The Engineer in Society: an exploration of the treatment of ethics in engineering education and practice

EOIN HOMAN

Department of Adult and Community Education, Maynooth University, Co. Kildare

Doctoral Thesis submitted in fulfilment of the requirements for the degree of Doctorate in Higher and Adult Education

Supervisor: Dr Michael Murray

Head of Department: Dr Mary B. Ryan

August 2020

Acknowledgements

I dedicate this thesis to my mother and father, both of whom instilled in me a love and appreciation for learning. I also wish to thank my family for their support during the many challenging times that I have encountered in completing this research.

To all sixteen research participants, I thank each of you for being so generous with your time and friendship and for each helping to create a wonderfully supportive learning group.

I wish to express my deep gratitude to my supervisor, Dr Michael Murray, for his wisdom, guidance and support throughout this research journey. I also wish to thank Dr Anne Ryan, who, as second reader, provided insightful review feedback at an important time in the evolution of the study.

Finally, I would like to thank each member of the programme team within the Department of Adult and Community Education. Each of you has helped to foster a powerful and yet enjoyable and rewarding learning environment.

Abstract

This thesis explores the treatment of ethics within engineering education and practice under a sustainability guise. The approach taken has been to consider influences of rationality, power and ideology in shaping modern society and in framing the treatment of ethics within both engineering education and engineering practice. There is also a consideration of how those influences then shape and constrain possibilities of transformation within engineering education, which would be required to support the holistic adoption of a sustainability culture. As a result, the research creates a framing for understanding power and cultural discourses and their influences on engineering education. It also provides a lens through which to view how these influences subsequently shape contemporary engineering positioning within the sustainability domain.

The research finds that there are competing rationalities within engineering, with instrumental/technocratic rationality currently dominating over substantive/reasoned perspectives. This positioning has a profound, but arguably misplaced, influence on how engineers then engage within the sustainability domain. Professional body influences, shaped by a dominant capitalist societal paradigm, also feature as an important consideration. The research finds that such influences, imbued with institutional power, have a significant shaping and constraining effect on engineering education. This leads to a validation, at the professional body level, of the type of knowledge currently privileged within engineering education.

This research captures a key historical moment within engineering education. The study uncovers a depth and breadth of highly influential structural and agency

imbued forces that rigorously shape contemporary engineering education, while also presenting potentially significant and imposing barriers to change. However, in the research, there are signs of emergent educational practices which address some of the underlying deficiencies, revealed in the study, which is of real importance when considering the need for transformative repositioning within the sustainability domain.

Table of Contents

Table of Figures

Chapter 1: Introduction

1.1 Background and Rationale for Study

The extent of qualitative research conducted in Ireland, focusing on the treatment of ethics in engineering education and engineering practice is limited. Some notable exceptions include research conducted by Conlon (2010; 2013; 2015), focusing primarily on the treatment of ethics in engineering education and Byrne (2010; 2012), whose work in this area focuses on sustainability themes. Heywood (2008; 2016; 2017) has also written extensively on engineering education, including curriculum content, learning outcomes, and philosophical considerations. While acknowledging the valuable research work completed by these and other influential voices in Irish engineering education, the treatment of ethics and social responsibility within engineering remains an under-researched aspect of engineering education and practice (Conlon, 2013; Heywood, 2017). In this study, the approach taken has been to consider the influences of rationality, power, and ideological positioning. There is also a consideration of how those influences then shape engineering education and the engagement of engineers with society when viewed under a sustainability guise.

It is also noteworthy that there has been a distinct lack of research from within engineering in exploring the societal positioning of engineering. As a result, this study is novel, within an Irish context, in its conception, and its framing. In that regard, the study is informed by my extensive engineering experience, as both a practitioner and academic.

Sustainability underpins this study thematically. Codes of ethics, established by engineering professional bodies, commonly require engineers to understand and promote the principles of sustainability and to maintain an awareness of their environmental, social and economic obligations (Byrne, 2012). However, these obligations are only embedded in very few engineering programmes in Ireland (Byrne, 2012), even though sustainability-related challenges, such as climate change, transcend boundaries and require joint responses from a range of stakeholders (Ryan and Murphy, 2018). It appears that the widespread approach to the teaching of ethics to engineering students focuses predominantly on engineers acting as individual agents, with the broader context of their work being largely ignored (Conlon and Zandvoort, 2011).

There is also a consideration of whether or not students develop an awareness of the environmental, social and economic obligations of their future engineering practice (Byrne, 2012) and inter-disciplinary and inter-sectoral approaches (Ryan and Murphy, 2018). It is evident that this is becoming an increasingly important and urgent consideration for engineering as contemporary societal risks, in areas such as environmentalism and sustainability, are becoming increasingly impactful (Nieusma and Riley, 2010; Pelling *et al.*, 2015).

As an engineering professional representative body, *Engineers Ireland* fulfils an overarching, guiding and supervisory role over both engineering education and engineering practice in Ireland. As a result, powerful professional body influences, reflecting dominant societal positioning, are also an important consideration in the study, in reflecting on the current treatment of ethics in engineering education and engineering practice in Ireland.

1.2 Research Context

> If the social responsibility of scientists and engineers implies a duty to safeguard or promote a peaceful, just, and sustainable world society,

> then science and engineering education should empower students to fulfil this responsibility. (Zandvoort *et al.*, 2013, p. 1413).

This study sets out to explore the extent to which current education and engineering practice equips engineers to fulfil the responsibility as outlined by Zandvoort *et al*. (2013) in the above quotation. In this regard, the study considers, to what extent, the social dimension of engineering work might be undervalued and misunderstood (Robbins, 2007; Baillie, 2009; Conlon, 2013; Zandvoort *et al.*, 2013; Jamison *et al.*, 2014).

This research is situated primarily within a sustainability guise. Sustainability is an important contemporary consideration for the engineering profession as sustainability and sustainable development are cornerstones of many of the greatest challenges that engineering, and indeed humanity, face in the 21st century (Wilson, 2019). In considering a pathway towards sustainability, the *Brundtland Report* (1987) called for a fundamental transformation in global socio-economic development approaches. However, in subsequent years, the world has become less rather than more sustainable (Jamison, 2013). Many of the problems confronting engineers are more complex, requiring cross-disciplinary and cross-cultural interactions, with associated risks, creating the potential for having a lasting impact on society for many generations (Canney and Bielefeldt, 2015). Amongst the key global sustainability challenges are energy and food security, competition and scarcity of natural resources, and climate change (UNESCO, 2010). In contributing to the building of a more sustainable world, future engineering graduates will face these issues throughout their working careers. They will be required to engage effectively with the complex and interconnected nature of such challenges (Qureshi and Nawab, 2013).

Within this primary context, there is a consideration of the placement of engineering education within the bounds of sustainability. There is also a consideration of whether or not opportunities are presented to learners to reflect on sustainability impacts beyond current disciplinary boundaries. This consideration is becoming increasingly relevant in higher education in general, as the need to address complex cultural and ecological problems intensifies (Burns, 2015). What the study considers is whether curriculum change is required to embrace a wider and more critical perspective in confronting sustainability-related challenges. In this regard, in considering the global effects associated with key discourses of modernity, the study explores whether there is a wider ethical dimension to engineering practice than might currently be recognised or understood (Conlon, 2015). Similarly, there is a consideration of the need for interconnected, interdisciplinary and inter-sectoral responses to global sustainability challenges (Ryan and Murphy, 2018). There is also a call for ecological knowledge and different ways of knowing (Santos, 2016; Ryan and Murphy, 2018) that might bring a deeper, interconnected and holistic focus to engineering education and its ethical orientation.

In reflecting on current engineering practice, the study also explores whether there might also be an understated consideration of social responsibility, in the context of sustainability, within engineering practice. In this regard, the study explores whether current approaches to professional ethics also recognise impacts beyond disciplinary boundaries. What is considered here is the need for engineers to focus on technical problem solving whilst also aspiring towards being 'change-makers, peacemakers, social entrepreneurs, and facilitators of sustainable development' (Amadei, 2014, p. 126). This leads to consideration in the study of what might represent a currently dominant engineering ideology. The thesis interrogates whether this ideological positioning might be narrowly framed, informed by objective, formally rational and expert-based perspectives. A key consideration explored in the study is how ideological positioning informs policy in shaping engineering education and engineering practice. The research also explores how such positioning currently acts as a barrier to the repositioning of engineering education and practice.

