how programmes meet the outcomes for accreditation. Evaluators also highlight the disparities encountered between the scores and the evidence prepared or presented on the spot at request, both in the case when the evidence of practice is insufficiently captured by the low score and when there is not enough evidence to justify a high score. It is also notable that outcome E has been highlighted as an outcome more prone to the mismatch between self-assessment scores, evidence and teaching practice compared with technical outcomes.

The findings highlight the importance for evaluators to communicate a common stance on the type of self-assessment scales to be employed and on how the evidence should be displayed, and to pass on similar recommendations in line with the official position of the accreditation body. It is especially important to show cohesiveness in the suggestions and observations made by the evaluators during accreditation events and in the formal accreditation reports given that the programmes show a tendency to adopt these suggestions. The research found that some participant programmes who did not use the recommended rubrics in the self-assessment of how they meet the outcomes for accreditation have received the suggestion to do so at the previous accreditation event.

The data pointing to discrepancies between scoring, evidence and practice highlights the existence of challenges both on the side of the evaluators and of the programmes. In light of the remarks made by evaluators about the meaning of the self-assessment scores for outcome E, there is a perceived need for extra guidance on the interpretation of each score, as well as on what type of evidence and in what amount to expect from each score.

9.5 Response to the weight given to programme outcome E, based on scores and evidence

The document analysis of accreditation reports and participant observation found notable the response of the representatives of the accrediting body and evaluator panels to the weight that ethics appears to have in the participant programmes, as captured through self-assessment scores and evidence. According to the representatives of the accrediting body and evaluator panels, some common traits that seem to arise in regards to the weight given to ethics are related to its variability and low scores.

The representative of the accrediting body deemed the treatment of ethics by institution Uni F as "variable." He further noted in regards to outcome E that "in some programmes, ethics does not have a strong heat map, it was not bubbled up in scoring, but evidence was there." In regards to the integration of ethics by programme Uni F5, evaluator E3 describes that "outcome E is well covered in some modules with no credit. But it needs emphasis on data security, privacy."

During the accreditation event of Uni F1, the evaluators' panel convened the faculty to discuss in more detail their concerns about the scale employed and the unevenness of scores and coverage for programme outcome E. Evaluator E7 made the following statement to open the discussion about the process of self-assessing outcome E in a meeting between the evaluators' panel and the programme team of Uni F1:

> We are here to talk about learning outcomes. Outcomes A and B are very well covered. We have concerns about ethics. About the mapping, usually it is not linked to ECTS, but to scores from 0-4. The numbers can turn low when calculating ECTS. We did not see any of what could be 4s for ethics. Looking at the map, the highest scores were not the ones that contributed the most, and most students failed that assignment. So how do you deliver ethics, how do you understand ethics? Just plagiarism, health and safety, or something broader? We are here to talk about ethics and how broad it is. I was looking on the theses, 200 page theses, with no comments on ethics, and some images were not even referenced. Where is ethics covered? Could we also discuss outcome G? This is how we do, this is how we assess it.

Nevertheless, although we see evaluators such as E7, E8 and E10 concerned with the presence of outcome E in the programme, other evaluators such as evaluator E4 consider that ethics does not need to have the same emphasis compared to technical outcomes. This view seems to be shared by the programme's instructors:

> Evaluator E4: It (n.m. the self-assessment scoring) is so highly subjective. And the situation worsens on E, F, G. What is the endgame here? You calculate based on the worst case scenario? Are outcomes evenly addressed, not evenly addressed?
>
> Instructor 7 (Uni E instructor): Outcomes E, F, G are hit lightly. Clearly, (n.m. the programme) will not be hitting health and safety as much as problem solving, but we are reaching a level of competence.
>
> […]
>
> Evaluator E4: What I am saying is probably is OK to have strong technical modules that do not cover the other E, F, G outcomes. Why should technical modules have an ethical input, if those outcomes are covered in specific modules?

During the final session between evaluators and the academic team of programme Uni E3, it was discussed how the programme outcomes appear to have been met. While the evaluators' comments about outcome A were positive, the comments about outcome E suggest that a seemingly weak curricular presence of outcome E, based on the POLO scores, can be deemed acceptable:

> Evaluator E4: Outcome A is very strongly addressed and plenty of evidence. Everything is very positive.

> Evaluator E5: I strongly agree. It has been a traditionally strong mark of your institution[32] and it should continue.
>
> […]
>
> Evaluator E5: I have to say I am a bit disappointed from the heat map (n.m. the self-assessment rubric) with the coverage in year 4 hitting Outcome E.. Having said that, there is a strong reliance on the professional formation module[33] and business studies module.[34] Those do very much hit the target sufficiently to avoid being a problematic issue. Thus, we are not in a condition territory (n.m. for accreditation).

The preponderance of low scores given to outcome E within a programme appears to be perceived as a common state of affairs. Evaluator E2 declares himself "satisfied with how ethics is covered in the professional formation module[35] by programme Uni C1, adding that there is "only one other course that scored highly, but mostly low scoring." Evaluator E6 responded that "this is mostly the case everywhere."

9.6 Key findings

Summing up the response of the accreditation body to the self-assessment scores, evidence and documentation provided by the participant programmes in support of outcome E, it can be stated that the accreditation panels and representatives of the accrediting body had strong reactions to the self-assessment scales used, the evidence put at disposal and how it is displayed, as well as on how the evidence matches the self-assessment scores and what it is considered to be the reality of practice.

At the same time, there appears to be more attention given to the procedural aspects related to how programmes prepare and display their evidence in support of outcome E, than to ensuring that sufficient weight is given to ethics in the curriculum or exploring the broadness of its treatment. While the lower weight given to outcome E in engineering programmes has been noticed by evaluators, it tends to be considered a common state of affairs, the reasoning

[32] Institution name was omitted to prevent identification.
[33] The name of the module was modified to a generic topic category to protect anonymity.
[34] The name of the module was modified to a generic topic category to protect anonymity.
[35] The name of the module was modified to a generic topic category to protect anonymity.

being that ethics does not need the same emphasis in the engineering curriculum compared to technical oriented outcomes. The study supports the view that the existence of an accreditation criterion dedicated to ethics does not necessarily lead to a curriculum which addresses the social and political dimension of engineering practice in a broad manner, nor that accreditation processes adequately interrogate the extent to which programmes address this outcome (Conlon, 2003; Murphy *et al*; 2019). The study thus points to a lower threshold for outcome E of what is judged to be a satisfactory education compared to technical outcomes. This might explain the earlier findings related to the lower weight given to ethics in the engineering curriculum.

In regards to the preparation of the accreditation process, evaluators make suggestions related to the use of self-assessment rubrics and the display of evidence. With the exception of one evaluator, evaluators mention the use of the 0-4 scale for self-assessing how programmes meet the accreditation outcomes. Evaluators also highlight the disparities encountered between the scores, the evidence displayed and what is perceived to be the reality of teaching practice, both when the evidence of practice is insufficiently captured by the low score and when there is not enough evidence to justify a high score.

It is also important to highlight the confusion encountered both at programme and evaluators' level on how to conduct the self-assessment process, what type of rubric to use, how to interpret the POLO scores and what strategy should be used for displaying evidence. These findings are congruent with US research highlighting similar challenges encountered by programmes and evaluators alike in the treatment of evidence in support of ethics and the need for more guidance provided by the accreditation body (LeBlanc, 2002).

CHAPTER 10 ARTICULATING THE STATUS OF ETHICS EDUCATION IN THE ENGINEERING CURRICULA

The previous chapters revealed a series of important findings about the current state of engineering ethics education that point to the lesser status of this discipline in the engineering curriculum. More specifically, the findings have shown that ethics is the programme outcome with the lowest weight in the curriculum of participant engineering programmes. When looking at the way in which ethics is conceptualized, the study also encountered confusion as to what falls under the scope of engineering ethics education and an emphasis on its practical dimension.

The present chapter aims to continue this exploration, by focusing on the beliefs about the status of engineering education expressed at individual and institutional level by the participants in this research study. This allows an examination of the explicit and implicit ways in which the status of ethics in the engineering curricula is articulated. For this, I first examine the status of engineering ethics education according to the participant programmes, based on their own assessment. This assessment is rendered in a numerical manner in the POLO rubric in which programmes estimate how they meet the programmes outcomes for accreditation, and also in a narrative manner in a rubric in which programmes are required to describe how they meet the programmes outcomes for accreditation. The chapter then continues with an analysis of the way in which the instructors and evaluators' understanding of the status of engineering ethics education is articulated in interviews as well as during participant observation.

10.2 What does the programmes' assessment reveal about the status of engineering ethics education?

Based on the numerical self-assessment carried out by each programme, chapter 6 showed that the average score for how the programmes deem to meet programme outcome E (ethics) are in contrast to those for outcomes A (mathematics and scientific knowledge) and B (problem solving), whose average scores are consistently the highest for the 17 programmes.[36] Considering all programme outcomes, the color gradient Table 29 captures a striking image of the existing dichotomy between what traditionally are called "hard" skills and "soft" skills.

Table 29. Averages for the seven programme outcomes for accreditation, by programme

Outcome / Programme	**A** Maths and Science	**B** Problem Solving	**C** Design	**D** Experiments	**E** Ethics	**F** Team work	**G** Commu nication
Iot A1	3.69	3.67	3.22	3.33	2.37	3.11	2.9
Iot A2	3.47	3.16	2.82	2.85	2.41	2.58	2.56
Iot A3	3.38	3.19	2.45	2.38	1.55	1.9	2.19
Iot B1	3.44	3.39	2.24	2.43	1.64	2.53	2.5
Iot B2	3.12	3.35	2.03	1.86	1.87	1.91	1.87
Iot B3	3.3	3.25	2.1	2	1.7	2.35	2.1
Iot B4	3.13	3.3	2.34	1.91	1.99	1.85	2.23
Iot B5	3.22	3.51	1.98	1.8	1.37	1.54	1.58
Uni C1	3.33	3.18	2.28	1.52	0.88	1.21	1.39
Uni D1	2.36	2.19	2.05	1.15	1.05	1.51	1.34
Uni D2	2.06	1.95	1.74	1.01	0.94	1.4	1.51
Uni D3	2.21	2.25	1.89	0.95	0.81	1.18	1.24
Uni D4	2.4	2.3	1.9	0.94	1	1.3	1.15
Uni E1	3.69	3.46	2.49	2.83	1.69	2.2	2.29
Uni E3	3.71	3.63	2.86	2.98	1.7	2.21	2.29
Uni E4	3.74	3.68	2.77	2.77	1.88	2	2.05
Uni E5	3.75	3.57	2.51	2.45	1.66	2.19	2.21
Average	3.18	3.12	2.34	2.06	1.56	1.94	1.96

[36]As mentioned in Section 4.6, only 17 of the 23 participant programmes are taken into account in the calculation of the programme averages by outcome due to the different and incompatible self-assessment scaled employed by 5 of the participant programmes.

The total average POLO scores for each outcome across the participant programmes reveals a strong focus of engineering education on developing skills traditionally associated with engineering as a technical profession, such as technical, mathematical and scientific knowledge, problem solving and design, which have the highest average scores. As evaluator E11 remarked during the accreditation event of Uni E, it is common for programmes to "get burnt in columns for outcomes A and B," describing the darker shades of colour used in the self-assessment rubric for a strong contribution to the programme outcomes. On the other side, the average scores for non-technical learning outcomes E-G, related to the development of ethics, teamwork, and communication skills are consistently self-assessed with lower averages.

Turning the attention to the narrative assessment of how the programmes meet the programme outcomes, extracted from the documentation submitted for accreditation, a similar distinction between technical and nontechnical skills emphasizing the attainment of the former is encountered in the description provided by the programmes.

For example, programmes Uni F1, Uni F3 and Uni F4 explain the distribution of the percentages across the seven programmes outcomes, by mentioning the distinction between technical and nontechnical outcomes, with the latter being described as "complementary." As such, the programmes consider that

> outcomes can be considered to be in two categories. Programme outcomes A, B, C and D can be viewed as the technical outcomes and are linked to specific achievements in the area of (n.m. the programme's engineering discipline) engineering. Programme outcomes E, F and G are associated with developing a *complementary skill set*[37] in graduates and are generic to most branches of engineering.

Outcomes E-G are described as complementary also by programme Uni F2, who mentions as a graduate objective equipping students with "advanced technical, design, research and

[37] Own emphasis.

complementary skills to be of direct benefit to the profession in particular and society in general."

Programme Uni F5 mentions a similar distinction between two types of outcomes. According to Uni F5,

> while the first four outcomes (A, B, C and D) relate to the acquisition of a sound technical and analytic base, and a mastery of the necessary discipline-specific knowledge, the last three outcomes relate to the practice of engineering in a work and professional context.

Programmes Uni F3 and Uni F4 highlight a stronger focus on the attainment of scientific and technical outcomes, distributed throughout the four years of study, while outcomes E-G are integrated in a few number of modules and module units. It is also notable that outcomes A and B are described as core technical outcomes. According to Uni F3 and Uni F4,

> the science and mathematics subjects result in high contributions to Programme Outcomes POa and POb in years 1 - 2. The majority of Learning Outcomes for science and mathematics subjects are concentrated on Programme Outcomes POa and POb. Many of the Learning Outcomes associated with the *core*[38] technical subjects offered in the later years are directed towards programme outcomes B, C and D. Many modules contribute to the development of problem-solving and design skills from the second year of the programme, with increasing content in later years. The major fourth and fifth year projects contain a significant design, assembly, integration and test focus. Programme outcomes E-G are addressed through modules laboratories/workshops for each module, fourth and fifth year project, the professional formation module[39], and work placement.[40]

Furthermore, programmes Uni F3 and Uni F4 continue to emphasize the distinction between technical and nontechnical skills when describing graduate attributes. The two programmes aspire to produce "graduates with the necessary theoretical foundations, domain-specific

[38] Own emphasis.
[39] The specific name of the module was replaced by researcher to a general module category, to avoid identification.
[40] The specific name of the work placement programme was replaced by researcher to a general module category, to avoid identification.

technical knowledge and practical and ancillary skills” Outcomes E-G are thus considered to have an ancillary role, compared to the necessary role of outcomes A-D.

Programme Uni F2, which employed a self-assessment scale in terms of the percentage contribution to the seven programme outcomes, describes a more consistent contribution to outcomes A-C throughout the programme, while outcomes D-F are described as having a limited but increasing presence from the first to the final year. As such, Uni F2 mentions the

> strong emphasis on the engineering science fundamentals in years 1 and 2. A consistent emphasis on programme outcome B of about 30% across all four years. A strong emphasis on design (programme outcome C), particularly in years 3 and 4. Limited activity in programme outcome D, programme outcome E and programme outcome F in year 1 but increased activity in later years. A strong emphasis on communications (programme outcome G) across all four years. The cumulative distribution shows a good distribution across all seven outcomes.