I note, in the previous section, the overarching role fulfilled by *Engineers Ireland* within engineering in Ireland. The study also explores how the professional body currently shapes the treatment of ethics in both engineering education and engineering practice via policies, procedures, codes, and guidelines. In considering its positioning concerning sustainability, *Engineers Ireland* upholds a powerful and influential role in shaping the education and professional development of engineers. Their publications provide a framework for engineering curricula design and the subsequent professional development of engineers. The consideration here is whether or not there is a call for more critical reflexivity, at the professional body level, around the limitations of current ways of knowing within engineering education. There is also the question as to how instrumentalism and technocratic thinking inform dominant ways of knowing, reflecting the currently dominant market-driven societal paradigm. In terms of professional development and professional practice, members are required to adhere to the professional body's Code of Ethics (Engineers Ireland, 2018a). Members are also obliged to pursue a prescribed professional development pathway (Engineers Ireland, 2014b) to attain professional membership status. As a result, a critical exploration of the role fulfilled by *Engineers Ireland* is a key aspect of the study.

Much of the value of the study lies in the opportunity it has presented, in interviews and focus group debates, to dialogically engage with others within engineering, all of whom displayed a passionate interest in expressing their views on these important themes relating to engineering education and engineering practice. The resulting discussions and debates reveal a range of valuable and contrasting viewpoints, all of which are respected and represented equally in the study. While there is an international context to my research, my focus is intentionally directed primarily towards engineering education and practice in Ireland. This research represents the commencement of an important conversation, one that I hope will help to shape the future ethical positioning of engineering education and practice in considering contemporary societal needs.

1.3 Biographic Formation: the context for the development of my theoretical perspective

I begin this section by providing an outline of my biographic formation. I do so as my biography has been highly influential in informing my positioning, both as an engineer and educator.

I grew up in Ireland, in the Dublin suburb of Rathfarnham. During my formative years, my mother and father were very supportive and particularly so with regards to my education. In terms of political outlook, my father was very influential in my thinking. My father favours socialism as a political system. He was an active supporter of workers' rights in general, and he was a workers' union representative throughout his working life.

Meanwhile, my mother fostered in me a passion for education which has stayed with me to this day. My parents were also heavily engaged in community development work. Both my mother and father encouraged my development of social and societal awareness. Along with my brother and two sisters, I was encouraged to read the daily newspaper as a means of developing an understanding of the political, economic and social affairs of the day. The *Irish Times*[1] was the paper of choice, and editorial comments often promoted lively family discussions during those early years and still to this day. I can see now how influential my father has been in sparking my lifelong interest in politics and my general curiosity about societal issues and world affairs. I share my father's views in favouring democratic socialism as a political ideology. In that regard, I favour the 'modernity socialism' political system proposed by the Party of Democratic Socialism (PDS) in Germany in the 1990s. This political system includes three parts; a non-profit sector made up of national, state, and municipal institutions and non-governmental organizations; a for-profit sector made up of privately-owned competing companies and democratic decision-making institutions in both sectors to ensure that entrepreneurial initiative is subordinated to social and ecological needs (Guentzel, 2012). To my mind, one of the key aspects of this political system is the subordination of the marketplace to the social and ecological needs of society. There is a substantively rational (Weber, 1968; Ritzer, 2001) underpinning to this political system, a values-based approach that runs counter to the currently dominant political systems in the Occident, informed by formally rational perspectives (Weber, 1968; Ritzer, 2001).

[1] The Irish Times is an influential Irish daily broadsheet newspaper launched on 29 March 1859. The newspaper is published every day except Sundays.

My formative learning experiences have since influenced my epistemological positioning, as both a learner and an educator. My father encouraged in me the development of a critical thinking philosophy that has been influential in the subsequent development of my views on higher education. On leaving secondary school, I commenced studying building services engineering in Bolton Street College of Technology (now TU Dublin). When I now reflect on my educational experience, I can see how the emphasis was placed firmly on the 'memorising and regurgitating of information' (hooks, 1994, p. 5). My formal educational experience contrasted starkly with my formative learning experiences with discussion, critical thinking and reflection being actively encouraged by my father and mother. Class time was often spent taking notes from an overhead projector, or directly from a blackboard. There was little time for discussion, due to the need for frantic notetaking to keep pace with the lecturer's writing. Student attendance rates were often poor as we soon realised, as learners, that we could easily share notes between classes and, given the lack of active class participation, the motivation to attend class was low. In a manner that reflected our educational experience, Freire (1996) describes a 'narrative education' as one whereby the narrated content of education turns students into 'receptacles to be filled by the teacher' (Freire, 1996, p. 53). The more completely the receptacle filling, the better the teacher and the 'more meekly we as *receptacles* permitted ourselves to be filled the better the students we were' (Freire, 1996, p. 53).

In contrast to our classroom-based learning experience, time spent in laboratories conducting scientific and engineering experiments provided an opportunity to engage in experiential learning, we acquired knowledge by doing, reflecting on the doing, applying insight and improving the result (Durkin, 2016). Our laboratory practice was based on a four-stage experiential learning model involved concrete experience, reflective observation, abstract conceptualization and active experimentation (Kolb, 1984, p. 30). In hindsight, I believe that this engagement with experiential learning helped to develop my preferred reflective and reflexive approach to learning.

Another feature of my educational experience was that there was a noticeable emphasis on the acquisition of *known* facts, as opposed to, for example, the *problem-posing* education advocated by Freire (1996). A *problem-posing* educational philosophy is one which recognises that we are 'conscious beings, and consciousness as consciousness intent upon the world' (Freire, 1996, p. 60). According to Freire (1996), this alternative form of education 'rejects communiqués and embodies communication' (Freire, 1996, p. 60). As a result, it would have broken our exposure as learners to a vertical pattern of education. In that regard, I concur with Freire's (1996) assertion that, in such a teaching scenario, the teacher is no longer viewed only as the one who teaches but who is taught in a dialogue with the students, representing an active learning style.

As I reflect now on my engineering education, I find myself drawn towards the Freirean theories on *problem-posing* education which contrast so directly with my educational experience at the time:

> Whereas banking education anaesthetises and inhibits creative power, problem-posing education involves a constant unveiling of reality. The former attempts to maintain the *submersion* of consciousness; the latter strives for the *emergence* of consciousness and *critical intervention* in reality (Freire, 1996, p. 62).

On qualifying as an engineer, I spent the first part of my career practising in London, before returning to Ireland in the early 1990s. Informed by my formative formal education, I had only a superficial awareness of the societal impact of my engineering decision-making in the early part of my career. In reflecting on my career in professional practice, I can now see how my early career focus on progression and development in effect blinded me to the wider societal impact of my engineering decision-making. Over time, and as I reflected in more depth on my engineering practice, drawing from my lifetime interest in politics and societal issues, I began to develop such an awareness.

Over the twenty-eight-year period I spent practising as an engineer, I completed projects in Ireland and various locations around the world. My focus lay exclusively on a series of reductionist criteria associated with *successful* project execution. The client in each case was the paymaster for the company I represented, and we sought to complete projects by fulfilling contractual obligations agreed with those clients. We deemed projects *successful* if we achieved specific and narrowly framed project performance benchmarks. We identified successful projects by their adherence to what was known as the triple project constraints, which included the delivery of the agreed project scope, on time and within the agreed budget. From an ethical standpoint, I was guided by what was a relatively narrowly framed interpretation of the professional body code of ethics. On that note, I explore the influence of professional body Codes of Ethics (Engineers Ireland, 2018a) in some detail in the next chapter. There was a requirement to act honestly to comply with the code of ethics, with professional integrity and to protect the client's best interests, in good faith and at all times. In Chapter 2, I describe a currently dominant engineering ideological positioning. It is apparent to me now that I adopted this positioning in my practice as an engineer.

One particularly noteworthy ethical dilemma which remained unseen to me at the time but has caused me to reflect subsequently, concerned an urban renewal project in London's Docklands during the latter years of the Thatcherism[2] era. Consistent with other Docklands development projects at the time, there was little, if any, engagement with the established communities in the East End of London when developing the project. As Toulouse (1991) notes, the London Docklands Development Company (LDDC) made little effort to shape development to meet any of the social needs of the indigenous working-class population. One of the most devastating impacts of the development was on local employment. Although the renewal project created 20,000 new jobs, including the transfer of 16,000 of those jobs into the area but importantly 11,000 local jobs were lost due to escalating property values, causing local manufacturers to move out of the area (Toulouse, 1991). Effectively, my colleagues and I adopted instrumentally rational approaches in supporting unfettered entrepreneurism and neoliberal policies. The maintenance of the welfare of society is a key principle included in the Engineering Code of Ethics (Engineers Ireland, 2018a). However, in this instance, my focus remained firmly fixed within the physical and contractual boundaries of the project. At the time, the wider societal impacts of the project remained unseen to me.

I adopted a narrowly framed focus on technical problem-solving and on achieving predetermined project performance benchmarks and metrics became more

[2] *Thatcherism* represents a belief system and principles of the British government under Margaret Thatcher as Prime Minister from 1979 to 1990. The belief system was based on minimal government, the importance of individual responsibility, a strong state to provide adequate defence and to uphold the rule of law, the promotion of a market economy, the moral rejection of high borrowing and the pursuit of lower taxes and sound money Kavanagh, D. (1990) *Thatcherism and British politics: the end of consensus?* , Oxford: Oxford University Press.

pronounced over time, as commercial demands of projects led to *fast-track* project execution methodologies. In practice, I often found myself fulfilling the role of 'the hired gun doing the bidding of clients and employers' (Vesilind, 2010, p. 13) while pursuing instrumentally/technocratically rational approaches in focusing solely on the economic benefits of those projects for my employer and their clients. It is important to note however, that whilst my narrowly framed focus at the time aligned with dominant positioning within the profession, the Code of Ethics (Engineers Ireland, 2018a) is open to more expansive interpretation when considering issues concerning the welfare of society. Over time, I became increasingly conflicted by the tension between my commitment to my professional practice and professional development goals and my ontological perspective, which I consider in-depth in Chapter 4. In the case of my professional practice, there was a drive towards project outcomes aligning with the (neoliberal) demands of the for-profit sector and entrepreneurial initiative was most certainly not subordinated to broad social and ecological needs.

The societal injustices relating to the projects in which I was involved in perhaps became most starkly apparent to me on projects that I completed in the Middle East. As a highly paid engineer from Europe, my living and working circumstances were in stark contrast to those of many of my fellow workers, who were poorly paid migrant workers from the Global South[3]. Those migrant workers, categorised at the time as TCNs (third-country nationals), formed the backbone of the

[3] The term relates to the global positioning of the "South," as well as in the ideological and political role assigned to it in global politics. The use of the term is perhaps best explained geographically; except for Australia and New Zealand, developed countries of the world lie to the North of the developing or undeveloped ones. Dirlik, A. (2007) 'Global South: Predicament and Promise', *The Global South*, 1(1), 12-23, available: http://dx.doi.org/10.2979/GSO.2007.1.1.12.

workforce on construction projects in the Middle East. Project participants from the Global North were cosseted in very comfortable living conditions in gated compounds, whereas the living conditions of migrant workers were often appalling. As an example of this, Figure 1-1 below illustrates the living conditions of migrant workers based in Abu Dhabi in 2014. It is interesting to note that this project was completed on behalf of New York University in Abu Dhabi.

Figure 1-1: Migrant workers living conditions in Abu Dhabi
(Ponomarev, 2014)

During my time working in the Middle East region, I witnessed many migrant workers experiencing similarly poor living conditions. Despite labour reforms in recent years in Abu Dhabi, migrant worker complaints of inadequate housing, non-payment of wages, and threats of deportation persist, according to Human Rights Watch (2015). Similar living conditions are experienced by migrant workers elsewhere in the Middle East.

In terms of working conditions, there were equally divergent health and safety practices for workers from the Global North and Global South. Figure 1-2 depicts a scene that is common on building sites in the Global South.

Figure 1-2: Construction Worker on Site in Cambodia
(Consiglio, 2014)

Referring to Figure 1-2, An Vy, the construction worker illustrated in the photograph, is wearing only flip-flops as protective footwear, he is also not equipped with any safety equipment. What is equally striking is that he is working at extreme height, on a fifteen-storey, high-rise condominium development in Phnom Penh, Cambodia (Consiglio, 2014). In a quotation included in the article, An Vy expresses concern for his safety;

> I am so scared that I'll fall down from the top to the ground, but I have to do it…I do not have any other skills apart from this. I stopped studying at grade three because my family is very poor', later adding that he cannot afford to buy his safety equipment on his pay of about $8 per day (Consiglio, 2014).

Often on such projects, the design team will consist of engineers and architects from companies based in the Global North and the human rights violations experienced by migrant construction workers will often go unnoticed by them.

Comparing the construction site safety statistics in the Global North to those of the Global South, it is apparent that the incident and casualty rate is far higher in the Global South. Again, referring to the above article, Consiglio notes that, in its *2011 to 2015 Decent Work Country Program for Cambodia* (International Labour Organisation, 2012), the International Labour Organisation estimated that at least 1,500 workers died in 2009 of occupational accidents. Furthermore, it (International Labour Organisation, 2012) noted that construction sites and brick kilns were the most dangerous workplaces in the country.

Over time, I became increasingly concerned by the contrast between the relatively affluent lifestyle that I enjoyed, and the experiences of my fellow workers from the Global South. It was apparent to me that the starkly contrasting lived experiences of those from the Global North and the Global South amounted to a blatant example of social injustice. It is a key consideration of this explorative study that the assessment of the societal impacts of engineering decision-making continues to remain very much of secondary importance within engineering practice if it is even present at all. The lack of consideration of societal impacts is perhaps unsurprising, given that the conventional approach to engineering education is largely technology-based (Cumming-Potvin *et al.*, 2013).

Later in my career, I became the director of engineering for a company operating in the energy sector. The innovative nature of the company's business created the need to look at engineering challenges from a fresh perspective that required unorthodox solutions. However, while engineers are educated to design and create, there is little focus in an engineer's education on the philosophical dilemmas that often arise as part of that design and creation process. For example, ethical dilemmas are often present and require negotiation when considering the social and economic benefits associated with engineering decisions. In considering this subject, O'Sullivan *et al.* (2002) note how many energy sector projects have resulted in destructive environmental change. In so doing, O'Sullivan *et al.* (2002) make a case for practices that provide access at the deepest level to 'learning and to the transformation of our fundamental assumptions and beliefs about ourselves and our relationship to the environment' (O'Sullivan *et al.*, 2002, p. 2). During my career in engineering practice, I confronted many similar dilemmas concerning the intersection of engineering with society.

In summary, when I reflect now on my biographic history, my experiences as an undergraduate student and my subsequent experience as an educator have been influential in informing my views on effective teaching and learning practices. Equally, my engineering practice shaped my views on the treatment of ethics in engineering education which, in turn, leads back to my reflections on my engineering educational experience. For me, it has been a process of ongoing reflection and reflexive responses (Freire, 1996). My biographic formation has heavily influenced the formation of my theoretical perspective. Reflections on my engineering practice and, in particular on ethical considerations concerning that practice, provoked a reflexive response in sparking my interest in this research. In Chapter 4, I describe my epistemological positioning; I describe how I maintain a reflexive position, embracing both the positivist and social constructionist approaches. I do so in bridging the engineering and the sociological worlds in my dual roles in education and research. This positioning has helped to inform my view that the societal impact of engineering decision-making is undervalued and at times, unseen in engineering practice.

1.4 Core Research Arguments

The theoretical framing of this study emphasises the importance of the role of rationality and power in shaping engineering education and how this then impacts on societal engagement within engineering when viewed under the guise of sustainability. This is the key contribution of the research; it creates a framing for understanding power and cultural discourses and their influences on engineering education. It also provides a lens through which to view how these influences subsequently shape contemporary engineering positioning within the sustainability domain. This theoretical framing leads to the series of core research arguments as outlined below.

The first overarching consideration to emerge from the research, is that there is a clash of rationalities, and indeed, world views within engineering, with formal/instrumental rationality currently dominating. The argument here is that this clash of instrumental and value rationalities has a profound, but arguably misplaced, influence on how engineers then engage within the sustainability domain. When viewed through a sustainability lens, the research argues that dominant reductionist (and instrumental) technocratic perspectives, which themselves seek scientific/technological solutions for individual sustainability-related challenges, are inadequate as a response to the scale, nature and interconnected complexity of those challenges (Gough and Scott, 2006).