The programmes offered by institution Uni E also mention the distinction between technical and nontechnical outcomes. As such, the programmes outcomes are described by opposing the core character of outcomes A-D to the complementary character of outcomes E-G. According to the programmes of Uni E,

> Outcomes PO(A) to PO(D) are technical in nature and are linked with particular achievements within the science and art of Engineering. Outcomes PO(E) to PO(G) reflect the complementary, so-called softer skills, which graduates should acquire.

The weight given to each of the seven programme outcomes in the curriculum of participant engineering programmes rendered in Table 29, together with the explanation provided by the programmes of institutions Uni E and Uni F, seem to place nontechnical skills on a different par from technical skills. The participant engineering programmes emphasize the attainment of technical, scientific, experimental and design outcomes throughout the four years of study, viewing them as “fundamental” and “core,” “discipline specific” skills. While ethics alongside the nontechnical learning outcomes purporting to communication and teamwork have their place in a fewer number of modules, and are described as providing a “complimentary” or “ancillary” skill set. The programmes offered by some of the participant institutions are thus seen to explicitly cultivate the dichotomy between what traditionally have been called “hard” skills and “soft” skills.

10.3 How do instructors and evaluators articulate the status of engineering ethics education?

After exploring the implications of the self-assessment undertaken by the programmes of how they meet the programme outcomes for accreditation, the chapter continues by focusing on the opinion on the status of engineering ethics education held at individual level, by the instructors and evaluators interviewed. The status of engineering ethics education is articulated either in an explicit manner, in which participants describe how engineering ethics education is perceived by them or in the engineering academic environment, but also implicitly, by the characterizations they make of the discipline when addressing other issues or informed by direct observation of the accreditation process.

Three main characteristics of engineering ethics education emerge, that point to the lesser status of the discipline. Taking into consideration the interviews conducted with instructors and evaluators, as well as the participant observation at accreditation events, the perception of the lesser status of ethics in the engineering curriculum is reflected in three aspects: (i) how ethics is viewed within a programme, (ii) the expertise of those who teach ethics or evaluate ethics for the purpose of accreditation, and (iii) student reception.

10.3.1 The perception of ethics within engineering programmes

Ethics is described by participants as a “soft” and “non-essential” skill, which is an “add-on” in the curriculum of engineering programmes serving the purpose of meeting the accreditation requirements.

10.3.1.1 Ethics is a soft skill

Ethics is regarded as a soft skill by the participants themselves (L1, L2) or within the institutional environment of the participants (L3; L9; L15).

Describing the perception of ethics encountered in the engineering academic environment, instructor L9 considers that ethics is “always soft and always optional.” Instructor L15 adds that ethics is seen as a “soft skill because you have to know to build the bloody bridge first before getting into ethics. So you have to know your mathematics, your geometry and your trigonometry and all that good stuff.”

Furthermore, soft skills are seen to diminish the quality of an engineering educational programme. According to instructor L2, “some of the colleagues would think you were dumbing down the actual engineering content to make room for these softer skills, not just ethics, but what else has gone in there, teamwork.”

The demarcation between “soft” skills and “hard” skills was highlighted also during the evaluation of how programmes meet the programme outcome taking place at accreditation events. Participant observation revealed that at all three accreditation events, the strategy for approaching evidence followed a similar format, focused on the distinction between “soft” and “hard” outcomes. As such, during accreditation, discussions related to the analysis of evidence led to an agreement among evaluators to distribute their responsibilities such that the panel is “split into a hard and soft outcome each” (evaluator E12). Reflecting on the approach to evidence, evaluator E3 remarks that ethics “tends to be not singled out. It almost happens that the programme outcomes A B and C are discussed as a group and D, E and F are discussed as another group.” There is also less time dedicated to the discussion of how programmes meet outcomes E-G during the evaluation, compared to the time for discussing outcomes A-D.

10.3.1.2 Ethics is not core to engineering

There is also the perception that ethics is not a core skill for engineers, framed in opposition to the fundamental role of technical skills. Ethics is described as a type of “support skill,” that is “other” than technical skills.

In this regard, instructor L5 describes ethics as a “support skill for engineering.” Instructor L6 shares the same opinion, adding that

> ethics does not really fit naturally into these hard technical subjects. […] you can argue about the support skills that they are not directly a skill that an engineer needs. […] One could lock all these things up in a different category and call them 'support skills' or some similar title.

Instructor L3 also opposes ethical skills to technical skills. L3 explains the lower prevalence of ethics due to the fact that “a lot of the engineering projects are technical, they are in a lab, so the ethics component is not very much at the centre of it at all.”

Referring to the presence of ethics in the engineering curriculum “along with communication, teamwork, universal design, health and safety,” instructor L2 notes that these “are not the technical skills, they are the other skills.” Furthermore, instructor L2 describes the problems raised by a crowded curriculum and a qualitative compromise that engineering programmes have to do in order to meet the accreditation criteria. According to L2

> to fit ethics in, you have to take something out, and a lot of my colleagues would think there is less room now for content that has to do with engineering, the fluid mechanics, thermodynamics, that kind of things, because you cannot keep the amount of contact hours the same.

Describing a similar attitude encountered in the academic environment, instructor L11 noticed the perception that

> in a crowded curriculum, […] my instinct is that this might be how ethics is viewed. ‘We do not need to do it, we can do our job without it.. We can do our job successfully and be successful professionals without this part. In fact these hours

> here are taking away from hours where we could actually be engaged in something that is more important for our professional development. Why do we have to do this?’

Instructor L4 also remarks on the negative reaction generated by the introduction of ethics, as “there would have been people who would have been sceptical and they would have thought 'oh, ethics, why are we doing this?'” The presence of ethics in the engineering curriculum is seen to generate scepticism rooted in the view that it is a non-essential component for the professional formation of engineers. Evaluators agree on the non-fundamental character of ethics in the engineering curriculum. Based on the experience of evaluator E2,

> programmes do not see it as important. They probably prioritize having the core skills as an engineer or as a technician as being the primary skills requirement coming from the course, and ethics is something they should maybe be aware of, but maybe it is not the core skill for the engineer or the technician.

Ethical concerns are not seen as an integral part of the profession compared with other professions. Evaluator E1 offers an explanation of why ethics is not considered a core engineering skill. According to E1, engineering practice is divorced from ethical concerns, compared to the prevalence of ethical considerations in other professions, such as pharmacy and insurance. As such, according to E1, “in pharmacy you have life and death situations. But in engineering? […] For engineers the consequences are not so severe.” Similarly, “for insurance and all the rest, ethics must be a very very important consideration in education, but in engineering we are a little bit isolated from it.”

10.3.1.3 Ethics is an add-on

The presence of ethics in the engineering curriculum is not explained in terms of its essential character for the practice of engineering, but is considered to be originating in the requirements set by the accrediting body.

Instructor L9 describes the perception of ethics in the academic environment, noting that "there is a sense this is not core to engineering, this is kind of an add-on that the professional association wants us to do." Evaluator E1 describes the role given to ethics in similar terms, stating that "for the colleges putting the course together, ethics always is a bit like an add-on for a car." Furthermore, instructor L8 remarks on the introduction of ethics in the engineering curriculum as a response to accreditation requirements, stating that "a lot of engineering programmes go 'well, we need to do something about it,' so they do something, and that is good, but it is seen as an add-on."

Given the perception of ethics as an add-on, its implementation in the engineering curriculum is not considered to be conducted in a systematic manner, but as a "box-ticking" exercise. Instructor L9 mentions a sense in which programmes are not invested in the systematic development of engineering ethics education. Engineering programmes are seen to have lower standards and expectations when it comes to the implementation of ethics, as opposed to the implementation of technical outcomes. According to L9, the perception within the academic environment is that the delivery of ethics can be outsourced to one person, through a fit for all pedagogical intervention:

> We are always the ethics work package and the work package is happening somewhere else. It is very difficult to integrate […] because there are different expectations and ethics is often seen as a burden and something that is just annoying, and you have to take the tick the box approach, but it does not really matter. […] People outside of ethics seem to have a sense 'oh, that is just kind of this general ethics module that you can plug it in everywhere. Just give us the general ethics' […] I think there is often the misconception that the ethics person can just come in and do whatever. […] I have been asked 'can you not just give us this kind of ethics module that we can plug into everything?' I cannot.

Instructor L1 adds to this impression of the lower expectations set for ethics education, considering that "ethics seems to be kind of brushed over" in the engineering curriculum. Evaluator E5 agrees that "many institutions still regard it as a sort of troublesome programme outcome and they have to go looking for 'is there anything that we are doing that actually meets it?', rather than really building it in the design of the programme." While technical outcomes are implemented in a systematic manner in the curriculum of engineering programmes, ethics does not receive the same treatment according to E5. As E5 claims,

> if you take technical subjects, like structures or signal processing, the academics will make sure that the design of the programme incorporates these, and in a logical and coherent way. But they do not take the same approach about the ethical material.

Evaluator E1 confirms that it is common for programmes to give a low priority to the implementation of ethics. According to E1, ethics "sometimes might appear like it is tagged on a bit at the end. […] It is not quite an afterthought, but it is probably not given as much importance." Evaluator E2 shares this opinion, stating that "ethics is way down the priority list" and is "mainly there just to cover the requirements of Engineers Ireland, […] but the amount of module content dedicated to it would be minimal."

The lack of a rigorous implementation of ethics conducted at programme level is reflected also in the observation that programmes typically have only one individual that oversees this outcome. Reflecting on his extensive experience as an evaluator, E5 remarks that

> programmes were all relying on this person to show that ethics has been integrated into the programme. […] So I think that institutions have to be made aware that ethics is not something you can just put into a pigeon hole and say 'right, you are the one doing it' and that is enough going to get us through. It needs a lot more attention from everybody, and it need only be to a relatively small degree.

Looking at the perception of ethics within engineering institutions, the chasm between technical outcomes and ethical outcomes is further revealed. Ethics is not perceived to be essential for engineering practice and an integral part of engineering education. The presence of ethics in the curriculum, rather than being organic, is linked to the pressure exercised by the accrediting body, through its formulation of mandatory programme outcomes. As such, ethics appears to be an "add-on," whose implementation can be "brushed over."

The next section further analyses how this view about the lesser status of ethics in the engineering curriculum is reflected in the level of expertise and motivation of those teaching modules with a high ethical content.

10.3.2 Expertise for teaching ethics

As mentioned in the research design chapter, the scope of the interviews conducted was limited to instructors of professional formation modules. This type of modules typically have the highest self-assessment scores for how the participant programmes meet outcome E, and are also singled out during accreditation events and in accreditation reports as comprising the main teaching unit that meets programme outcome E. Given the important role that modules of professional formation have in the engineering curricula to convey content related to ethics, it is important to enquire how motivated and prepared the instructors interviewed consider themselves to be to teach ethical content.

Exploring through interviews the familiarity with the topic, as well as the process of preparation for teaching a module of professional formation, several instructors expressed their unfamiliarity with the topic. Ethics is considered to be "a harder subject to teach because it is softer" (L1), and "can always be farmed out to the youngest staff member" (L9). According to L4 "I am not qualified to teach that," and L1 notes that despite her lack of familiarity with the topic, she was chosen to teach this module due to her professional experience in the private sector. L1 considers that "if there was someone more expert in the field in my school, they would be teaching it. Now I am not saying that I am better than them, but we are all on a similar par." The diminished expertise for teaching ethics acknowledged by engineering instructors can be linked to the demographic characteristics rendered in Table 5. According to Table 5, the participant instructors were predominantly educated in an engineering system that did not include a mandatory requirement for ethics instruction. Desha and Hargroves (2014, p. 46) found a similar rationale for the "lack of faculty competences" in sustainability education. According to Desha and Hargroves (2014, p. 46), "educators teach according to their education and experience" and "where sustainability has not formed part of their training, faculty are unlikely to consider it as a skill of value or be prepared to include it in programs".

Instructor L2 offers the most detailed explanation of the process of preparing a module containing ethics, by appealing to a popular TV series, due to the difficulty of engaging with specialized literature on the topic:

> I did not get to read some of the philosophy books. I tried, but they are a bit heavy. I use web resources mainly, I watched YouTube clips […] very short little videos on the ethics element of the Good Place and how it relates to the different philosophers, Kant and utilitarianism and rights and all the rest. And I found them very useful, because it was somebody, an academic, taking what was in the Good Place and distilling it down into an ethical snippet. […] students just need the edited version. […] The books were a bit too high level for me. […] I still find getting my head around ethics pretty tough.

The description of the preparation process provided by L2 raises an important question whether a similar treatment would have been considered acceptable when teaching a technical subject. Given the diminished expertise, there is an agreement for the need for more guidance on how to implement ethics more effectively, especially in technical modules (L1, L10, E1, E2, E4).

In regards to the motivation for teaching ethics, only four instructors admitted that they intended to teach a module that includes ethical content. The majority of instructors mentioned the "necessity" (L6) of teaching ethics, being asked at programme level to do so. Ten instructors admitted that initially they were not interested in teaching ethics, but there was no one else that could teach the subject. According to L10, "I was told to teach it, of course.” Instructor L6 states that he is teaching ethics because “somebody needed to do it.” Instructor L7 was assigned this type of module “when I got here,” and “did not ask for it.”

At the opposite end, we have two instructors (L5; L8), who aimed to introduce ethical content in the curriculum of their engineering programme, and to attain this, had to pursue what they describe to be an institutional battle. L5 recalls that

> I have to fight harder for this particular content in the module and I have fought an ongoing battle to retain it. Despite my efforts it has been pared down over the years, so I have been fighting a rear-guard action for some time.

L8 also mentions the struggle that an individual instructor faces in order to make room for ethics in the engineering curriculum, and the role of the accreditation criteria in facilitating this process. According to L8, if

> somebody actually has an interest in doing it and trying to do it well, then if ethics becomes a battle, then it [n.m the accreditation criteria purporting to ethics] helps get the permission. […] And that is what I am doing in my university to an extent.

Having looked at the motivation of instructors teaching modules of professional formation, which are a type of modules deemed to have a high contribution to outcome E, two situations stand out. On one hand, we have a majority of participants teaching the subject due to the fact that there was no one else in their home institutions that could teach it, despite lacking an explicit interest or expertise in ethics. On the other hand, we have a few number of instructors very interested in ethics, who had to face institutional challenges to introduce a module dedicated to ethical content. These two extreme attitudes are revealing of the status of ethics in the engineering curriculum, highlighting that ethics is a topic for which appears to be a lack of expertise and institutional support. In what follows, the views on the preparedness of the members of accreditation panels in evaluating ethics will be examined.

10.3.3 Expertise for evaluating ethics

It has been noted the importance of the accreditation process and programme requirements in the implementation of ethics in the engineering curriculum. The recommendations received by programmes following the accreditation process have the power the shape the curriculum of that respective programme. The question that arises is how prepared are the members of the accreditation panel to evaluate module content purporting to ethics, as to make recommendations targeting outcome E that can serve as guidance for programmes in their implementation of ethics.

Participant observation reveals that members of accreditation panels expressed difficulties in evaluating this programme outcome. During all 3 accreditation events, even if my role as an observer was clearly explained, when it came to the evaluation of programme outcome E, evaluators have asked for my help. For example, during the accreditation event of Uni C, evaluator E1, who was named responsible for overseeing outcome E, approached me to ask about my opinion of how the module with the highest self-assessment score for outcome E managed to implement ethics.