Linked to this first overarching argument is a consideration as to what informs this positioning, from an educational perspective. Here, we come to professional body influences and how those influences, imbued with institutional power, have a significant shaping effect on engineering education. The argument here is that the professional engineering body in Ireland, *Engineers Ireland*, holds a uniquely dominant and powerful position towards validating the type of knowledge which is privileged within engineering education. Professional body values and interests, reflecting dominant societal positioning, shape the instrumental thinking that currently predominates. As a professional body, it maintains a purposeful bureaucratic hold on engineering education and strongly influences how engineers view their societal roles within the profession.

While the dominant instrumentally/technocratically rational approaches, evident in engineering education and practice, are in essence purported to be 'value-neutral' from their own perspectives, the research finds that the instrumental rationalisation of engineering is imbued with the values of powerful interest groups (Brubaker, 1984) and, in particular, within an Irish context, professional body values. That positionality, heavily influenced by the aforementioned instrumental thinking, naturally aligns with, and uncritically supports, key discourses of modernity, including globalisation and neoliberalism. Crucially, in the context of this argument, this is informed by non-reflexive, expert-based thinking which prioritises neoliberal approaches. There is currently a dominant and rigid orthodoxy within engineering education, which is blind to other ways of knowing and thinking. This non-reflexive orthodoxy is then ill-equipped to engage with sustainability concerns and, indeed, debates associated with reflexive modernity (Beck, 1992; Lash *et al.*, 1996; Beck, 2010). Conceptually, the research describes how sustainable development and reflexive modernity are intimately connected. Rigid, technocratic ways of thinking and knowing, currently dominant within engineering, are ill-suited as a responsive mechanism, within either of these conceptual domains (Gough and Scott, 2006; Borne, 2010). Importantly, this research is not focused on a binary argument between the relative *rights* and *wrongs* of apparently dichotomous positions or ideologies. As a means of informing future debates in this thematic area, the research contrasts the currently dominant instrumentally rational engineering ideology with an alternative reflexive engineering ideology. In that comparison, there are aspects of each of these ideological formations that are complementary and, equally, there are elements of each that are in direct conflict.

The research leads to the further argument, which has garnered a mixed level of support from within this research, that there is a call for a paradigm shift in perspective, as a result of the failure of engineering to engage appropriately with, and fully appreciate, the interconnected nature of sustainability-related challenges (Gough and Scott, 2006; Ryan and Murphy, 2018). The argument here is that the debate about sustainability and education, in the context of globalization, requires a nuanced appreciation for, and development of, praxis-based reflexivity within engineering education (Bacon *et al.*, 2011; Karwat *et al.*, 2014). Such an approach would recognise the uncertainties, complexities and interrelationship of sustainability-related challenges. This research points to a need for imbuing reflexivity within all levels of engineering, including at the professional body, educator, learner and practitioner levels. The argument here tentatively proposed given the mixed level of support from within the research, is that such reflexive, open-ended learning is needed (Vare and Scott, 2008). The call for such praxis-based reflexivity is proposed as an acknowledgement of the complexities and uncertainties associated with sustainability and given that desired *end-states* cannot necessarily be specified in all instances. There is also a consideration of how the fostering of such learner reflexivity is key to living sustainably in an interconnected and globalized world (Ryan and Murphy, 2018). The argument being that rigid and unquestioning adherence to orthodox engineering thinking, as a means to all engineering ends, is not appropriate in contemporary society and, as a result, will no longer suffice.

This research captures a key historical moment within engineering education. What has been uncovered in the research is a depth and breadth of highly influential structural and agency imbued forces that perpetuate the status quo in engineering education, while also presenting potentially significant and imposing barriers to change. There are signs, evident within the research, of emergent educational practices, each of which is addressing, to varying degrees, some of the underlying deficiencies revealed in the research. The research partially validates the integration of reflexive approaches, in a social context, within engineering education. However, this is not to underestimate the challenges associated with introducing such approaches, given the powerful and overarching influences that maintain and perpetuate the currently dominant engineering ideology, founded on instrumentally rational thinking. This represents an early stage in this important debate; indeed we may be on the cusp of a paradigm shift in thinking and approaches, given how sustainability-related challenges are taking on increasing levels of urgency and societal importance (Byrne and Fitzpatrick, 2009). The perpetuation of current engineering educational practices and, the privileging of apparently (but mistakenly) value-neutral knowledge, focusing on instrumentally rational methods, is, I argue, no longer remotely fit for purpose when considered within the sustainability domain.

1.5 Research Question

In a broad context, this research considers the extent to which engineering, and society are inextricably interlinked. As a result, in considering this hypothesis, what is also in question is how engineering decision-making might account for the consideration of implications associated with those decisions. In exploring this theme under a sustainability guise, this study explores whether social responsibility is appropriately and adequately addressed in engineering education and engineering practice, in preparing engineers for their participation in contemporary society. Specifically, in focusing thematically on the positioning of engineering practice to fully support sustainable development and how engineering education might support such positioning, the research question that this study seeks to address is:

> *What are the challenges and opportunities associated with adopting a social responsibility approach to engineering education and practice?*

There are many considerations associated with this primary question. There is the consideration of how rational perspectives and ideological positioning might currently influence the engagement of engineering with society and within the sustainability domain. There is also the question of how institutional power, which are in turn shaped by the dominant societal paradigm, might influence engineering education, and how those influences might shape the treatment of ethics in engineering education and engineering practice? Also, linked to these questions is a consideration of whether there is a call for approaches to professional engineering ethics within engineering education that recognise impacts beyond current disciplinary boundaries in order to address sustainability concerns?

The research question is considered under an overarching sustainability guise which provides a foundation to this study thematically. In responding to this question in the study, there is an acknowledgement of the inter-disciplinary, inter-sectoral and global dimensions of sustainability (Gough and Scott, 2006; Ryan and

Murphy, 2018). There is also a consideration of the awareness levels within the discipline of engineering of the consequences, intended or unintended, of interventions (Beck, 1996; Lash *et al.*, 1996; Loon, 2002; Vallero and Vesilind, 2007). This awareness level consideration brings to the fore social justice themes as a function of the inter-connectedness and inter-dependency that inform sustainability. Given the importance of debates within higher education focusing on sustainability themes (Sterling, 2004b; Burns, 2015; Nicolaou *et al.*, 2017), the argument here is that the addressing of the above questions is of real importance in considering the future development of engineering education and practice.

1.6 A Note on Reflexively Following the Research Trajectory

In the early stages of my research, I had anticipated that the outcome of this study might provide an agreed basis for change within engineering education. I am a critical researcher, and I hold the view that my critical perspective and those of my fellow research participants are influenced by a range of social, political, cultural, economic, ethnic, and gender factors relating to my research (Creswell and Miller, 2000). In commencing the research, informed by my biographic formation, as I alluded to earlier in this chapter, I was motivated to bring about change in terms of the social positioning of engineering education and practice. I saw a clear need for engineering to embrace a social responsibility approach and, to more fully recognise a social dimension in both engineering education and practice (Herkert, 2005; Conlon, 2010; Riley, 2012; Jamison *et al.*, 2014). I had envisaged that some degree of consensus might emerge from the research, recognising the need to more fully embrace the social dimension of engineering, thereby positioning engineering education more fully within the sustainability domain. I foresaw a resounding recognition for the need to re-shape the educational treatment of engineering ethics within engineering education and perhaps based around a capabilities approach (Sen, 1985; Nussbaum, 2003; Sen, 2004; Walker, 2010; Walker and McLean, 2015). In anticipating this outcome, I had completed extensive work in adapting Walker's (2005) capabilities approach for application within engineering education. I was exploring the use of a capabilities-based framework within engineering education as a response to what I had perceived to be an undervaluing of the social dimension in engineering education and practice. I foresaw a version of education that supports the transformational possibilities of professional work and the contributions of professions to equitable and socially just societies. Walker and McLean (2015) point to the need for an approach to professional education and professionalism that moves beyond social critique, to give a positive definition to the potential achievements of the professions. The need for such an approach became clear to me as I reflected on my career experiences in engineering and my subsequent experiences as an engineering educator. However, no clear consensus emerged from the research to support such an agenda for change.

I recall proposing the parameters for my research in early supervisory meetings. My life experiences as an engineer and educator heavily influenced my proposal. Earlier in this chapter, I allude to the ethical dilemmas that caused me to reflect deeply about my role as an engineer and, the societal impact of my work. It appeared to me that there was a very obvious flaw in ethical positioning of engineering, which practically ignored the social dimension of that practice. At the time, I had a basic understanding of the sociological phenomena underpinning engineering ethics. The opportunity to deeply engage with this subject was one of the key attractions to me, as an engineer, in undertaking this sociological research.