During the accreditation of Uni F, evaluator E10 prompted me several times to give them suggestions on how to evaluate evidence purporting to ethics, and prompted me "not to be passive," despite my role as an observer. The discussion between evaluators and the representative of the accrediting body during the accreditation event of Uni F presents the approach to evidence split by type of outcomes, highlighting the difficulties raised by outcome E:

> E10: How are we going to do it?
>
> Representative of the accrediting body: Let us split outcomes A, B, C.. and the last ones are easier.
>
> […]

> E17: It is easy to decide who takes outcome E, we have you [n.m. pointing at me].
>
> Researcher: “I am an observer, I would not be able to comment”
>
> E17: Oh sorry, that is right
>
> E10 [n.m. to the representative of the accrediting body]: On our way here, I was trying to convince her to join us and help. To do some work.

A similar discussion took place during the accreditation event of Uni E, which highlighted outcome E as the most challenging one to evaluate for the purpose of accreditation:

> E5: When it comes to the evidence room, I usually find that a good way to do it is by dividing by programme outcomes.
>
> E4: I am probably least comfortable with ethics.
>
> E5: That is perfectly OK. You are probably more comfortable with problem solving, experiments. What about communication?
>
> E4: Yes, I just do not like the ethics one. I think the first outcomes are the easiest. We have an ethics person here [n.m. pointing to me].

The interview with evaluator E4 explored in more depth the reason why outcome E is considered to be the most challenging to evaluate. According to E4, this is due to the fact that

> we are not specialists in ethics. […] there is this part of us that believes that we are not really qualified to evaluate that […] because we are not trained to do that. So first of all, this is something new. Second of all, a lot of us, and especially people teaching highly technical tools, never thought about it and they never asked that question. So the difficulty is from both sides. When you become an evaluator, you think ‘I might need to do that now, as an instructor’.

While discussing the challenges encountered in regards to evaluating programme outcome E, evaluator E4 makes an important point, revealing the double sided character of these difficulties. The challenges encountered by evaluators reflect those encountered by instructors, and can be similarly explained in light of the demographic characteristics of the participants rendered in Table 6. Thus, the challenges encountered in the evaluation of ethics can be considered to originate in the overly technical education received, as well as in the current lack of training about how to adapt to the new accreditation requirements and to a holistic model of engineering education.

10.3.4 Student reception of ethics education

In what follows, students' reception of ethics will be analysed, from the perspective of the instructors interviewed. These interviews revealed a similar divide among students between, on one side, ethics alongside other nontechnical skills, and technical skills on the other side. Students are perceived to be less engaged with nontechnical topics, and to treat assignments dedicated to these topics in a less serious manner. There is also a lower attendance recorded for modules of professional formation compared with technical modules.

10.3.4.1 Engagement

Instructor L1 considers that "engineering students have the tendency to not care about the soft subjects as much," the reason being that students can understand the material without the instructor's help, "they can read the material at home or they do not need the help from the instructor." Instructor L16 holds a similar opinion that in the module she teaches, which combines technical with nontechnical components, "students probably would prioritize the technical components." Explaining students' reticence towards ethical content, instructor L12 considers "it is always a challenge for engineering students because they like technical content and they do not like something where there is no clear answer."

According to instructor L2, the professional formation module "is seen as an easy module to do. Very easy. Which it is." Instructor L3 emphasizes the importance of having ethics integrated across all years of study in remedying students' perception that "moral responsibility is a soft skill that they do not need to worry about." According to L3, "students see ethics as soft and possibly irrelevant early on in their student career with us. But my hope is that as they get towards the end of their four years that they are starting to see that this is integral to their success as future engineers."

In regards to the attendance rate for modules of professional formation, the instructors interviewed remarked that it tends to be lower than the attendance registered for technical modules. As such, L1 considers that "attendance is usually worse, […] maxed out about 60% and as low as 40% attendance." Instructor L2 also notes that the "attendance was mixed," due to the early hours at which the module is scheduled, pointing out that "if I was a student, I would not be coming in just for this lecture."

10.3.4.2 Attitude towards assessment

Students' attitude towards assessment also highlights students' disengagement with ethics. Unlike in the case of technical outcomes, ethics is seen as a component that is very difficult to fail. According to instructor L1, students regard ethics as a "subject that is relatively easy to pass." Students are seen to treat the assessment of ethics and nontechnical components different than the assessment of technical components. Instructor L1 considers that

> In the hard ones, if you say two and two is five, is wrong. But in the softer subjects, depending on how much you can regurgitate and just throw onto a page, you may get enough attempt marks to pass, and typically you do. […] So the problem is that for students it is not like in maths, where they can get it wrong. All they need to do is fill in that 'waffle', in quotation marks, they are just trying to get enough on the paper to pass the question.

Reflecting on how students approach the assessment, instructor L10 considers that only a "minority, maybe let us say 10%, have showed some serious reflection of ethics and have something original to say, while a lot of it would be kind of parroting very standard stuff."

There is also a lower fail rate for assessment related to ethics and other nontechnical components, associated with a relative lack of effort needed to pass. Instructor L1 considers that students can render common sense statements about ethics, in a way that resembles "waffle." According to instructor L1,

> the only time that people actually fail a question is if they have, for example, said the same thing. They basically described this word and they rearrange the statement you had and they just rearrange it and then they just keep rearranging it rather than actually defining it. […] But usually, if they have hit some of the points, some of the main points that you want to get, they can pass. So for instance, in the ethics, generally half the question is 'list five of the obligations of an engineer' and obviously then they can pick out the ones that come naturally to their head 'not doing work that they're not qualified to do' and 'not claim client confidentiality.' […] So they can get points very quickly from a relatively educated common sense. Once they read through the notes, […] then they can usually teach themselves enough to pass on 40, and that is all they want to do usually.

Instructor L6 encounters a similar difficulty in terms of failing students in the assessment of ethical components, as it is considered easy to make common sense and noncontroversial statements:

> If somebody had demonstrated that they have not become familiar with one or other of the codes of practice and just did not know what the various criteria were, that would be close to failing. And sometimes students, even if they have not studied, let us say the codes of practice, they may be able to actually still make valid arguments, so somebody might get above a passing mark if they were able to work things out from first principles themselves.

Instructor L6 makes explicit that it is very hard for students to fail the ethics component, if they do a minimum of work.

> It is very hard for a student to fail if they engage, only if they do not turn up for the online assessments. But anyone who takes part in the online assessments and does reasonably well, they have more than 50% of what they need for a pass before doing the written exam.

Instructor L12 holds a similar view about the low rate of students that fail the module of professional formation, which is on a pass/fail basis:

> Any student who writes this [n.m. assignment] would pass, because they would not be in third year engineering otherwise. So if they put in an effort and write something, yes, they would pass it, if they do not write it, they will not pass. So some people will not submit, some people maybe have other issues and will not do

> it, but by and large, almost everybody submits, and if they submit, it will be very difficult to fail.

Following the interviews, two issues that have emerged in regards to the assessment of ethics are the lower rate of students failing this component, and the possibility of passing the component through less time commitment, by what instructors consider to be "waffle" and "parroting."

10.3.5 Key findings

The chapter aimed to explore the status given to ethics in the engineering curriculum. Four key findings have emerged, that all point to the lesser status of ethics in the engineering curricula. First, in regards to its implementation, ethics, alongside the other nontechnical outcomes, has a lower weight in the engineering curriculum compared to technical outcomes, and is perceived to be implemented in a non-systematic manner. The presence of ethics in the engineering curriculum is thus justified by making appeal to accreditation requirements. Second, ethics is commonly portrayed as having a non-essential role in engineering education, due to the perception that engineering practice is isolated from ethical considerations. Thirdly, it seems that there are fewer instructors specialised in teaching ethical content, compared with staff that are specialised in teaching technical content, to the point that expertise in this teaching area is highlighted as a challenge. Evaluators experience similar challenges rooted in a lack of expertise when serving on accreditation panels. Fourth, students receive ethical components differently than they receive technical component. Students are perceived to be less engaged. More so, according to instructors, the ethical components of the engineering curriculum are perceived by students to be easy components to pass, and are associated with a low failure rate.

The findings of the present study are congruent with those by McGinn (2003), Flynn and Barry (2010), Fabregat (2013), Miñano *et al. (*2017), Lönngren (2019) and Sucala (2019), which revealed the diminished presence and lower status of ethics in the engineering curriculum. Instead of a systematic implementation, Flynn and Barry (2010, p. 2) note the temptation of a "tick box approach to the teaching of ethical issues." More so, modules with a strong emphasis on ethics are regarded as "soft" and have a marginal role in a technically dominant curriculum, with fewer exams and assignments (Stonyer, 1998; Miñano *et al.*2017, Fabregat, 2013). As such, ethics is perceived as a "fuzzy" discipline (McGinn, 2003), that is "something other" than engineering, "not very important" and of "inferior quality" (Lönngren, 2019, p.1). Students also report their preference for having ethics as a non-compulsory topic that is not assessed (Sucala, 2019).

To put in perspective the findings presented above, in light of the CR approach adopted, it is important to pinpoint a structural explanation about the generative mechanism that determined the status of engineering ethics education. The exploration of how the status of ethics in the engineering curricula is articulated managed to reveal a dichotomy between technical and nontechnical skills and outcomes. Exploring this dichotomy in further detail will be the subject of the following chapter, by asking if it can help explain the findings encountered in this study at individual, institutional and policy level, within the domains of the actual and the empirical.

The next chapter will propose a retroductive explanation for the generative mechanism responsible for these findings. My argument is that, at societal level, the dichotomy between the technical and nontechnical cultures, alongside the traditional view according to which engineering is conceptualised as a strictly technical discipline, represent the generative mechanisms within the domain of the real.

CHAPTER 11 DISCUSSION: THE TWO CULTURES OF ENGINEERING ETHICS EDUCATION

Previous chapters showed that engineering ethics education is a complex system, constitutive of various beliefs and practices which are manifest at individual, institutional and policy levels. At the same time, engineering ethics education, in its coverage or institutional method of implementation, shapes and affects the professional identity of students. The role of the present chapter is to bring together the beliefs and practices identified in the Irish engineering education system and to enquire about an explanation pointing to their root.

In light of the CR theoretical model that guided the research study, this explanatory attempt frames the findings within the different levels of engineering education, aiming to posit their generative mechanism. As mentioned, the system of engineering education has been previously examined at a number of interrelated levels, belonging to the ontological domains of the empirical and actual: (i) the individual level of single agents such as instructors, evaluators, university personnel; (ii) the institutional level comprised of engineering programmes, departments and units and (iii) the policy level represented by accrediting bodies and national policies. In what follows, it will be argued that the key generative mechanism shaping the activity at these different levels, belonging to the ontological domain of the real, is the culture of engineering education, which valorises the technical over the social dimension of engineering.

The need for situating findings related to individual beliefs and practices within deeper structures is highlighted by Godfrey (2009, p.8), who develops a theoretical model that admits three layers of analysis. According to Godfrey (2009, p.8), the first level of analysis is comprised of observable artefacts, such as programme documents and mission statements, practices rendered by the curriculum, teaching and assessment methods employed, and the behaviours and language used. The second level of analysis is comprised of the shared values and norms behind the artefacts, practices and behaviours exhibited. Finally, the third level of analysis is based on the premise that the observable "manifestations and cultural norms identified in the first two levels of analysis had developed from shared beliefs and assumptions that had formed over time" (Godfrey, 2009, p.9). The concern with developing a multi-layered ontological analysis of engineering education is also found in Sterling (2004, p.64), who through the use of an iceberg metaphor points to the deeper levels of paradigm and purpose that guide policy and practice in higher education, and which are considered to be mostly hidden from view and consequently from debate. A similar claim in favour of deploying a depth ontology is made by Lattuca and Stark (2009, p.303), who argue that the higher education curriculum reflects its sociocultural context.

Thus, the first question that arises is how can the state and status of engineering ethics education identified in the previous chapters be explained? A second question that then needs to be addressed is at what level should transformative measures be directed at? In order to address the first question, I first explore how the concept of engineering culture is articulated in the literature. The chapter then focuses on how the concept of culture is perceived by the participants in the study to be at the root of the current state and status of engineering ethics education, before attempting a retroductive explanation that posits the culture of engineering as a generative mechanism for the current findings. The chapter then moves the focus on the second question, by exploring strategies for change, rooted in existing studies and literature.

11.1 Towards a concept of culture of engineering education

The study is guided in the use of the concept of "culture" by the definition provided by Schein (1992, p.12) and popularized in engineering education research by Godfrey and Parker (2010), according to which culture is understood as

> a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid, and therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems.

As Godfrey (2009, p.3) points out, the definition of culture provided by Schein highlights its nesting in "the deepest, unconscious level of basic beliefs and assumptions, which underpins the more visible cultural manifestations."

The characteristics of engineering culture were first cast by Snow (1959) in opposition to those representative of the literary culture. Snow argues that scientists and literary intellectuals exist as distinct "cultures in the anthropological sense […], linked by common habits, common assumptions, and a common way of life." The distinction made by Snow between the two cultures overlaps with a 200 year old hierarchisation of sciences, according to which natural sciences are placed at the top of the hierarchy, and social sciences are found at the bottom (Cole, 1983; Budd, 1988). Despite the diffusion of different hierarchies of sciences, Fanelli (2010) notes that they all shared a similar intuition according to which some fields of research, indicated as "harder," follow a more rigorous research method and are more reliant on data and theories than other fields, described as "softer," which are ruled by sociological and psychological factors.

The distinction between "hard" and "soft" sciences referring to the duality between engineering and natural sciences, on one hand, and humanities and social sciences, on the other, hides a valorisation of the "hard" over the "soft" (Storer, 1967), as well as gendered connotations (Keller, 1985).[41] "Hard" sciences are considered superior to "soft" sciences (Becher & Trowler, 2001, p.192;[42] Gardner, 2013), which prompted Cassell (2002, p.179) to remark that in the use of "a barely disguised (tautological) phallic metaphor, 'hard' science is more scientific than 'soft'." Referring to the "hard" versus "soft" sciences distinction, Biglan (1973) notes that this terminology was actually meant to capture the level of paradigmatic consensus among the individuals within a specific discipline. According to Biglan (1973, p.210), there is more consensus in the "hard" disciplines in the adoption of a "common framework of content and method," while in "soft" disciplines "content and method […] tend to be idiosyncratic" (Biglan, 1973, p.202).

This conceptualisation of academic disciplines points to the isomorphism of the different disciplinary cultures of the "hard" sciences, which transcends fields of specialization, institutional affiliations or geographical characteristics. As Becher (1994, p.153-155) has argued,

> disciplinary cultures, in virtually all fields, transcend the institutional boundaries within any given system. In many, but not all, instances they also span national boundaries. […] To say this is not to deny that there may be differences in research traditions, profiles of undergraduate programmes and the like between one national system and another […] Even between different institutions in the same system, the phenotypical variations can be substantial, but one can nonetheless clearly identify genotypical cultures endemic to each discipline.

In Becher's (1981, p.109) view, academic disciplines are "cultural phenomena: embodied in collections of like-minded people, each with their own codes of conduct, sets of values and distinctive intellectual tasks," which he later named "academic tribes" (Becher & Trowler, 2001). In a similar spirit to Becher, Ashwin (2009) has highlighted the

[41]Referring to the cultural dichotomies between natural and social sciences, (Keller 1985) observes an assumption present in scientific practice between objectivity, reason, and mind, which are cast as male features, and subjectivity, feeling, and nature, which are perceived as female features.

[42] Becher and Trowler (2001, p.192) remarked that soft disciplines are "seen internally as politically weak and externally as lacking in good intellectual standing," which "has rendered the social sciences especially vulnerable to attack from unsympathetic external forces".

homogeneity of engineering, due to the role played by national professional and regulatory bodies in determining the manner in which disciplinary knowledge practices are translated into curriculum material.

What emerges is the legitimacy of talking about a culture specific to engineering which is rooted in shared beliefs, methods and content, as well as the contour of its main characteristics. The cultural identity of engineering established over time is of a more rigorous, difficult and complex discipline, a masculine field, fit for those who excel in mathematics and the physical sciences, devoid of subjectivity, and with a lesser orientation towards societal issues (Tonso, 1999; Godfrey 2010; Stonyer, 2002; Stevens *et al.,* 2007; Cech, 2014; Carberry & Baker, 2018). Herkert (2001b) sums up best the major characteristics of engineering culture:

> The prevailing engineering culture is readily recognised from both inside and out. Engineers are no-nonsense problem solvers, guided by scientific rationality and an eye for invention. Efficiency and practicality are the buzzwords. Emotional bias and ungrounded action are anathemas. Give them a problem to solve, specify the boundary conditions, and let them go at it free of external influence (and responsibility). If problems should arise beyond the work bench or factory floor, these are better left to management or politicians.

After having traced the features of engineering culture, the chapter proceeds by exploring whether and how the conceptualization of engineering culture is reflected in engineering education.

11.1.2 Contending paradigms of engineering education

Reflecting on the dichotomy between the scientific and humanities cultures proposed by Snow (1959), Petrina (2003, p.70) considers that "Snow was right and Snow was wrong. There are two cultures, but they only exist in education." The paradigmatic nature of engineering presupposes a high degree of consensus and a tightly structured subject matter, which is considered to affect the instructors' teaching beliefs and practices (Braxton &

Hargen, 1996; Braxton *et al*., 1998; Jones, 2011). In this regard, Brint *et al.*'s (2008) large scale survey has revealed the presence of two cultures of undergraduate academic engagement rooted in differences between academic majors. On one hand, there is a culture of engagement specific to the humanities and social sciences, characterized by "individual assertion, classroom participation, and interest in ideas" (Brint *et al.,* 2008, p.390). On the other hand, there is a culture of engagement specific to natural sciences and engineering, which is based on "working toward quantitative competencies through individual study and collaborative effort," with students reporting an interest in modules that "explain and solve problems" and aspiring to obtain "prestigious, high-paying jobs" (Brint *et al.,* 2008, p.390).

There also appear to be two cultures of assessment and grading. According to Barnes *et al.* (2001), there are differences in faculty attitudes about assessment and grading among disciplines. As such, Barnes *et al.* (2001) found that instructors teaching technical subjects were more likely than those teaching nontechnical subjects to consider that grades serve a gate keeping function, which is traced back to the expectation that students in technical fields are expected to master a body of knowledge. Additionally, assignments oriented towards the attainment of theoretical knowledge were linked to the teaching goals related to "subject matter facts and principles" set by instructors teaching technical subjects, compared with goals related to "student development" favoured by instructors teaching nontechnical subjects.

More recently, the distinction between the two cultures has been recast by Jamison *et al.* (2014) in their analysis of engineering educational paradigms and their associated conceptions about what it means to be an engineer. Table 1 presented the three modes of engineering education proposed by Jamison *et al.* (2014). First, there is the academic vision of engineering as applied science, dominant in science universities, which uphold a traditional engineering identity. Second, a market-driven vision of engineering as technological innovation, present in an entrepreneurial university model, which promotes an identity of engineers as innovators and entrepreneurs. Thirdly, there is an integrative vision of engineering as public service, promoted by an ecological oriented university, which is seen to foster the identity of students as social reformers and agents of change. According to Jamison *et al.* (2014, p.255), this last model represents “a more balanced or comprehensive approach to educational reform.” Nevertheless, Jamison *et al.* (2014, p.264) highlight the less prominent historical presence of the hybrid mode of engineering education that combines the technical with the social. As Wicklein (1997, p.72) points out:

> For much of the profession, the current curriculum framework is little different from the old vocational models used in years past that concentrate on the technical aspects of selected tools and materials. […] Educators concentrate the majority of their efforts on the technical procedures used to create artefacts and give the processes used by technologists and the impacts of technology on society only cursory attention. Students sometimes gain knowledge about […] the impacts of technology as a by-product of the curriculum. These outcomes occur in a haphazard way, however, rather than through a coordinated curriculum that shares the stage with the major elements of the technology education curriculum.

It appears then that the culture of engineering education has been articulated in terms of a dominant discourse focused on science, to the exclusion of alternative discourses of philosophy and ethics, environmental studies, politics or sociology (Johnston *et al.,* 1996, p.33). Stevens *et al.* (2007, p.3) agree that the technical dimension is overemphasized and that engineering education does “an insufficient job in giving students the experience of engineering as a meaningful craft, or that as engineers they will be able to contribute to a better world.” Examining students’ perception of the values fostered in engineering education, Cech (2014) makes a similar remark that the culture of engineering education is characterised by disengagement with societal concerns and public welfare.

11.1.3 Generative engineering identity

Furthermore, Jamison *et al.*'s (2014) analysis of the three distinct modes of engineering education links these to different conceptions of what it means to be an engineer, thus revealing what can be called a generative view of engineering identity. By engineering identity is understood who is an engineer, what does an engineer do, what does performing the role of an engineer entail, and what are the responsibilities of engineers (Murphy *et al.,* 2015).

Engineering identity development is typically portrayed to comprise a singular engineering identity, "rather than many types or manifestations" (Rodriguez *et al.,* 2018, p.259). For Patrick and Borrego (2014, p.4), the examination of identity development should give credence to "socio-cultural and environmental factors that shape 'becoming' in the process of 'doing' engineering." As such, engineering identity can be considered to be largely determined by one's disciplinary culture (Becher & Trowler, 2001; Biglan, 1973; Toma, 1997; Umbach, 2007; Ashwin, 2009). Tonso (1996, p.218) also described engineering education as "enculturation into a well-established system of practices, meanings and beliefs" as students "learn what it means to be an engineer" and what is valued by the discipline. In this regard, Brint *et al. (*2008, p.394) note that

> once students have begun to take classes in their majors, they are also socialized into the cultures of the disciplinary domains […] and come to understand what it takes to gain recognition in the humanistic fields and competence in the scientific fields.

In a similar manner, Meijknecht and van Drongelen (2004, p. 448) compare the monolithic identity of engineers rooted in education to that of professions such as medicine, considering that engineers "constitute a tribe, with its own traditional set of values that are transmitted to the new members in a symbolic way during their initiation. […] University is a place of initiation for the tribe of engineers." As Stonyer (2002, p.397) points out, academic enculturation leads to a specific dominant socio-historical engineering identity, as "nuts and bolts" technicists (Faulkner, 2007).

While current engineering education culture promotes the development of a technically rigid identity disengaged from societal and welfare concerns (Cech, 2014; Monteiro *et al.*, 2017), a socio-technical integrative model such as the one suggested by Jamison *et al. (*2014) can foster the "formation of a hybrid identity and the exercise of social responsibility."

Although distinct concepts, the articulation of the features of the dominant engineering culture and discourse, engineering education paradigm and engineering identity converge towards a similar valorisation of the technical over the social in engineering education. What emerges for the purpose of the present study is a collective understanding of what it is to be an engineer and educate an engineer as a key generative mechanism that explains the practice, implementation and evaluation of engineering ethics education.

11.2 Engineering education: a matter of culture?

Several lecturers and evaluators interviewed pointed to cultural issues as the root of the current challenges and deficiencies encountered in the education of engineering ethics. These cultural issues are represented by the traditional view of engineering as "a nuts and bolts profession", as well as the primacy of technical skills perpetuated by engineering education.

According to instructor L11, the diminished role of ethics in the engineering curriculum is "structural, it is not about my colleagues, it is coming from somewhere else." Instructor L8 considers that the structural problem is represented by "a traditional mode, perhaps a reductionist scientific method, which divorces values and ethics from technical problems." This reductionist vision of science is seen by L8 to lead to a conception of ethics "that is just an add-on." Furthermore, L8 considers that instructors concerned with the integration of ethics are "fighting for a broader societal perception of ethics." For L4, this is due to the "traditional conception that still exists, […] a traditional engineering perspective of that we have solved the problem technically and that is it." The challenges experienced in the implementation of ethics are traced to the way in which current instructors have in turn been taught. As evaluator E1 states, "that is what we learned," adding that "maybe it will take a while for this to change." E1 highlights the role of education in shaping the mind set and values of engineering graduates, as well as passing on the message of what engineering amounts to. In this regard, E1 notes that "the current students will produce the future engineers, and will have a better understanding of ethics because they have been brought up with it, compared with those of us who have been through the system a long time."

Instructor L9 agrees that engineering instructors "are enculturated in a particular discipline," which influences how ethics is perceived within an engineering programme. L9 considers "important that the way they are being enculturated is the right way," and to achieve this there is a need to change how engineering education is conceptualised. For this, L9 considers to be important to ask "how do you change culture?," and points to the pressure exercised by social circumstances in enabling this change. "I think culture changes when the circumstances change," concludes L9.

Instructor L13/Evaluator E6 also highlights the contributing role of education in shaping the attitude towards engineering ethics education. According to L13/E6,

> the existing crop of academics were taught engineering in a very different way to the way we are teaching engineering now, and so getting people to think more holistically in their approach to engineering education is a slow process that is filtering its way through the programs in this country right now. But it is not quite there yet.

The traditional model of engineering education that prioritizes the acquisition of technical skills at the expense of ethics and socially oriented skills is considered to perpetuate a similar hierarchy by the current instructors. Evaluator E3 considers that the downplaying of ethics in the engineering curriculum "is coming from academic purity, from their own environment. That is the environment they have lived in, that is environment they know, and that is the environment they focus on." Reflecting on this model of engineering education that shaped him as an instructor, L10 considers that "in some ways, I have a very traditional view and I would defend the A, B, C outcomes. I do not want to compromise that." Nevertheless, L10 thinks that "a transformative thing is needed," which is linked to the development of a holistic model of engineering education. As such, L10 notes that "I would like to see the engineering profession as a whole stepping up to that. I guess that begins in education." For instructor L9, in order to achieve a transformation of engineering education, there is a need for "a little bit more collaboration, a little bit more integration" of the technical and ethical aspects.

Although "there is an increased consciousness by a lot of the colleagues" (L14), nevertheless there is some resistance encountered at institutional level in effecting this change. For this reason, evaluator E5 thinks that "it is much easier to engage students than staff." According to L1,

> although the more senior instructors are great at helping, they are willing to help you and they are really friendly, they have been lecturing the same subjects for maybe a decade and they do not want to change them as it has been working perfectly fine for them for a decade. So they are not too eager to adapt and change.

Reflecting on the resistance to change, instructor L9 notes the ambivalence between the aspirations expressed in codes of ethics and accreditation requirements, and the actual implementation of ethics in the engineering curriculum. According to L9,

> the profession itself is ambivalent. They want to show how as a profession they take ethics seriously, but when they think about themselves as a profession, they think about themselves as people with a lot of technical skills. So there is the societal accountability element of the profession, that yes, it needs to show to society that they are taking concerns seriously, but that can quite heavily conflict with all the

> technical skills that people think would maybe need to be sacrificed if you give more space to the ethical side. So I think that the profession itself needs to be clear of what they want.

The interviews conducted with instructors and evaluators alike point to the existence of a causal link between the diminished presence of ethics and its lesser status in the engineering curriculum on one hand, and on the other hand, the engineering educational culture, characterised by a valorising of technical knowledge, in which the current generation of instructors has been formed. Instructors have identified two forces for change. One is represented by the accrediting body, through the formulation of mandatory learning outcomes that programmes have to meet in order to gain accreditation, and of recommendations for improving the education offered by engineering programmes. The accreditation body is perceived as a powerful actor that has led to the inclusion of ethics in the curriculum of engineering programmes. The second force is represented by the increasingly complex societal challenges faced by engineers. These are considered to have the potential to prompt a stronger emphasis on ethics in the engineering curriculum.

11.3 In search of a retroductive explanation: culture of engineering as a generative mechanism

As mentioned in section 4.3.3, CR research relies on retroductive explanations, which start from an examination of phenomena registered in the "empirical" and "actual" ontological domains, to the pinning of possible causes, which pertain to the domain of the "real" (Easton, 2010; Ackroyd & Karlsson, 2014; Fletcher, 2017). The role of a retroductive explanatory purpose is to propose generative mechanisms, through inference towards the best explanation (McEvoy & Richards, 2006). By using retroduction, "events are explained through identifying and hypothesising causal powers and mechanisms that can produce them" (Xiaoti Hu, 2018, p.123).

As pointed out by Bunt (2018, p. 179), “CR has not developed robust practical and accessible methodological tools which can be easily utilised for empirical research.” Such that there is limited guidance on the application of analysis methods for CR in addressing ontological and epistemological assumptions, as well as in the use of methodological approaches (Fletcher, 2017; Hoddy, 2019; Bogna *et al.*, 2020). According to Xiaoti Hu (2018, p. 123), a retroductive study requires at least two things: (1) an explanation about the domain of the actual from empirical observations and (2) a hypothesis of the existence of causal powers, mechanisms and their underlying structures that are not subject to direct observation.

In what follows, I describe the CR framework put forward in this study for describing the system of engineering ethics education. As seen in Figure 3, it includes the beliefs and practices encountered at individual, institutional and policy levels, within the ontological domains of the empirical and the actual, and proposes an explanation of their generative mechanism at societal level, within the domain of the real. In what follows, the focus will be on situating the findings identified in the previous chapters within their respective ontological domains and levels, before putting forward an explanation for their generative mechanism.