I had an apparent *solution*, and now in my research, it was simply a case of framing the question to support a *valid* and qualitative research methodology, to support the research. When viewed through a task-focused engineering lens, all appeared to be straightforward. I would complete a comprehensive literature review; I would then afford research participants the time and space to openly consider the research themes; a focus group would then consider research findings. It represented a robust research approach, with triangulated research data to validate the outcome of the study. I perhaps naively envisaged a research outcome leading to development of an educational resource; a new module or framework that might support the reshaping of the treatment of ethics within engineering education.

In hindsight, this was a classic means-end instrumentally rational (Weber, 1978; Ritzer, 2001) approach. I entered the field as the engineering *expert* imbued with my value system and determined to produce a *valid* outcome using a coherent qualitative research approach and methodology. However, what then became apparent in the research was a diverse range of opinions on a potential future trajectory for engineering, in the context of appropriate societal positioning. There was a clear contrast in the opinions expressed by individual research participants, apparently embracing more transformative and substantively rational perspectives within the sustainability domain, with the dominant instrumentally/technocratically rational views expressed within the focus group, in considering any potential agenda for change. What I experienced, in transcribing the focus group discussion, can only be described as a profound sense of disappointment when discovering the conflicting positions and rational perspectives. It appeared that the underlying structure of my research thesis was flawed, with a resulting sinking of my research project. No roundly endorsed agenda for change would emerge from the study.

The research took a sharp turn at that point, which challenged my reflexivity as a researcher. I adopted a Freirean (1996) praxis-based approach in grappling with the themes and divergent views to emerge from the research. Whilst this was an unsettling experience, I now recognise that what emerged from that reflexive engagement with the complexity of the data subsequently enriched the research outcome. The potential benefits of adopting a social responsibility approach to engineering education and practice were recognised most apparently in individual interviews. In the focus group, however, the challenges and indeed, the potential barriers associated with adopting such an approach became most apparent.

In the study, I have recognised a diverse range of perspectives, experiences and standpoints, including my own. I remained sensitive to a range of interpretations and voices in the data; I also remained open and willing to critique and question my interpretations as well as those of all participants (Mason, 2002). In that reflexive and dialogic interaction, and in recognising the diverging participant responses when considering the research themes, the trajectory of the study changed and became more exploratory over time. It became apparent that the research had pivoted and, as a result, had become more exploratory in nature. Over time, the research evolved towards the consideration of engineering positioning within the sustainable domain. In this consideration, the prominence of power and ideology and their influencing effects on contemporary engineering education and practice became more apparent.

This conversation has emerged at a critical time in modern society. It is a time when sustainability-related challenges take on increasing levels of importance and urgency. It, therefore, makes a compelling case for continuing this important debate. It is not possible to predict the trajectory of the ongoing debate; however, given the societal importance of these issues, the assertion here is that the debate must continue.

1.7 Thesis Structure

This opening chapter provides a context for this study. The chapter begins with an overview of the aim of the research. The overview of research aims is followed by a consideration of the background to the study, with my biographic formation being particularly influential in leading me to this field of study. The core research arguments, pointing to the profound influences of power and instrumental/technocratic rationality within engineering education, are established. Within the chapter, I also introduce a tentatively proposed call for an alternative approach to the treatment of sustainability in engineering education, which more fully recognises the social dimension of engineering practice. The chapter includes a narrative of the research journey, with a significant twist at a key point in the study profoundly challenging my reflexivity and leading to a significantly altered framing of the research from that point onwards.

Chapter 2 provides an exploration of the literature describing the current positioning of engineering education and practice, concerning how both recognise the ethical engagement of engineering with society. In that exploration, what becomes evident is the predominance of a rigid orthodoxy of approaches. In critiquing these approaches, there is a consideration of contrasting socially expansive approaches towards the educational treatment of engineering ethics. The chapter also includes a critical review of a range of publications produced by

Engineers Ireland. In completing this critical review, I reveal how societal engagement is represented by *Engineers Ireland*, concerning engineering education and engineering practice, and also consider how powerful professional body influences, which in turn are shaped by the dominant societal paradigm, shape engineering education.

In **Chapter 3**, I turn to a consideration of sociological influences on engineering. In that regard, I consider key discourses of modernity, reflexive modernity and sustainability. My intention in doing so is to reveal how those influences impact on engineering education within the sustainability guise. I also consider ideological formations and rational perspectives and how these might influence how engineers view their work and their roles in society. In exploring sociological influences on engineering, my aim was to derive meaning from those influences to more fully understand how they might shape engineering education and practice from the ethical and social responsibility perspectives. There is also a consideration of influences of power and bureaucracy in maintaining the engineering status quo.

Chapter 4 describes my research approach and how my chosen research methodology has evolved. I then outline my ontological and epistemological positioning and how my positioning, in turn, influenced my research approach and the selection of my research methodology. This is followed by a description of my field research and data collection processes. The first field research stage focused on developing an understanding of how research participants might view the positioning of engineering concerning the research theme both from the engineering education and engineering practice perspectives. The second field research stage then considered the findings to emerge from the first field research stage within a focus group setting. There is also a consideration of reflexivity and reflexive responses throughout, which is a key aspect of the study.

In **Chapter 5**, I present the findings from the field research. What becomes evident in this chapter is widely contrasting views and perspectives when comparing individual research participant contributions with those that became apparent within the focus group. As I described earlier in this opening chapter, this clash of perspectives was not something that I had envisaged in entering the field. However, the contention is that the resulting conflicting perspectives revealed, and the varying world views expressed serves to enrich and deepen the research. As a result, the field research provided a diverse, complex and rich dataset for further analysis.

In the analysis within **Chapter 6**, the tensions between competing rationalities within engineering become apparent. However, a dominance of instrumentally/technocratically rational approaches emerges from the research, with resulting implications when considered under a sustainability guise. Profoundly powerful and overarching professional body bureaucratic influences are also analysed together with the role of these influences in shaping engineering education. What becomes apparent in the analysis, is the scale of the challenge to integrate a more transformative vision for sustainability within engineering education, given the currently dominant expert-informed approaches underpinned by instrumental/technocratic rationality. I argue that such transformative restructuring is crucial when considering the complexity and multi-dimensional challenges within the sustainability domain.

Finally, **Chapter 7** brings the study to a close. The chapter summarises what the research has found in considering the challenges and opportunities associated with adopting a social responsibility approach to engineering education and practice. The chapter notes the roles of power, ideology and reductionist epistemological approaches in profoundly shaping engineering education and in restricting the development of a holistic sustainability culture. In the recognition of a need for ongoing debate, the chapter highlights the contribution of the research in providing a framing for understanding how power discourses and their influences shape engineering education. The chapter closes with a list of recommendations for further research to advance this important debate.

Chapter 2: The Ethical Positioning of Engineering

2.1 Introduction

In the opening chapter, I refer to Zandvoort *et al.'s* assertion (2013) that if social responsibility within engineering implies a duty to safeguard or promote a peaceful, just and sustainable world society, then in their education engineering students should be empowered to fulfil this responsibility (Zandvoort *et al.*, 2013). In this chapter, I now explore the extent to which such a social responsibility focus is evident in current engineering education. In adhering to the sustainability theme, I also explore the positioning of engineering practice in this regard.

The role fulfilled by *Engineers Ireland,* the professional representative body for engineers in Ireland, is first critiqued with a view towards this research theme. A consideration of values and perspectives in the professional body publications is the key focus of the critique. The professional body provides an important link between engineering education and practice. I consider how, as a representative body, *Engineers Ireland* shapes and influences both engineering educational content and engineering practice. *Engineers Ireland* fulfils an important role in this regard, in the validation of the type of knowledge included in engineering programmes and in establishing professional development criteria for engineers. I also critique how *Engineers Ireland*, in its publications, apparently undervalues external engagement, in the context of societal and community engagement and, ethical and social responsibility positioning. I do so to explore professional body influences in considering the potential need for inter-sectoral and interdisciplinary responses to sustainability concerns (Qureshi and Nawab, 2013; Ryan and Murphy, 2018). I critically review a range of publications produced by *Engineers*

Ireland to reveal how the professional body frames the themes of societal engagement, ethics and social responsibility.