Figure 3. Critical Realist analysis of the education and evaluation of ethics in the Irish engineering education system

DOMAIN OF THE EMPIRICAL

INDIVIDUAL LEVEL

Ethics is perceived to have a lower status among students and peers

Confusion in the understanding of falls under the scope of ethics

Diminished expertise and motivation for teaching ethics

Diminished expertise for evaluating ethics

INSTITUTIONAL LEVEL

Ethics is understood as a soft and nonessential learning outcome, while technical knowledge and skills are essential learning outcomes

POLICY LEVEL

Belief that ethics has to be integrated across the curriculum

DOMAIN OF THE ACTUAL

INDIVIDUAL LEVEL

Numerous challenges in the teaching and evaluation of ethics

INSTITUTIONAL LEVEL

Ethics has the lowest weight in the engineering curricula of all outcomes

Ethics is implemented in a nonsystematic manner

Less specialized staff

POLICY LEVEL

Less time and attention given to ethics during accreditation events

Lower threshold in what is deemed a satisfactory incorporation of outcome E

DOMAIN OF THE REAL

SOCIETAL LEVEL

The prevalence of a traditional conception of engineering education, as a solely technical discipline

Dichotomy between technical and nontechnical cultures

11.3.1. The empirical domain

The empirical domain incorporates the beliefs and attitudes of instructors and evaluators about the education and evaluation of engineering ethics, as follows:

11.3.1.1 Individual level

At individual level, ethics was shown to be perceived as having a lesser status among students and peers. The instructors who participated in the study expressed their belief that students invest less study time in addressing ethical components and regard it a subject that is relatively easy to pass without engaging in deep reflection or putting too much effort. Instructors also mentioned a perceived resistance among peers when it comes to the inclusion of ethical components in the engineering curricula. As such, instructors believe that it is difficult to find room for ethics in an already crowded curriculum, and that some peers regard such attempts as a way of "dumbing down the actual engineering content" (L2). More so, instructors as well as evaluators expressed their belief that ethics is considered as an add-on inserted in the programme in order to meet the accreditation criteria. What comes through is a perception of the primacy of technical knowledge and skills, both among students and peers.

At individual level, instructors also report feeling less familiar with teaching and assessing ethics. Several instructors mentioned that it was not their choice to teach a module with a high ethical component, but there was no one else in their programme or institution to teach it, which seems to suggest there is diminished motivation and expertise for teaching ethics in engineering programmes. The study found that evaluators serving on accrediting panels also mention their unfamiliarity when dealing with ethical components. Evaluators referred to ethics as the hardest outcome to assess and reported struggling to understand how to interpret evidence in support of this outcome as well as how to judge what type of contribution counts as meeting this outcome.

It is also important to note the confusion and difference in beliefs among instructors as to what falls under the scope of engineering ethics education. Themes such as sustainability, safety and plagiarism were the ones that gave rise to dissenting opinions, having reported a lack of clarity as whether they have an ethical bearing.

11.3.1.2 Institutional level

At institutional level, the study showed that ethics is often described as a “soft” and “non essential” learning outcome, set in opposition with technical outcomes which are described as “hard” outcomes that are “core” to the engineering curriculum.

11.3.1.3 Policy level

At policy level, participant observation found that the accrediting body makes explicit during accreditation events that ethics has to be integrated across the curriculum. This suggests that the accreditation body wants to convey the belief that ethics should not be isolated and compartmentalised, but seen as an integral part of the technical curriculum.

11.3.2 The actual domain

The actual domain refers to the practices adopted in connection to engineering ethics education, which the study revealed to be the following:

11.3.2.1 Individual level

At individual level of teaching and assessment practices, instructors report encountering numerous challenges when dealing with ethical content. According to some instructors, these challenges are linked explicitly with what was previously identified as a diminished familiarity with the discipline, while other challenges are more of an institutional nature.

The study also encountered challenges in the practice of evaluating ethics for the purpose of accreditation. Evaluators referred to ethics as the hardest outcome to assess and struggled to understand how to interpret evidence in support of this outcome as well as how to judge what type of contribution counts as meeting this outcome. In all accreditation events observed, this led to evaluators serving on accreditation panels asking the researcher to help them evaluate outcome E, despite the role of a participant observer.

11.3.2.2 Institutional level

At institutional level, the study found that ethics has the lowest weight in the engineering curricula of all outcomes. More so, the study found that the scores employed by the programmes to self-assess how they meet the programme outcomes for accreditation are consistently low for nontechnical outcomes, as opposed to those for technical outcomes.

The study also found that ethics is implemented in an uneven and non-systematic manner, and that none of the participants programme to date has undertaken a strategy for implementing ethics. This is confirmed by the beliefs held by instructors and evaluators mentioned previously, according to which ethics is an "add-on", whose implementation can be "brushed over" as a "box-ticking exercise" for the purpose of accreditation. The presence of ethics in the engineering curricula appears to be justified through appeal to accreditation requirements, rather than by a philosophy of education underpinning the educational offer of the programmes or a holistic vision of engineering education.

It also seems that there are fewer instructors specialised in teaching ethical content, compared with staff that are specialised in teaching technical content, to the point that expertise in this teaching area has been highlighted as a challenge.

11.3.2.3 Policy level

At policy level, the study found that during accreditation events, there is less time dedicated by evaluators to analyse and discuss outcome E, compared to technical outcomes.

The study also notes there is a lower threshold in what is deemed a satisfactory treatment of outcome E.

11.3.3 The real domain

As seen in previous chapters, several instructors and evaluators pointed to cultural issues as the root of the current challenges and deficiencies encountered in the education of engineering ethics. These cultural issues are represented by the traditional view of engineering as a “nuts and bolts profession”, as well as the primacy of technical skills perpetuated by engineering education.

The beliefs held by instructors and evaluators on the lesser status of ethics in the engineering curricula, on one hand, can be interpreted as the manifestation of the prevalent engineering culture according to which engineering is essentially a technical activity, and on the other hand, can be considered to influence the education of engineering ethics.

I now put forward an explanation of the previous findings of the research study, based on (i) how the status of engineering ethics education is perceived at individual and programme level within the empirical domain, (ii) how the state of engineering ethics education has been revealed at the individual, institutional and policy level within the domain of the actual and (iii) the theoretical articulation of the concept of culture in engineering and engineering education.

There are three key findings about the status of engineering ethics education that reveal the dichotomy between technical and nontechnical skills. First, ethics appears to be commonly portrayed as having a non-essential role in engineering education, due to the perception that engineering practice is technical in nature and isolated from ethical considerations. Second, the ethical components of the engineering curriculum are perceived by students to be easy components to pass, which are associated with a low failure rate. Third, the inclusion of ethical components in the engineering curricula also encounter resistance from teaching staff, who considers it as a diluting of the technical content that “dumbs down” the engineering curricula.

Three key findings have emerged about the way in which the dichotomy between technical and nontechnical skills is reflected in the exploration of the state of engineering ethics education. First, ethics, alongside nontechnical outcomes, has a lower weight in the engineering curriculum compared to technical outcomes. Second, ethics appears to be implemented in a non-systematic and uneven manner, and its presence in the engineering curriculum is justified by making appeal to accreditation requirements. Third, it seems that there are fewer instructors specialised in teaching ethical content, compared with staff that are specialised in teaching technical content, to the point that expertise in this teaching area is highlighted as a challenge. The challenging aspects encountered in the teaching of ethics, rooted in a lack of expertise, are also experienced by evaluators.

In the context of the Irish engineering education system, I thus retroductively infer from the findings of our study related to (i) the status of ethics education and (ii) the state of ethics education, that the (iii) the cultural paradigm of engineering education, according to which engineering is a “hard” and technically oriented discipline, can serve as an explanation for these. The retroductive process steps from the data obtained at empirical and actual level, takes into consideration the theoretical conceptualisation of the culture of engineering, in order to propose the latter as the generative mechanism for the lesser status of ethics in the engineering curricula and the state of its implementation.

The chapter proceeds by examining in the context of Irish engineering education the different ways in which ethical considerations are cast in opposition to the technical dimension of engineering. Recalling Snow (1959), these two curricular dimensions appear as the manifestation of two different cultures. The findings of the present study reveal that the existence of two distinct cultures are reflected at the surface level of the curriculum, through the lower weight given to ethics alongside other nontechnical skills, as well in the beliefs and values held at institutional level on the role of ethics in engineering education that point to its lesser status. As such, ethics has been articulated as a "soft" and "non-essential" feature of engineering, a curricular "add-on" implemented in a non-systematic manner and surrounded by a degree of confusion as to its conceptualization and application. The development of technical acumen, on the other hand, is regarded as an essential part of engineering education, and is allocated the biggest weight in the curriculum.

11.4 Dismantling the two cultures of engineering education: towards a sociotechnical reconfiguration of engineering and an education for "ethics"

Reaching a diagnosis for the current state and status of engineering ethics education is a prerequisite for suggesting strategies for change. As Rover (2008, p.389) notes, "the key to change is first understanding "what we are", and then taking steps toward "what we are capable of becoming." In what follows, the aim is to explore how previous findings can give rise to a discussion about the need for a culture change of engineering education, and the role of the different levels identified in the study in effecting change.

To dismantle the two cultures existing in engineering education, it is imperative to move from a treatment of ethics as a curriculum add-on towards a full reorientation and development of engineering curriculum "for" ethics. Engineering education "for" ethics is a transformative process, which aims to challenge existing core assumptions and values promoted in engineering education (Mezirow, 1978; 1991; Cranton, 2006). Although many studies have been dedicated to the concept of transformation of higher education, and in particular to higher education for sustainability (Holmberg *et al.*, 2012; Trowler *et al.*, 2013;

Filho *et al.*, 2018), the question of the integration of the ideal of engineering education "for ethics" in this conceptualization has been largely ignored, highlighting a potential area for further research.

The use of CR has led to the identification of the need for cultural change and a refocusing of the purpose of engineering education. It also cast the focus on the different levels of the system of engineering education, highlighting the importance of locating individual agents in the socio-cultural and institutional contexts in which they operate. The failure to integrate these different levels into models for change has been identified as a failing in engineering education research, with different research communities having focused separately on different levels (Froyd *et al.*, 2008, Seymore, 2001). The present CR driven research study reveals the importance of linking change initiatives at different levels in order to generate long lasting and sustainable transformation. Throughout the chapter, it has been argued that measures targeting different levels need to be considered in the process of transformation of engineering education towards a hybrid model.

To achieve this, the study used a CR ontological approach which identified different levels within the empirical, actual and real ontological domains, highlighting the interaction between structure and agency. Their main features, influence and interrelations have been analysed in more detail. These levels are (i) the societal level represented by the cultural milieu in which engineering education takes place, (ii) the policy level represented by national accrediting bodies, (iii) the institutional level represented by engineering units such as departments, colleges and universities, and finally, (iv) the individual level, represented by instructors and evaluators. Throughout the chapter, it has been argued that measures targeting each of the four levels need to be considered in the process of transformation of engineering education towards a hybrid model.

As Godfrey (2014, p.438) points out, it is important to focus the analysis of engineering education not only on "characteristics of behaviours and practices," but to also direct it towards "the values, beliefs, and assumptions that underpin "how these came to be" in order to develop strategies for change. In relation to higher education more broadly, Trowler (2008, p.151) also emphasizes the importance of placing the individual in the wider context, noting that "change based on 'improving' individuals will usually be a disappointment if not done with an awareness of the context individuals operate in."

Furthermore, it has been remarked that change strategies need to link different levels in order to generate long lasting and sustainable transformation (Trowler, 2008; Hannah & Lester, 2009; Graham, 2012). In this regard, Trowler (2008, pp.155-7) argues that "there are intimate and important connections between them…It is important to think vertically, about interdependencies at higher and lower levels of analysis." This requires a systemic rather than a linear approach to change (Sterling, 2004). For Sterling (2004, p.64), the question then becomes "how can education and society change together in a mutually affirming way, towards more sustainable patterns for both"?

Having identified the different types of individual agents and structural forces that shape engineering education, a question that arises is about the role of each in the process of transforming engineering education towards the development of a hybrid model that integrates the scientific, technical, social and environmental dimensions of engineering, such as the one envisioned by Jamison *et al. (*2014).

11.4.1 Societal level

The present research study found a strong influence of the traditional cultural model of engineering education as a solely technical discipline on the weight and status given to ethics in the engineering curriculum, as well on the instructors' preparedness to engage with ethical content.

Cultural beliefs about the purpose of higher education have been found to shape curricular content (Lattuca & Stark, 2009). Petrina (2000; 2003) highlights the role of the culture of engineering education in perpetuating the disengagement between scientific and technological topics, on one hand, and socially oriented topics on the other. The marginalization of ethics in engineering education is linked to a dominant discourse about the discipline that locates ethical decisions outside the responsibility of engineers (Johnston *et al.*, 2006; Downey *et al.*, 2007). According to Petrina (2003, p.70), engineering instructors "have little concept of what it means to reintegrate socio-political with technical knowledge," and this is because "they have been taught to disintegrate politics from technical cultures."

Recent decades saw a call for changing the culture of engineering education (Williams, 1988; Institution of Engineers Australia, 1996; Beder, 1998; Sterling, 2004; Radcliffe, 2006; Bucciarelli, 2008; Jamison *et al.*, 2014; Kolmos *et al.*, 2016). There is a growing need to recast the discourse surrounding engineering and the conceptualization of engineering education, as to include ethical, political, social, economic, and environmental considerations (Johnston *et al.*, 2006, p.4). As Sterling points out (2004), a change in the curricular development of engineering education has to be preceded by a change in ethos and purpose. This means that instead of focusing on the integration of ethics in an already crowded curriculum or the addition of single courses, there should be a systemic change for transforming higher education towards an "integrative and more whole state" (Sterling, 2004, p.50;[43] Bucciarelli, 2008, p.147).

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[43] The locus of concern for Sterling is on education for sustainability, but a similar argument can be made for ethics.

Crucially, this will involve clarifying the purpose of change. While there has been much debate about the need for change in engineering education, Jamison *et al. (*2014, p.254) argue that a key issue is that different approaches to change are based on different perceptions of engineering and engineering education, and therefore tend to pull attempts to change engineering education “into opposing, even contradictory, directions.” For Godfrey (2014, p.452), the key issue is “forming new collective understandings and creating new beliefs about what is valued in engineering education.” This involves dipping below the iceberg and grappling with the issues of purpose and paradigm, which according to Sterling (2004) are rarely considered. It has also been argued that in order to elicit change in engineering education, the current value system and cultural assumptions need to be reformulated (Stonyer, 1998, p.290; Bucciarelli, 2008, p.147).

Nevertheless, despite higher education institutions promoting learning, this does not apply to their capacity to learn for and about themselves (Adams *et al.,* 2018). Despite engineering education promoting innovation in product creation, it is less innovative in reconceptualising what it means to be an engineer (Mitcham, 2014). There is thus a resistance in changing engineering culture, with little curriculum change targeting ethics (Brink *et al.*, 2020). Disciplines such as Design Engineering, Information Engineering and Electric Engineering in particular are found to be resistant to change. (Brink *et al.,* 2020, p.1448).

If a holistic model of engineering education is to succeed, it has to be the outcome of a transformative process, rather than an adaptive response to external pressures such as requirements for accreditation. In the latter case, “there is minimal effect on the institution, and the values and behaviour of teachers and students,” while the former type of response is “based on a realisation of the need for paradigm change” (Sterling, 2004, pp. 59-60). As (Fullan, 2007) points out, real change requires reculturing, not just restructuring.