In the second part of the chapter, I explore the narrow focus that currently predominates in the treatment of ethics and social responsibility within engineering education. While my focus is directed primarily towards the education of engineers in Ireland, within the critique of the dominant narrowly framed approaches, I also draw on comparisons with educational practices that are currently in situ elsewhere in the world.

2.2 Professional Body Influences in the Programme Accreditation Process

Concerning engineering education in Ireland, *Engineers Ireland* describes the role it fulfils as follows:

> The Institution has as one of its purposes: setting up and maintaining proper standards of professional and general education and training for admission to membership or to any category of membership of the Institution. (Engineers Ireland, 2014a, p. 3)

There is a statutory grounding for its positioning as the professional representative body for engineers in Ireland. The professional body's 'Bye-laws' (engineers Ireland) constitute the rules whereby *Engineers Ireland* carries out its statutory functions. This positions the professional body as the internationally recognised representative body for engineers in Ireland.

The engineering programme accreditation process is one of the primary means by which the professional body fulfils its statutory function in relation to engineering education. Engineering education programmes that satisfy the appropriate accreditation criteria prescribed by *Engineers Ireland* are deemed to have met the educational standard required of those seeking one of *Engineers Ireland's* registered professional titles of *Chartered Engineer*, *Associate Engineer* or *Engineering Technician*.

Programmes are submitted for accreditation by higher education institutes in Ireland on a five-yearly cycle. As part of the accreditation process, an independent panel of experts, drawn from academia and industry, is formed to evaluate a programme proposed for accreditation. The accreditation panel will look for evidence to determine if the programme outcomes, defined by *Engineers Ireland* (Engineers Ireland, 2014a), have been met. Specifically, concerning the themes of ethics and social responsibility, programme outcome 'E', forming part of the accreditation criteria for the *Chartered Engineer* professional title, is described as follows:

> 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. (Engineers Ireland, 2014a, p. 16)

In describing how graduates might demonstrate how this outcome has been met in terms of knowledge, skills and competency, *Engineers Ireland* points towards the following:

> [T]he ability to reflect on social and ethical responsibilities linked to the application of their knowledge and judgements
>
> knowledge and understanding of the social, environmental, ethical, economic, financial, institutional, sustainability and commercial considerations affecting the exercise of their engineering discipline
>
> 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
>
> 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

> knowledge, understanding and commitment to the framework of relevant legal requirements governing engineering activities, including personnel, environmental, health, safety and risk issues. (Engineers Ireland, 2014a, p. 16)

In their framing, it is noteworthy that the ethical and social responsibility themes are phrased in such a broad manner in this programme outcome as to be open to a range of interpretations. On a similar note, in considering the ethical canons that apply to engineering practice in North America, Bucciarelli (2008) asserts that, in avoiding specifics, so much room is left for free interpretation as to render the codes almost irrelevant in practice. Equally, it might be argued that the avoidance of specifics allows room for the pioneering development of engineering programmes, safe from the criticism of those who may hold differing perspectives.

Conlon (2013) also notes how the accreditation processes do not fully address the extent to which programmes meet the specified learning outcomes and particularly so concerning the ethics and social responsibility related programme outcome. In participating in several accreditation processes on behalf of *Engineers Ireland*, I have witnessed how difficult it can be for engineering faculties to demonstrate compliance with programme outcome 'E' during the accreditation process. In considering why this might be the case, Conlon (2013) asserts that in the composition of accreditation panels, which include industry representatives and engineering academics, there is a lack of expertise to adjudicate the provision of content relating to social responsibility within engineering programmes.

There is also an apparent focus on the *individual* actions of the engineer in the phrasing of programme outcome 'E', which simplifies the ethical and social responsibility considerations encountered by engineers in confronting sustainability dilemmas. In this regard, in considering sustainable approaches, Donnelly and Boyle (2006) note how there ought to be a requirement for students to develop an understanding of how environmental, social, and political concerns are interlinked. However, the sense of the interlinking and interactions between engineering disciplines, non-technical fields and society is not explicit in the framing of the above programme outcome. It might also be argued that this objective might more broadly be applied across higher education institutes.

2.3 A Social Critique of Professional Body Documentation

Together with the influential position that *Engineers Ireland* upholds concerning engineering education, the professional body also influences and shapes engineering practice. The contention here is that it is particularly important to develop an appreciation of professional body positioning, given the body's broad shaping influence across engineering and at all levels. As a result, given its role in bridging engineering education and practice, it is useful to focus on how the themes of ethics and social responsibility are addressed within the selected publications. In order to do so, I critically review the following *Engineers Ireland* publications:

- *Engineers Ireland Accreditation Criteria for Professional Titles* (Engineers Ireland, 2014a): provides a reference point in defining the professional attributes that Engineers Ireland perceives to be of importance in the formation of the professional engineer.
- *Engineers Ireland Code of Ethics 2018 (Engineers Ireland, 2018a)*: in becoming a member of the professional body, engineers are required to comply with this code in guiding their practice ethically. As a result, it is an important artefact for consideration.
- *Engineering 2018: A barometer of the profession in Ireland* (Engineers Ireland, 2018b) and *Engineers Ireland Strategy 2017-2020: A community of creative*

professionals delivering solutions for society (Engineers Ireland, 2016): both are useful in illustrating how the professional body views the profession currently and as a portrayal of how the professional body envisions the future of the profession strategically.

- *Engineers Ireland CPD Accredited Employer Standard* (Engineers Ireland, 2012), *Engineers Ireland Continuing Professional Development Policy* (Engineers Ireland, 2017a) and *Engineers Ireland CPD Accredited Employer Standard Quick Guide* (Engineers Ireland, 2017b): the selected CPD policies are instructive in terms of revealing what the professional body perceives to be of importance in framing the professional development of engineers.
- *Regulations for the registered professional title of chartered engineer* (Engineers Ireland, 2014b): these regulations provide a reference point in defining the professional attributes that Engineers Ireland perceives to be of importance in the formation of the professional engineer.

This representative sample of *Engineers Ireland* publications has been carefully drawn from a wide range of guides, policies and reports produced by the professional body. Each publication provides a contemporary lens through which to explore professional body positioning within the dominant market-driven/capitalist societal paradigm and how that positioning then influences and shapes policy direction. The critique focuses on how the engagement of the engineering profession with society is represented in these selected publications. I explore references to societal and community engagement within the range of publications. I also explore the overall direction of policy, in the contexts of ethical positioning. In doing so, the ethical positioning of the professional body and its approach to societal engagement begins to emerge. The importance of these considerations will become apparent later in this chapter, in the critique of contemporary engineering positioning within the sustainability domain.

2.3.1 The representation of *community* within selected publications

It is striking to note the framing of references to the engagement with wider society as a one-way engagement process; phrases such as 'make an impact on' and 'delivering solutions for' create this impression. The following provides one example of such positioning in the *Engineers Ireland Strategy 2017-2020* (Engineers Ireland, 2016) publication:

> Good communication - working to advance our shared agenda with government and the community - can affect real change and in the process, it will help to build genuine understanding and appreciation of our sector. (Engineers Ireland, 2016, p. 9)

There is an aspiration to advance a shared agenda with the government, and 'the community' in the above quotation. However, from a policy perspective, the manner of doing so is not apparent; there is also no encouragement for members to do so actively.

It is noteworthy that while the word 'community' appears on a total of twenty-nine occasions in the referenced *Engineers Ireland* publications, in all but one instance, the framing of the community reference is around the professional positioning of a 'community of practitioners'.

The following mission statement, extracted from the *Engineering 2018: A barometer of the profession in Ireland* (Engineers Ireland, 2018b) publication, provides a representative example of the use of the word 'community' throughout the publications critiqued:

> Engineers Ireland is an organisation that enables the engineering community to progress their professional development, make an impact

> on society and encourage and educate the future generations of engineers. (Engineers Ireland, 2018b, p. ii)

This report contains the single reference provided in any of the publications to a more aspirational vision for the profession concerning community engagement:

> Behind every design-led engineered solution are communities and families that benefit. (Engineers Ireland, 2018b, p. ii)

In a further quotation from the *Engineers Ireland Strategy 2017-2020* (Engineers Ireland, 2016) publication, a desired outcome from the above strategic objective would entail 'more public appreciation of the role of engineering in our society' (Engineers Ireland, 2016, p. 9). There is a sense of authoritative knowledge in this quotation; with the stated objective being to foster a greater public appreciation for the role of the engineer. There is no aspiration for the engineer to develop a deeper appreciation for the significance or impact of their role in society or how, for example, technology ought to be co-produced with society. This theme is considered from a sociological perspective in the next chapter.

The *Engineering 2018: A barometer of the profession in Ireland* (Engineers Ireland, 2018b) publication includes the results of a survey completed in 2018 by a market research company, *Behaviour & Attitudes*. The survey includes a face-to-face poll with 1,000 members of the public, aged 16 years old and over. In commissioning the report, *Engineers Ireland* was interested in learning about the general public's perspectives on the engineering profession and how these perspectives compared with feedback from their members.

Encouragingly, the results of the survey indicate that there is strong public trust in the competence and truthfulness of the engineering profession when compared to other professions. A total of 91% of the participants surveyed thought that engineers were highly competent and that they apply expertise in their daily work.

Furthermore, 90% of adults surveyed trusted engineers to tell the truth. Of the ten professions listed, only doctors were more trusted. In the report, *Engineers Ireland* expressed the belief that one of the reasons why the public holds such high levels of confidence in engineers is the role the profession plays in public health and safety. In the survey, 77% of participants surveyed agreed that engineers are essential in reducing risks to public health and safety.

Again, there is a relatively narrowly framed engagement with the public in this survey. Indicators of trust, framed around truthfulness and confidence in the profession, are based on the public's trust in the profession in the role that it plays within a narrowly framed brief of maintaining public health and safety. This framing is a particularly narrowly considered interpretation of a *do no harm* principle. There is, for example, no consideration of the public's trust in the profession to actively engage with the community, to take account of their views and concerns in relation to engineering work, as would be required in fully obtaining informed consent as outlined in the previous section for example. The word tree illustrated in Figure 2-1 reflects how the 'community' is represented in the publications (see also Appendix 6):

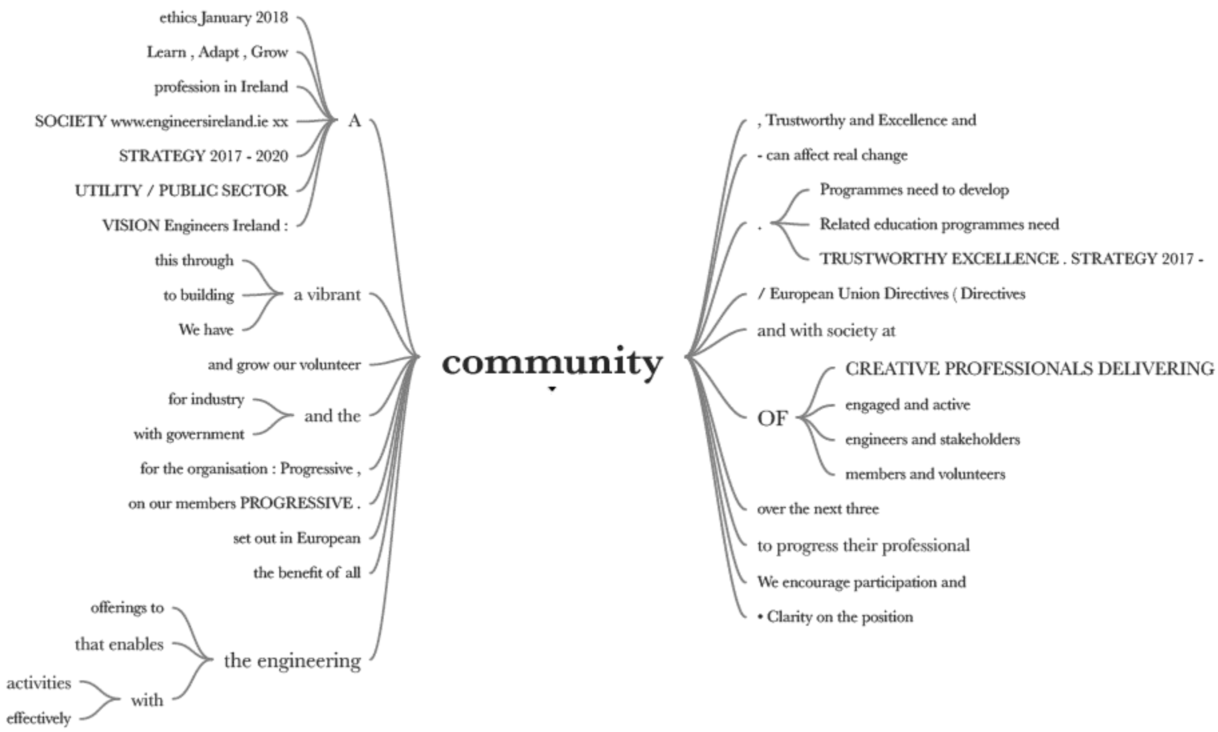


Figure 2-1 References to 'community' in *Engineers Ireland* Publications

In the above illustration, there is little sense of participatory engagement within the wider community or indeed, any form of community engagement. For example, the phrase 'creative professionals delivering…' carries a sense of the use of expert knowledge for the assumed benefit of society. There is a sense of society being the beneficial recipient of endowed professional expertise. The assertion here is that this is problematic when such positionality is viewed under a sustainability guise, calling for reflexive and participatory approaches (Gough and Scott, 2006; Borne, 2010). This consideration is examined, in sociological terms, in the next chapter.

2.3.2 Engineering interaction with society: the authoritative voice emerges

The publications are framed consistently in a manner which describes how engineering is having an impact 'on society'. The following mission statement is taken from the *Engineering 2018: A barometer of the profession in Ireland* (Engineers Ireland, 2018b) publication:

> *Engineers Ireland* is an organisation that enables the engineering community to progress their professional development, make an impact on society and encourage and educate the future generations of engineers. (Engineers Ireland, 2016, p. 9)

There is again a sense of authoritative knowledge being applied by the discipline of engineering *on* society and of engineering creating solutions for the benefit of society. What is missing perhaps is a vision of how such a beneficial impact might be co-created with society as might be required, for example, in considering engineering engagement within the sustainability domain. The following quotation taken from the *Regulations for the registered professional title of chartered engineer* (Engineers Ireland, 2014b) is noteworthy in this regard:

> Within Ireland, *Engineers Ireland* is the authoritative voice of the engineering profession on relevant national issues. (Engineers Ireland, 2014b, p. 3)

When considering the authoritative voice behind such an aspirational vision for engineering, it leaves open to question as to how engineering can make an appropriate impact on society and in the best interests of society in the absence of open communication with society.

The following vision statement, taken from the *Engineers Ireland CPD Accredited Employer Standard Quick Guide* (Engineers Ireland, 2017b) publication, again reveals the authoritative voice of the profession:

> A community of creative professionals delivering solutions for society. (Engineers Ireland, 2017b, p. 1)

In supporting a repositioning of the profession, in terms of its interaction with society, it might perhaps be beneficial to consider whether 'delivering solutions for society' might be replaced with *co-developing solutions with society* in this vision statement.

In another pointer towards a claim to authoritative knowledge within the publications, the *Engineering 2018: A barometer of the profession in Ireland* (Engineers Ireland, 2018b) publication includes the following statement:

> From life-saving biomedical technology to energy-efficient housing, engineers are developing innovative solutions for the benefit of society. (Engineers Ireland, 2018b, p. 1)

Again, there is no consideration of how technological developments and societies might usefully co-evolve to the benefit of society. This positioning suggests a lack of awareness or appreciation within the discipline of engineering of the technological risks imposed on society. I further explore this theme in the next chapter.

In framing an appropriate means of communication, members of *Engineers Ireland* are encouraged to seek out opportunities to 'explain' what contribution engineering makes to 'enhance' society; there is an inference that the contribution currently made is, by default, an enhancement to society. The following quotation taken from the *Engineers Ireland Code of Ethics 2018* is enlightening in terms of reinforcing this one-way expert-based communication philosophy and vision for the profession:

> Members shall use appropriate opportunities to outline and explain the contribution of the engineering profession in enhancing society's well-being and respond to unfair criticism or comment about the profession. (Engineers Ireland, 2018a, p. 5)

Furthermore, criticism is framed as being by default *unfair* this perhaps creates a block towards 'fair' critique or criticism. There is no consideration of a place for constructive criticism. What, for example, are the ethical obligations of the engineer to listen to views the public might express when considering the impact that engineering actions have on society. Such ethical positioning might, for example, be required if applying a more broadly framed informed consent principle? Should the engineer not be obliged to listen to criticism of the profession in an open and non-judgemental manner, to determine then whether corrective action might be required?