The question then is “how do you change culture?” (L9). As instructor L9 considers, “cultural change, just sitting here and saying 'engineering should be so much more aware of ethics,' is pointless.” Having posited the influence of engineering culture on institutional and individual beliefs and practices, the chapter proceeds by exploring the influence and role of agents operating at the different levels of the system of engineering education in effecting change.

11.4.2 Policy level

The interviews conducted with instructors and evaluators for the present study highlighted the role of the national accreditation body Engineers Ireland as a driving force for enhancing the presence of ethics in the engineering curriculum. Nevertheless, it has also been pointed out that this change is mostly at surface level, as the implementation of ethics is not considered to have been achieved in a systematic manner. The perception of ethics is that of an “add-on” in the engineering curriculum, in order to meet the accreditation criteria. Ethics still has the lowest weight in the curriculum of engineering programmes, and there is confusion present as to what falls under the scope of engineering ethics education. More so, none of the instructors interviewed could name a recommendation or suggestion for improving engineering ethics education that was formulated during an accreditation event or, following it, in the accreditation reports.

A major influence on changing the engineering curriculum was exercised by the requirements set by national accreditation bodies (Lattuca & Stark 2009; Graham, 2012; Lewis, 2016). Since the adoption of the Washington Accord, signatory countries are required to align to a similar set of graduate attributes, including ethics, and their national systems of accreditation need to ensure that these are being met. As such, the introduction of an accreditation criterion dedicated to ethics in the signatory countries of the Washington

Accord is considered to have led to an increase in the number of modules addressing ethical issues (Volkwein *et al.,* 2004; Lattuca *et al.,* 2006; Skinner *et al*. 2007; Barry & Ohland 2012).

Despite the positive findings on the role of accreditation in increasing the presence of ethics in the engineering curricula, there are doubts that the pressure exercised by accrediting bodies can translate into a deeper curricular change. Little (2019) found that institutional change rooted in the demands set by accrediting bodies leads to a culture of compliance rather than of transformative change. This type of pressure originating in the interplay between external influences and administration control is considered to marginalize the importance of individual instructors (Suskie, 2015), and give rise to a "transactional environment" (Little, 2019, p.33). As such, the implementation of accreditation recommendations formulated in an increasing level of detail does not translate into quality curricular change, enhanced student learning and achievement (Bolden, 2007; Haviland, 2014; Kuh *et al.,* 2015).

More so, older higher education institutions with a long legacy of alumni are also more resistant to implementing curricular change for the purpose of accreditation. As Ulker and Bakioglu (2019) found, accreditation leads to more improvements in the processes and practices of programmes in institutions younger than 20 years old than in longer functioning institutions, as their endurance tends to be equated with quality (Dew, 2009). Klassen (n.d.) also found that institutional prestige can be used to resist what is considered to be a "perceived misinterpretation of criteria by accreditors, in ways that would not be possible in lower status institutions." As Bernstein argues, elite universities can maintain their position with "less need to change their discourse or organisation to maintain their power and position" (Bernstein, 2000, p.69).

Although policy agents have the role of initiating change through the formulation of mandatory learning outcomes that engineering outcomes have to prove, this type of change is considered to fall short of achieving a deeper change in the ethos cultivated by engineering programmes and a systematic reflection on the purpose of engineering education.

11.4.3 Institutional level

It has been argued that disciplinary cultures not only transcend institutional boundaries, but they also define them to some extent (Simpson, 2015). Reflecting on Biglan's (1973) genotype-phenotype analogy, Simpson (2015, p.1529) notes that it

> may apply not just to disciplinary cultures but to the relationship between disciplines and institutions as well. While an institution is much more than the sum of the disciplines it teaches, at its core, the institution may be the manifestation of the genes of its disciplines

At the same time, institutional agents such as universities have played a major historical role in societal transformation and promoting civic engagement (Watson *et al.,* 2011). They also play a role in the transformation of higher education itself (Kezar & Eckel, 2002; Merton *et al.,* 2004).

Institutional forces are seen to impact engineering ethics education by the participants interviewed through the allocation of resources, rooms and scheduling (L1; L2; L9; L10; L16) and by the preconceptions held by about the academic staff about the role of ethics in the engineering curriculum (L2; L5; L8).

Knight and Trowler (2000, p.77) have highlighted the unfixed and "not wholly determinant" nature of university departments and their subunits as "activity systems," which leaves room for agency rooted in reflection on the purpose of education. To effect a change at institutional level, it has been pointed out the importance of staff training, strategic decisions, resource prioritization and accountability in implementing change (Kezar &

Eckel, 2002; Ndoye & Parker, 2010; Barth & Rieckmann, 2012). A particular effective strategy for ensuring change is through incentives and measures that are internalized in the ethos and the reward system of the institution (Freeland, 1992; Seymour, 2001). Furthermore, it has been noted the importance of gaining an external perspective on the practices within an individual institution, through word of mouth, engaging in dialogue with external consultants and other institutions and conference participation (Kezar & Eckel, 2002; Froyd, 2011, p.5; Graham, 2012).

Engineering departments have been described as "engines of change," with successful curricular reform being the outcome of a department wide involvement (Graham, 2012, p.3). It has been argued that the focus for change agents should be at the middle of organisations (Croissant, 2007, p.46). In light of this, Seymour (2001, p.96) considers that "the department is the rock against which the teaching innovations of individuals or small groups of faculty are most apt to founder," given that they "operationally define, structure, evaluate, and reward the teaching and learning activities of higher education institutions." According to Bohunovsky *et al. (*2020), the recipe for comprehensive and advanced organizational transformational lies at the fruitful interplay between management and the individual academic actor.

Nevertheless, a high resistance to change has been noted among the "middle band of management," represented by "senior instructors or programme chairs, of long standing, and wielding great influence, sometimes through committees or less formally, as the protectors of their discipline or of the university's identity" (Kelly and Murphy, 2007, p.12). Given the "primary loyalty to the discipline over the institution" and the collective commitment to cover the approved canons of knowledge, as determined by the discipline, it is crucial to find the means to "leverage relevant shifts in values and practices" (Seymour, 2001, pp.96-7).

11.4.4 Individual level

Given the limitations discussed above at the institutional and policy levels, the attention turns to the role that individual agents have in effecting a change in culture.

As Lattuca and Stark (2009, p.301) point out, "although external influences sometimes create strong currents for change, colleges and universities are not passive recipients of societal pressures," noting that faculty and administrators are "active agents in the curricular change process." Academic planners are considered to have a particularly important role in promoting change, by focusing on education and the research undertaken in their institution, but also on the physical, operational, and external community functions of the university (Orr, 2002; Cortese, 2003).

The importance of change rooted at individual level is acknowledged also by Clark (1983), who concludes that effective change in universities is bottom-up, incremental, and often invisible.

Culture change can be effected at individual level in micro-situations (Sterling, 2004, p.61) or by being championed by committed individuals. (Godfrey, 2003a; Koester *et al.,* 2006; Ndoye & Parker, 2010; Blake & Sterling, 2011; James & Card, 2012). Mitcham (2009) and Billington (2006) have highlighted the historical significance of individual engineers in the development of an engineering culture fostering greater public accountability through the promotion of public safety, health, and welfare.

Filho *et al. (*2018) note the commitment of individual faculty members in fostering transformation in learning and education. The attitude and actions of academic leaders and senior members in an engineering programme can influence the broader institutional dynamics as to enable change (Jamieson & Lohman, 2009, p.4; Blake & Sterling, 2011, p.141; Bohunovsky *et al.,* 2020). As Billington argues (2006, p.212), "it is only the professors who can establish values in engineering and hence make clear to students, to the profession, and to the public at large what works and which people represent ethical behaviour." Educational leaders also have an important role through the values promoted and the power of example (Little, 2009). In this regard, head of engineering departments are considered to be primary players for supporting or initiating change (Graham, 2012, p.2).

To effect change, it has been noted the importance of individual academic and administration staff to act collectively and in collaboration (Graham, 2012; James & Card, 2012, p.171; Filho *et al.*, 2018, p.293). Engaging the educational community in curricular change is seen to foster a common vision and culture that supports the overall restructuration of the educational institution (Oliver & Hyun, 2007). This can be achieved through "working groups and faculty learning communities, with open discussions about how to redesign courses" (Filho *et al.*, 2018, p.293) and by encouraging faculty members to "think outside their discipline" (Graham, 2012, p.5).

Nevertheless, it has been pointed out that instructors struggle with what Fullan (2007) refers to as reculturing or the ability to rethink their roles and actions. This is not because they "do not care about improving instruction, […] but rather they have deep conflicting commitments, beliefs, and habits that inhibit and resist change" (Herman & Crowley, 2014). The study conducted by Sunal *et al. (*2001) also found that personal resistance to change, lack of training and curriculum materials represent an important barrier which has to be taken into consideration in initiatives for change.

11.5 Key findings

The present chapter first aimed to explore the characteristics of engineering culture, and its manifestation in engineering education. First, the cultural perception of engineering culture has been analysed, which emerges as a rigorous and difficult discipline, a masculine field, fit for those who excel in mathematics and physical sciences, devoid of subjectivity and with a lesser orientation towards societal issues (Tonso, 1999; Godfrey 2010; Stonyer, 2002; Stevens et al, 2007; Cech, 2014; Carberry and Baker, 2018). These cultural characteristics of engineering are seen to, on one hand, influence the development of an engineering identity as “nuts and bolts” technicists (Faulkner, 2007), and on the other hand, are reflected in the overemphasis of technical and scientific aspects in the engineering curriculum to the exclusion of ethical and societal concerns (Johnston *et al*, 1996; Stevens *et al*, 2007; Bucciarelli, 2008; Cech 2014; Jamison *et al*, 2014).

The second aim of the chapter was to put forward a retroductive explanation for the findings related to the current state and status of engineering education identified in all previous chapters. This explanatory process relied not only on the data manifest at the empirical and actual ontological domains, but it also relied on the theoretical conceptualisation of the culture of engineering. Thus, the prevalence of a conception of engineering education as a technical discipline, was identified as the generative mechanism within the societal level of the ontological domain of the real. For this retroductive explanation, several instances have been considered in which the findings of the study revealed a dichotomy between, on one hand, technical skills and knowledge, and on the other hand, ethics, alongside nontechnical skills and knowledge. While the former are treated and considered essential to engineering practice and engineering education, the later are considered and treated as nonessential.

The chapter then set to examine strategies for dismantling the dichotomy between the two distinct technical and nontechnical cultures together, based on existing studies and literature. The proposal is to devise and implement strategies for change that address all the levels of the engineering education system identified in the study.

12. CONCLUSION

The aims of my doctoral study were to examine the education and evaluation of engineering ethics, and also to provide an explanation of these findings rooted in the broader structures of the Irish engineering education system.

To achieve these aims, a mixed methodology has been adopted, consisting of participant observation at accreditation events, documentary analysis of module descriptors, accreditation reports and of the documentation submitted by the participant programmes for accreditation, a numerical analysis of a mandatory rubric by which programmes self-assess how their modules contribute to the accreditation outcomes, as well as interviews with instructors of modules of professional formation and evaluators serving on accreditation panels.

The study has three main contributions.

12.1. Contribution of the study to theory

The contribution of the study to theory consists in the use of a CR framework to examine the system of engineering education at three interrelated levels: the individual level of single agents such as instructors and evaluators; the institutional level comprised of engineering programmes and the policy level represented by the national accrediting body. Furthermore, a retroductive explanatory endeavour identified the generative mechanism affecting the activity at these levels. This mechanism was found to be the culture of engineering education and its valorisation of the technical over the social dimension of engineering.

The advantage of this theoretical approach is that key actors are placed in their socio-cultural and institutional context. This allows us to address some of the limitations of research in higher education which tends to focus only on individual actors such as instructors (Trowler, 2005, 2008; Ashwin, 2008, 2009), or remains focused on the levels of policy and practice without examining the deeper levels of paradigm and purpose guiding them (Sterling, 2004). By adopting an orientation focused on deeper levels, the study has linked some of the deficiencies in the education of engineering ethics with wider debates about which overarching paradigm should guide engineering education (Jamison *et al.*, 2014). Thus, a key issue that emerges is the need for clarity about the purpose of engineering education and the aims of programmes of reform.

12.2 Contribution of the study to research

The contribution of the study to research is rooted in the empirical analysis of the main characteristics of the education and evaluation of engineering ethics in a national setting, at the different levels mentioned above. While there is an emerging body of research in Ireland, it is focused on singular aspects such as the implementation of ethics in individual modules (Byrne *et al.,* 2013), specific curricular content (Fitzpatrick, 2010; Nicolaou & Conlon, 2012; Byrne, 2012), conceptual clarification of the different approaches to ethics education (Conlon, 2011), or the evaluation of ethics for the purpose of accreditation (Murphy *et al.,* 2019). This study represents the first attempt to examine the education of engineering ethics more broadly at national level. While the study does not claim to represent Irish engineering ethics education as a whole, it has given important insights about the process by which ethics is being integrated into the engineering curricula. The findings are thus envisioned to contribute to improving the education and evaluation of engineering ethics in Ireland. More so, it has been pointed out that research on change in engineering education has neglected the integration of different levels of the engineering system (Froyd *et al.*, 2008). Given the absence of a multilevel scope in engineering education empirical research, the study can contribute to international debates on the implementation of engineering ethics education and curricular change.[44]

The following main findings about the education and evaluation of engineering ethics have been revealed:

12.2.1 Low curricular presence

The study found that ethics is the programme outcome with the lowest weight in the curriculum of participant engineering programmes, considering all seven outcomes set by the accreditation body. Although the low presence of ethics in the engineering curriculum has been previously highlighted (Colby & Sullivan, 2008; Barry & Ohland; 2012; Ocone, 2013; Monteiro *et al.,* 2016), the study succeeds in revealing the weight of ethics in comparison with other outcomes, using the programmes' own assessment that is undertaken for the purpose of accreditation.

Despite ethics having been identified as the outcome with the lowest weight in the engineering curriculum, its presence is perceived to have been lower or even non-existent prior to the introduction of a dedicated accreditation outcome. This finding is in line with studies conducted in the US (Barry & Ohland, 2012; Volkwein *et al.*, 2004; Lattuca *et al.,* 2006), UK (Ocone, 2013) and Australia (Johnston *et al.,* 2000; Skinner *et al.,* 2007), which noted an increased emphasis on ethics in the engineering curricula following the introduction of a dedicated accreditation criterion. National accrediting bodies thus appear to play an important role in supporting engineering ethics education, through the formulation of accreditation requirements targeting ethics. The introduction of an outcome

[44] In the US, parallel to this project, Polmear (2018; 2019) has conducted a doctoral study which also used a multilevel approach.

dedicated to ethics by Engineers Ireland has been positively highlighted by participants as contributing to an increased attention given to ethics in the engineering curricula.

12.2.2 Unsystematic and uneven implementation

The implementation of ethics by participant programmes appears to be uneven and unsystematic.

The study shows a lack of uniformity in the implementation of ethics, confirming Colby and Sullivan (2008)'s findings. The uneven implementation of ethics is manifested most markedly at institutional level, with variations in the percentage of modules deemed to have no contribution to outcome E or as having a strong contribution to this outcome among the programmes offered by the different participant institutions.

In terms of the method of implementation, the study found that accreditation panels favour an approach across the curriculum. A similar message has been expressed by representatives of the accrediting body, who during accreditation related events describe this as the preferred method of implementing ethics This approach is considered to foster the development of holistic engineering graduates that do not divorce ethics from the technical solutions they pursue, reflecting considerations similar to those expressed by Cruz and Frey (2003), Newberry (2004), Drake *et al. (*2005) and Ocone (2013).

Nevertheless, few programmes were deemed to have successfully implemented ethics across the curriculum. The study also notes a reported lack of guidance on how to adopt this approach at programme level, as well an expressed need for resources to guide the implementation of ethics. Among the ethical themes most present in the curriculum of participant programmes, three themes stand out as suitable candidates for an integration across the curriculum. The themes of sustainability, health and safety and legislation are present in a variety type of modules, such as technical modules, design modules, professional formation modules, capstone projects, work placement and dedicated modules. The focus on sustainability and policy may facilitate the broadening of engineering ethics through the inclusion of societal, political and institutional issues that arise in relation to technology (Herkert, 2000b; Gorman *et al.*, 2000; Conlon & Zandvoort, 2011; Byrne *et al.*, 2013; Bekker & Bombaerts, 2017). The study also highlights that a more comprehensive understanding of these thematic areas (i.e. of all three dimensions of sustainability) can be achieved through their inclusion in different module types and through various instruction methods (Fisher & McAdams, 2015).

Nevertheless, in the absence of guidance or efforts concentrated at programme level, the implementation of ethics is considered to be conducted in an unsystematic manner. It is most often portrayed by participants as a "box-ticking" exercise for receiving accreditation. More so, ethics is perceived as an "add-on" implanted in the engineering curriculum, supporting the views of Newberry (2004), Flynn & Barry (2010), Lambrechts *et al. (*2013).

12.2.3 Primacy of the practical dimension of engineering ethics

The analysis of the conceptualisation of engineering ethics education, together with that of the prevalent curricular content and teaching methods employed, point to a primary understanding of engineering ethics education in practical terms, which takes precedence over the theoretical dimension of ethical knowledge.

When defining engineering ethics education, the majority of participants highlighted its connection to engineering practice. As such, engineering ethics is considered to come into play when decision-making in complex situations is required. As Hess & Fore (2018; 2020) point out, learning goals are seldom directed at developing ethical dispositions and there is a low engagement with philosophical theories, while rules and codes are emphasized in engineering ethics education. According to Barnes *et al.* (2001), the lesser focus on the attainment of theoretical knowledge can be attributed to the dichotomy between technical and nontechnical subjects. As such, Barnes *et al.* (2001) found that instructors teaching technical subjects were more likely than those teaching nontechnical subjects to set teaching goals related the development of “subject matter facts and principles”, compared with goals related to “student development” set for nontechnical subjects. Thus, Barnes *et al.* (2001) imply that for nontechnical subjects, grades and assessment are not linked with the expectation of mastering a body of knowledge, and do not serve a gate keeping function for the profession, as in the case of technical subjects. Following the explanation provided by Barnes *et al.* (2001), gaining practical experience could be interpreted as a means for personal development, in terms of the goals set for nontechnical subjects identified in their study.

This emphasis on the non-theoretical dimension of engineering ethics education is reflected not only in terms of teaching content, but also in the teaching method favoured by instructors. There is an explicit preference for teaching methods containing a practical element, such as case studies that employ real/realistic scenarios and engage external stakeholders.

12.2.4 Confusion and misunderstanding

It is notable to point out that the study encountered some confusion expressed by the participants as to what topics fall under the scope of engineering ethics education. This confusion is mostly present when considering curricular content related to safety and legislation, but also a treatment of plagiarism in academic ethics terms. The confusion appears to be rooted in a lack of guidance for teaching ethics and, given the increased presence of these topics in technical modules, with the instructors’ unfamiliarity with the subject. This finding mirrors the challenge of linking ethical concerns with technical subject matters, reported by Sinha *et al. (*2007), Harding *et al. (*2009), Romkey (2015) and Polmear *et al. (*2018).

12.2.5 Multiple Challenges

Several challenging aspects surrounding the education and evaluation of engineering ethics have been reported by participants. Most notably, these are related to a diminished expertise of instructors teaching modules with high ethical content, the prejudices regarding the lesser status of ethics encountered among staff and students, a lack of adequate training, guidance and institutional support in the implementation of ethics. The challenges experienced in the evaluation of ethics mirror those encountered by instructors, as the programme outcome dedicated to ethics is considered to be the most difficult to evaluate. This is explained by the participants as being due to a lack of expertise in the topic, given the technically oriented educational formation of the faculty body.

These challenges resonate with those reported in studies conducted in the US and Canada between 2000 and 2018 (Besterfield-Sacre *et al.,* 2000; Goldin *et al.,* 2006; Sinha *et al.,* 2007; Harding *et al.,* 2009; Walczak *et al.,* 2010; Barry & Ohland, 2012; Romkey, 2015; Ferguson & Foley, 2017; Polmear *et al.,* 2018), which suggest that the progress in implementing ethics has been slow and challenges still persist two decades following the introduction of an accreditation criterion dedicated to ethics.

12.2.6 Lesser status

Ethics appears to be commonly portrayed as a “soft” discipline that is an “add-on” in the engineering curricula and has a non-essential role in engineering education, congruent with the findings of McGinn (2003), Flynn and Barry (2010), Fabregat (2013), Miñano *et al. (*2017), Lönngren (2019) and Sucala (2019). The ethical components of the engineering curricula are reported to be perceived by students as easy components to pass. They are considered to have a low failure rate, associated with the possibility of passing the component through what instructors consider to be "waffle" and "parroting."

12.2.7 Cultural perception of engineering as a technical discipline

Finally, the generative mechanism proposed as an explanation for the aforementioned findings is the prevalent cultural perception of engineering as a technical discipline, reminding of the cultural status of ethics in engineering described by Godfrey (2010), Cech (2014), Carberry and Baker (2018). This cultural perception is reflected at the surface level of the curricula, in the lower weight given to ethics, and also in the beliefs and values held at institutional level on the role of ethics in engineering education pointing to its lesser status.

The study thus highlights the need for a multilevel transformative process that can lead to a reorientation of the engineering curriculum "for" ethics, in the spirit of the hybrid model of engineering education proposed by Jamison *et al. (*2014). In the following subsection, I will explore how a program for change can be articulated.

12.3 Contribution of the study to practice

The contribution of the study to practice is that of guiding transformative curricular measures, at the different levels of the engineering system based on the findings of the study, as well as those reported in the literature. The study thus suggests that a reorientation of the engineering curricula "for" ethics needs to target four levels of the engineering education system. With this aim, the study recommends the following multilevel change measures:

12.3.1 Individual level measures

At individual level, the actions and example set by individual instructors are powerful means to instil educational change. As Lattuca and Stark (2009, p.301) remark, faculty and administrators are "active agents in the curricular change process." To achieve change, it has been noted the importance of collective action and collaboration (Riley *et al.*, 2004; James & Card, 2012; Filho *et al.*, 2018) in order to foster the overall reorientation of the programme (Oliver & Hyun, 2007). It was suggested that this can be accomplished through working groups and faculty learning communities, with open discussions in which instructors are encouraged to think outside their discipline and how to redesign courses (Graham, 2012; Filho *et al.*, 2018).

12.3.2 Institutional level measures

At institutional level, participants highlighted the need for additional resources dedicated to ethics instruction, adequate room repartition and timetabling, as well as fostering the development of communities of research and practice for guidance and sharing best practice in the education of engineering ethics. Participants also point to the preconceptions about the role of ethics in the engineering curricula as a barrier in its implementation. The literature supports the undertaking of an overall redesign of the engineering curricula (Graham, 2012). This can be achieved through staff training, resource prioritization, incentives internalized in the reward system of the institution, accountability in implementing change, as well as by gaining an external perspective through conference participation and engagement with non-engineers, educational consultants and other institutions (Seymour, 2001; Kezar & Eckel, 2002; Ndoye & Parker, 2010; Froyd, 2011; Barth & Rieckmann, 2012; Graham, 2012). The potential of individuals acting as "agents of social change" has been identified by Byrne *et al.* (2013, p. 391). It is thus important to have networks of engineering ethics educators that can "communicate and share experiences at national, transnational and disciplinary and trans-disciplinary levels" (Byrne *et al.*, 2013, p. 391). One such network initiated in the European context is the Special Interest group on Ethics of SEFI – The European Society of Engineering Education.

Given that the study revealed a low level of engagement between engineering and philosophy or social science departments, fostering collaboration between the two disciplines represents another way to develop an integrative model of engineering education at institutional level. Taken a step further, it is suggested that this interdisciplinary approach can be implemented through hiring practices, and reflected in the componence of engineering departments (Murphy *et al.,* 2019).

12.3.3 Policy level measures

At policy level, participants in the study commended the impact of the national accrediting body on enhancing the presence of ethics in the engineering curricula. National accrediting bodies can initiate curriculum change through the formulation of mandatory requirements for accreditation that include ethics (Lattuca & Stark, 2009; Barry & Ohland 2012; Lewis, 2016).

Although the measure is not sufficient by itself (Bolden, 2007; Haviland, 2014; Kuh *et al.,* 2015; Little, 2019), it can nevertheless represent an impetus for including more curricular content purporting to ethics in national engineering systems that do not feature ethics as a mandatory accreditation requirement (Monteiro, 2016; Monteiro *et al.*, 2017). The way such requirements are formulated is also important, given that accreditation criteria are seen to reflect shared values across industry, academia, government, and the broader community (Riley, 2016). It is thus important for accrediting bodies to be proactive in exploring with various stakeholders how ethics should be incorporated in the accreditation criteria in terms of scope and the formulation of learning outcomes. Another aspect that accreditation bodies can consider, mirroring the discussion about the implementation of ethics across the curriculum, whether ethics should be confined to a dedicated accreditation criterion or be incorporated across all criteria.

Furthermore, instructors who participated in the study noted the need for an active role played by the accrediting body, by providing additional support in the implementation and teaching of ethics. The support measures indicated include dedicated training sessions, expert advice or by facilitating stakeholder engagement. These are similar to the suggestions presented in the study by Byrne *et al*. (2013, p.391) about the role of accrediting bodies in supporting the enhancement of sustainability in engineering education, by "disseminating good practice, sharing examples and providing for staff to come into contact with champions".

Evaluators serving on accreditation panels also highlighted the need for additional training and guidance in the evaluation of ethics. According to participant observation, a helpful measure would be to bring in accreditation panels academics or professionals with experience in addressing the ethical and societal dimension of engineering. In line with calls expressed by the Liberal Education Division (Quiles-Ramos *et al.,* 2017) and findings of Murphy *et al. (*2019), specialists that can be involved in the evaluation of ethics or training initiatives can be engineers with experience in nongovernmental initiatives, policymaking, instructors teaching modules with a high ethical content, philosophers or social scientists with an expertise in engineering ethics or the philosophy of technology.

To improve the preparation of the accreditation process, given the lack of consistency between self-assessment scores, evidence and reality of practice identified, as well as the contrasting recommendations in regards to self-assessment and display of evidence that programmes are exposed to, it is important for accrediting bodies to explore what strategies work for the purpose of preparing and displaying evidence. Other actions include the organization of training sessions or developing a guidebook on these issues.

12.3.4 Societal level measures

At a deeper level, the study identified the culture of engineering education as the generative mechanism for the current challenges and deficiencies encountered in the education and evaluation of engineering ethics. These cultural issues are represented by the traditional view of engineering as a "nuts and bolts profession," as well as the primacy of technical skills perpetuated by engineering education. It is thus imperative the need for changing the ethos and purpose of engineering education (Sterling, 2004) towards a socio-technical cultural identity. This means that instead of focusing on the integration of ethics in an already crowded curriculum or the addition of single courses, there should be a systemic change for transforming higher education towards an integrative state (Sterling, 2004; Bucciarelli, 2008). This approach requires reculturing, not just restructuring (Fullan, 2007). As Harding *et al*., p.5 (2009) point out, it is essential for "engineering education leaders to continue, and even intensify, the message that ethics and professionalism are critically important and essential parts of undergraduate engineering education".

These multilevel actions revealed by the study and the literature highlight the wider practical implications of the research study for the engineering education community. In what follows, the focus is on presenting the implications of the study for suggesting new areas of research.

12.4 Implications for further research

Having highlighted the need for a systematic transformation of the engineering curriculum, it is important to research strategies for curriculum redesign and identify examples of best practices in the development of a hybrid educational model. Recent years saw growing debates and research on education for sustainability (Holmberg *et al.,* 2012; Trowler *et al.,* 2013; Filho *et al.,* 2018) and an equal attention should be given to the transformation of engineering education for ethics.

Given that the study revealed the unsystematic implementation of ethics in the engineering curriculum, further research is needed to explore the “appropriate balance of tool skills with other curriculum areas,” which according to Wicklein (1997, p.74) is the key to a healthy engineering curriculum. Research questions can thus explore the implementation of different strategies for rebalancing the curriculum undertaken at programme or institutional level.

As the present study has identified three topics (sustainability, safety and legislation) amenable to the implementation of ethics across the curriculum, further research can examine the integration of ethics topics and curricular units at the level of specific programmes and institutions. A particular focus can be given to case study research of programmes that report positive results or describe initiatives for implementing ethics across the curriculum, similar to those exposed by Riley *et al. (*2004) and Mitcham and Englehardt (2019).

In light of the limited research available on the effectiveness of the various teaching methods employed in engineering ethics instruction and in particular of case studies (Lundeberg, 2008; Barry & Ohland, 2009, p.381, Yadav & Barry, 2009, p.138; Romkey 2015, p.25), the study suggests further research for exploring the alignment between teaching methods employed and the goals set for engineering instruction. Additionally, this might require research targeted at developing teaching materials, guidelines and guidebooks (Reed *et al.,* 2004), in line with these empirical findings on the effectiveness of different teaching methods.

Further research is also needed to examine the effectiveness of various teaching approaches for enhancing student engagement, given that student reception has been identified both in the study and in the literature as a challenge for engineering ethics instructors (Harding *et al.,* 2009; Romkey, 2015; Polmear *et al.,* 2018).

Participant instructors highlighted the need for more guidance in the teaching of engineering ethics, as there is a lack of familiarity with the topic, supporting the findings of Sinha *et al. (*2007), Walczak *et al. (*2010), Monteiro (2016) and Polmear *et al. (*2018). Consequently, a recommended avenue for further research is to provide an in-depth exploration of the challenges experienced by instructors for teaching ethics, as well as to examine the effectiveness of different strategies countering these. Similarly, it is important to research challenges faced by members of accreditation panels in the evaluation of ethics (LeBlanc (2002), given the role that accreditation recommendations have in shaping the engineering curricula.

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APPENDIX 1: Nondisclosure Agreement Signed With Engineers IrelRe

MUTUAL NONDISCLOSURE AGREEMENT

THIS AGREEMENT is made this **20th** Day of **November 2017** (the "**Effective Date**")

BY AND BETWEEN

1) **Dublin Institute of Technology** of Grangegorman Lower, Dublin 7, D07 H6K8 (hereinafter referred to as "DIT") and.
2) **Engineers Ireland** having its registered office at **22 Clyde Road, Ballsbridge, Dublin 4** (hereinafter referred to as "**Third Party**").

(The aforesaid organisations are hereinafter referred to individually as "Party" and collectively as "the Parties").

IT IS HEREBY AGREED as follows:

1. **Purpose**. DIT will undertake an analysis of the accreditation reports by Third Party of third level engineering programs (the "Project"). Third Party will disclose its Confidential Information to DIT, related to the accreditation of of Level 8 engineering programs.

2. **Definition**. "**Confidential Information**" means accreditation reports by Third Party of third level engineering programs.

Confidential Information does not include information, technical data or know-how which:

i. was in the public domain at the time it was disclosed or falls within the public domain, except through fault of the receiving party; or
ii. was known to the party receiving it at the time of disclosure as evidenced by the receiving party's written record; or
iii. was disclosed after written approval of the disclosing party; or
iv. becomes known to the receiving party from a source other than the disclosing party without breach of this Agreement by the receiving party provided that such source was not known by the receiving party to be bound by a confidentiality agreement with or other contractual, legal or fiduciary obligation of confidentiality to the disclosing party or any other party with respect to such information; or
v. is disclosed to third parties by the disclosing party without a duty of confidentiality; or
vi. was independently developed by the receiving party without the benefit of data received from the disclosing party, as evidenced by the receiving party's written record.

3. **Non-Use and Non-Disclosure of Confidential Information.** DIT agree not to use the Confidential Information disclosed to it by the other party for its own use or for any purpose except to carry out the Project. DIT may publish the results of the Project if DIT redacts from any such publication the name of all third-level institutes and the names of all third level engineering programs disclosed to DIT in the Confidential Information. DIT will report the findings of the project in such a manner that individual programmes cannot be identified.

4. **Mandatory Disclosure**. In the event that DIT or its respective directors, officers, employees, consultants or agents are requested or required by legal process to disclose any of the Confidential Information of the Third Party, DIT shall give prompt notice so that the Third Party may seek a protective order or other appropriate relief. In the event that such protective order is not obtained DIT shall disclose only that portion of the Confidential Information which its counsel advises that it is legally required to disclose.

5. **Return of Materials.** Any materials or documents of which have been furnished by one party to the other will, upon request, be returned within fourteen (14) days, accompanied by all copies of such documentation, after the business relationship has been rejected or concluded.

6. **No License Granted.** Nothing in this Agreement is intended to grant any rights to either party under any patent, copyright, trade secret or other intellectual property right nor shall this Agreement grant either party any

PM
20/11/17

rights in or to the other party's Confidential Information, except the limited right to review such Confidential Information solely for the purposes of determining whether to enter into the proposed business relationship between the parties.

7. **Term.** The foregoing commitments of either party in this Agreement shall survive any termination of discussions between the parties, and shall continue for a period of five (5) years from the Effective Date of this Agreement.

8. **Miscellaneous.** This Agreement shall be binding upon and for the benefit of the undersigned parties, their successors and assigns, provided that, Confidential Information of either party may not be assigned without the prior written consent of the disclosing party. Failure to enforce any provision of this Agreement shall not constitute a waiver of any term hereof.

9. **Governing Law and Jurisdiction.** This Agreement shall be governed by and construed and enforced in accordance with the laws of Ireland and the Irish courts shall have exclusive jurisdiction in relation to disputes related to this agreement.

10. **Remedies.** Each party agrees that its obligations hereunder are necessary and reasonable in order to protect the other party and the other party's business, and expressly agrees that monetary damages may be inadequate to compensate the other party for any breach by either party of any covenants and obligations set forth herein. Accordingly, each party agrees and acknowledges that any such violation or threatened violation will cause irreparable injury to the other party and that, in addition to any other remedies that may be available, in law, in equity or otherwise, the other party shall be entitled to seek injunctive relief against the threatened or actual breach of this Agreement or the continuation of any such breach.

11. **No Obligation.** Nothing herein shall obligate either party to proceed with any transaction between them, and each party reserves the right, in its sole discretion, to terminate the discussions contemplated by this Agreement concerning the business opportunity.

12. **No Warranty.** All Confidential Information is provided "As is". Each Party makes no warranties, express, implied or otherwise, regarding its accuracy, completeness or performance.

EXECUTED by the Parties to this Agreement

SIGNED BY:

For and on behalf of: **Engineers Ireland**

Name: [illegible]

Position: Registrar

Date: 20th November 2017

SIGNED BY: Paul Maguire

For and on behalf of: **Dublin Institute of Technology**

Name: PAUL MAGUIRE

Position: SNR. LIC. EXEC, DIT HOTHOUSE

Date: 24/11/17

APPENDIX 2: Ethical Approval for Conducting The Research Study

REC-17-127

From: **STEVE MEANEY** <steve.meaney@dit.ie>
Date: 15 January 2018 at 21:54
Subject: Your application to the REIC (Ref REC-17-127)
To: Diana Martin <diana.martin@mydit.ie>
Dear Diana,

Your application to the REIC entitled 'Enhancing the Social Responsibility of Engineers:

An Investigation into the Patterns of Ethics Education in Engineering Programmes in Ireland' awareness of the social dimension of the engineering profession' (our ref REC-17-127) was reviewed at the December meeting of the REIC. Apologies for the delay in providing the feedback. The committee was unsure about some aspects and have requested clarifications as below.

1. Please clarify that WP1 and WP2 are desk based reviews of existing documentation and publicly avaialble data.
2. The interview described in WP3 lacks details in several areas including recruitment, informed consent process, power relationships (e.g. if interviewing colleagues).
   The REIC notes that the full details of WP3 may not be completed as yet and may indeed be contingent on completion of WPs 1 and 2. On the basis that WP1 and WP2 are indeed desk based without any primary data collection, the REIC will approve these workpackages but not WP3 at this time.

The committee has agreed that Chair's action can be taken on this application, if you can clarify the above points. We would appreciate if you could respond in a point by point fashion, to expedite the progress of the review.

Regards,

Steve

REC-18-263

Research Ethics Committee | Diana Adela Martin; Edward Conlon | Mon 6:41

Confirmation of Approval re. REC-18-263

Dear Diana,
CC Eddie

In relation to your submission to the committee regarding your project '*Enhancing the social responsibility of engineers: An investigation into ethics education in engineering programmes in Ireland*'. On reviewing of the submitted material today it is clear that this aspect of the work was carried out to high ethical, research and scholarly standards and the committees previous decision was approval with a number of very minor amendments noted. On the basis of the feedback, I can confirm that this work should be considered approved as all of essential ethical aspects were considered in your submission.

APPENDIX 3: Information Sheet and Consent Form Given To Participants Interviewed

Information Sheet

An Investigation into the Patterns of Ethics Education and Evaluation in Engineering Programmes in Ireland

You are being asked to participate in a research project examining ethics education in Level 8 Engineering programmes in Ireland. This project is examining how the ethical requirement for accreditation is understood and assessed by Engineers Ireland, and how it is incorporated by level 8 engineering programmes in Ireland. This project, which has the support of Engineers Ireland, includes examination of programme documents, interviews with lecturers and those involved in accreditation events and participation in a number of accreditation events.

For the purpose of this project, I am requesting that you consent to be interviewed and recorded. Questions will explore your

You should note:

1. All information gathered during this event will remain confidential to the researcher. No individuals or programmes will be identified in the reporting of the research findings in publications and conference presentations. The project, as a whole, is covered by a Non-disclosure Agreement between Technological University Dublin, the researcher, her supervisors and Engineers Ireland;
2. All data gathered during the interviews will be anonymised and stored on an encrypted device which is password protected;
3. You will receive a transcript of the recorded interview and you have the right to request edits;
4. You are free to withdraw your consent at any time;
5. I am happy to answer any questions you may have.

If you agree to participate, I am requesting that you complete the standard consent form overleaf.

Diana Martin (Doctoral Candidate)

School of Multidisciplinary Technology
Technological University Dublin
Bolton St
Dublin 1.
Dianaadela.martin@tudublin.ie

Consent form

Researcher's Name	DIANA ADELA MARTIN
Academic Unit	SCHOOL OF MULTIDISICPLINARY TECHNOLOGIES, COLLEGE OF ENGINEERING AND BUILT ENVIORNMENT, TECHNOLOGICAL UNIVERSITY DUBLIN
Title of Study	Enhancing the Social Responsibility of Engineers: An Investigation into the Patterns of Incorporation and Evaluation of Ethics Education in Engineering Programmes in Ireland

The following section should be completed by the research participant

	Yes	No
Have you been fully informed of the nature of this study by the researcher? (Note that this typically includes use of a participant information sheet)	☐	☐
Have you had an opportunity to ask questions about this research?	☐	☐
Have you received satisfactory answers to all of your questions?	☐	☐
Have your received sufficient information about the potential health and/or safety implications of this research?	☐	☐
Have you been full informed of your ability to withdraw participation and/or data from the research?	☐	☐
Have you been fully informed of what will happen to data generated by your participation in the study and how it will be kept safe?	☐	☐
Do you agree to take part in this study, the results of which may be disseminated in scientific publications, books or conference proceedings?	☐	☐
Have your been informed that this consent form shall be kept securely and in confidence by the researcher?	☐	☐

Name of Participant	Please use block capitals		
Signature of Participant		**Date**	
Signature of Researcher	DAMartin	**Date**	

APPENDIX 4: Semi-Structured Interview Template

E-mail message for requesting an interview with instructors

Dear Dr/Prof ,

I am a PhD researcher at TU Dublin conducting a study on the implementation of ethics in engineering programmes in Ireland. This work is being conducted in cooperation with Engineers Ireland.

To date, I have been reviewing documentation submitted by several programmes of ….. for accreditation by Engineers Ireland. I have also observed a number of accreditation events. Some of your modules have been identified as contributing towards meeting Programme Outcome E, which refers to "an understanding of the need for high ethical standards in the practice of engineering".

Therefore I am writing to ask if you would agree to a brief interview in relation to these modules. I am also interested in your views about engineering ethics and the process of accreditation.

I ensure you that our conversation will be subject to confidentiality, and is protected by a nondisclosure agreement signed with Engineers Ireland

Please let me know if you agree to be interviewed. I will send a full information sheet in relation to the interview before proceeding so that you can provide informed consent.

If you have any questions, do not hesitate to contact me.

Regards,

Question template for interviews with Lecturers

As a way of starting our interview, please tell me what was your motivation for teaching a module that includes ethics?

Could you please give me an example of the kind of topics you cover in this module?

How did you decide on which topics to include?

Could you please describe your process of preparation for teaching ethics?

What type of resources did you find useful when preparing to teach ethical content?

What were the most challenging aspects you encountered when preparing to include ethics in your teaching? What about challenges encountered in the classroom?

Could you tell me about the support you received when starting teaching ethics?
Is there any additional support that you would appreciate?

What do you aim for students to gain at the end of the module? What learning goals have you set in relation to ethics?

What teaching methods do you use for conveying ethical content?

How would you describe students' perception of ethics? What is their perception of ethics compared with technical modules?

How do you find that students engage with the module?

According to you, how do you see the role of ethics education in an engineering programme?

Have you always been involved in academic endeavors or have you been active outside academia as well?

Do you collaborate with any external stakeholders (companies, local NGOs) for the module? If yes, what do you think of this collaboration? If no, would you like to collaborate with external stakeholders?

Before we conclude, I want to ask if you have any comment or suggestion about the incorporation of ethics that I haven't addressed through my questions?

Thank you

Demographic data - Please choose the most appropriate option from below:

Gender: F M Nonbinary/Other

Age group: <30 30-39 40-49 50-59 >60

Area of specialization:

Approximate student size:

Professional experience: Industry Policymaking Nongovernmental

Other (Please specify)

E-mail message for requesting an interview with evaluators

Dear……. ,

We recently met during the accreditation event of …, where Engineers Ireland facilitated my participation as an observer. I am a PhD researcher at TU Dublin conducting a study on the implementation and evaluation of ethics in engineering programmes in Ireland, in cooperation with Engineers Ireland.

To date, I have been reviewing documentation submitted by several Engineering programmes in Ireland for accreditation and I have also observed a number of accreditation events. Following the observation of the accreditation event, a number of questions have arisen which I would like to explore with you further, so I am now writing to ask if you would agree to a brief interview in relation to your role as an evaluator for Engineers Ireland.

I ensure you that our conversation will be subject to confidentiality and is protected by a nondisclosure agreement signed with Engineers Ireland.

Please let me know if you agree to be interviewed. The schedule for the interview is expected for mid August- September. I will send an information sheet with a detailed description about the scope of the research in relation to the interview, before proceeding, so that you can provide informed consent.

If you have any questions, do not hesitate to contact me.

Regards,

Question template for interviews with Evaluators

As a way of starting our interview, please introduce yourself briefly

What is your educational formation? *If from academia:* Have you always been involved in academic endeavors or have you been active outside academia as well? *If from outside academia:* Have you also been involved in academic endeavors in the past?

At how many accreditation events have you took part in as evaluator?

Can you tell me more about your motivation to serve as an evaluator for accreditation events?

What is your opinion on the introduction of an outcome purporting to ethics among the accreditation criteria?

If you could please tell me more about how you view the scope of this outcome and what falls under ethics?

What is your opinion on how the programme outcome E is formulated?

Based on your experience as an evaluator, how do you consider that the programmes managed to integrate outcome E? Why do you think to be the case?

On a general level, given you participation in accreditation events, what are your thoughts on how ethics is being implemented in the curriculum of engineering programmes?

What do you consider to be an effective method of integrating ethics?? Do you find that ethics mostly belongs to dedicated single modules or have you found evidence that ethics permeates also technical modules?

How would you describe the experience of examining evidence in support of outcome E, and matching the evidence with the reality of practice?

Could you describe the more challenging aspects encountered when evaluating outcome E?

What role does it have for you the POLO rubric programmes by which the programmes self-assess how each module in the programme meets the accreditation criteria?
What kind of support or advice on how to approach the evaluation of outcome E have you received from the representatives of Engineers Ireland prior to or during the accreditation event?

If there is anything to improve in regards to the evaluation process, what would those aspects be in your opinion?

Turning to the coverage of ethics, what topics covered in relation to outcome E do you hope to see in the curricula of the engineering programmes being accreditated?

When you make recommendations or when you think of recommendations targeting this specific outcome, outcome E, what do you take into account? Furthermore, what type of change do you want to see?

How can the accrediting body support better the implementation of ethics? What about the support you consider beneficial from the accrediting body in the evaluation of outcome E?

Thank you for your time

Demographic data - Please choose the most appropriate option from below:

Gender: F M Nonbinary/Other

Age group: <30 30-39 40-49 50-59 >60

Specialization:

Professional Activity: Academia Industry Policymaking Nongovernmental
Other (Please Specify)