In summary, societal engagement is silent throughout the publications critiqued. The following is quotation, taken from the *Engineers Ireland Strategy 2017-2020: A community of creative professionals delivering solutions for society* (Engineers Ireland, 2016) publication. The quotation is interesting in providing an insight as to where the professional body sees collaboration being necessary to benefit society, with such collaboration limited to the engineering profession and industry partners:

> It's only by working together in collaboration with the engineering profession and industry partners that we will be able to achieve our ambition to improve society and encourage and educate future generations of engineers. (Engineers Ireland, 2016, p. 4)

The following quotation is taken from the introductory section of the *Regulations for the registered professional title of chartered engineer (Engineers Ireland, 2014b)* publication:

> Because, regardless of whether you are responsible for writing code for a banking system, developing a medical device, designing a wind farm interconnector or teaching our next generation of engineers, as a Chartered Engineer, you are reassuring the public of your respect and consideration for their society, their safety and their security. The public no longer desires this reassurance; they demand it. (Engineers Ireland, 2014b, p. 4)

After that, in this publication, there are six further references to society, with each framed ethically around demonstrating an awareness of the professional engineer's obligations to society, such as the following:

> Demonstrate your knowledge and understanding of the importance of the engineer's role in society and the need for the highest ethical standards of practice. (Engineers Ireland, 2014b, p. 21)

However, in the publications critiqued, in terms of guidance for the prospective professional engineer, there is no clear explanation of what those obligations might be, aside from maintaining the welfare of society from a health and safety perspective.

There is also a requirement to communicate 'effectively' with the public to attain professional title status. However, there is no guidance provided as to what the professional body perceives to be effective communication in this regard:

> Demonstrate how you have communicated effectively in public. (Engineers Ireland, 2014b, p. 22).

In summary, the word tree depicted in Figure 2-2 (see also Appendix 7) is reflective of how 'society' is represented in the referenced publications:

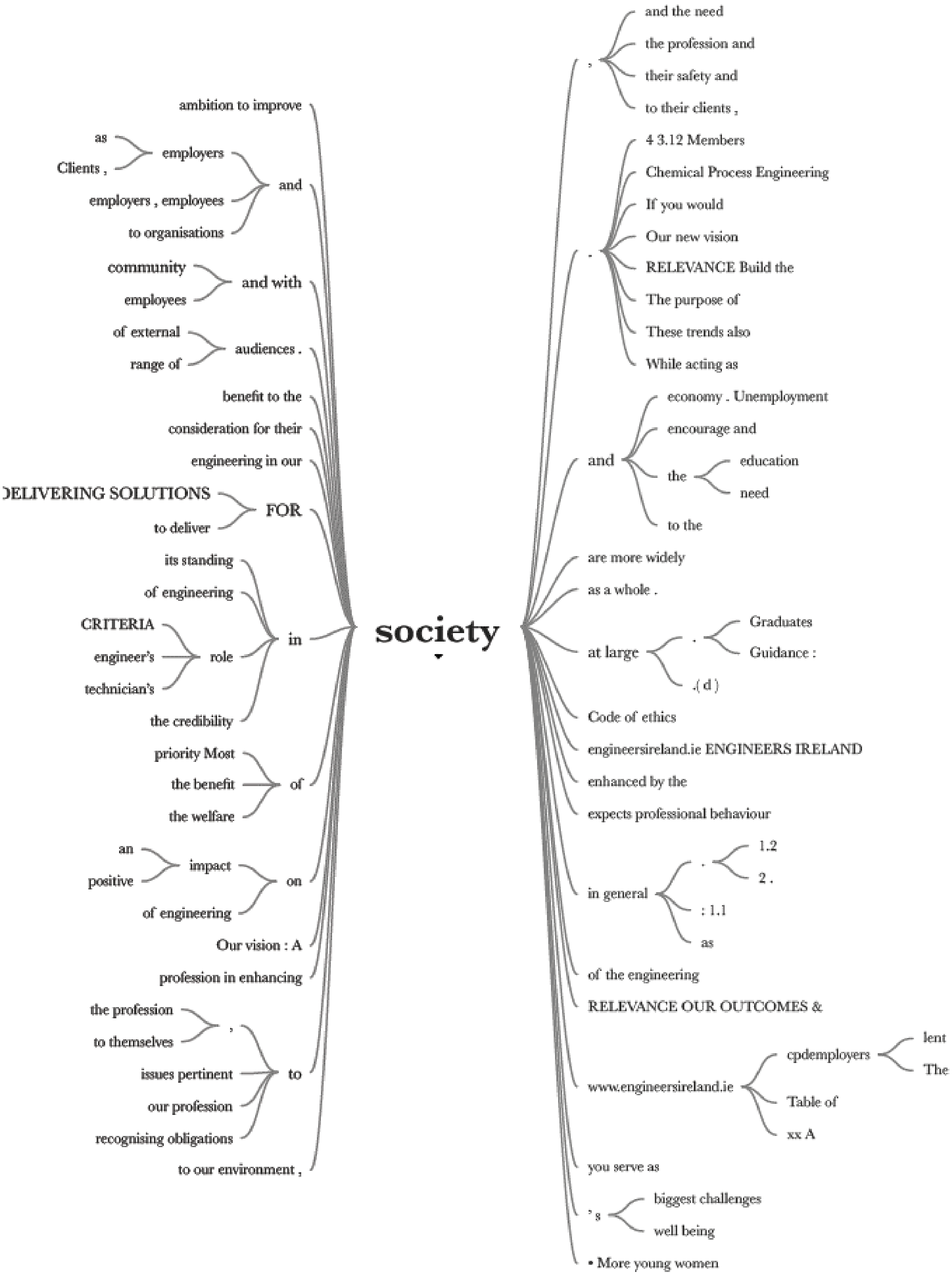


Figure 2-2 References to 'society' in *Engineers Ireland* publications

In the above illustration, professional standing in society emerges as one of the primary considerations. With the overarching sustainability theme in mind, it is noteworthy that there is no reference to inter-sectoral and interdisciplinary engagement or indeed engagement *with* wider society as might be required in grappling with the complex interweaving sustainability strands (Qureshi and Nawab, 2013; Ryan and Murphy, 2018).

2.3.3 An understated consideration of inclusiveness in the publications

> [S]ustainability requires more inclusive forms of governance, especially given the long-term radical reforms that it demands and the social inequalities and divisions that these reforms might generate. (Hendricks, 2010)

Diversity within engineering is considered under a social inclusion theme and within the sustainability domain in this section with a lack of diversity in engineering is of concern in many developed countries. With this in mind and to promote engineering as a people-focused, problem-solving and socially beneficial discipline, the *Institution of Mechanical Engineers* (IMechE) in the UK called for change on all sides (Institute of Mechanical Engineers, 2016). The institute also noted the need for the engineering community to reflect on the narrative it is presenting to young people. In this regard, it particularly identifies those whose background and interests may be quite different from those traditionally associated with engineering and, who may have the potential to be successful and creative engineering professionals (Institute of Mechanical Engineers, 2016).

In pointing to the inclusivity challenge within the profession from a societal perspective, the following quotation taken from the *Engineering 2018: A barometer of the profession in Ireland* (Engineers Ireland, 2018b) publication identifies the current gender gap within engineering as a particular cause for concern and includes the objective of promoting more diversity in engineering practice:

> The engineering profession must, therefore, bridge the gender gap and promote a more diverse and inclusive workforce. (Engineers Ireland, 2018b, p. 35)

The same report further adds:

> Nevertheless, an extraordinary gender gap remains and is restricting the growth of the engineering profession and its potential to deliver for society. (Engineers Ireland, 2018b, p. 31)

A recurring theme in the report is the measurement of the extent of the gender gap in the engineering profession, with female representation amounting to just 12% of the membership. The report recognises the challenge this represents to the profession; however, within the publications reviewed, the word 'inclusive' only appears twice, with both references included in the *Engineering 2018: A barometer of the profession in Ireland* publication. The first reference is in the context of addressing the skills shortage:

> However, if, as a country, we are to overcome skills shortages in the medium term, we must encourage many more young people to choose careers in engineering. In this context, one of the biggest challenges facing the profession is bridging the gender gap and promoting a more diverse and inclusive workforce. (Engineers Ireland, 2018b, p iii)

Another reference to inclusivity concerns the need for interdisciplinary solutions to address societal challenges and, as a result, points to the need for inclusive practices:

> Most of society's biggest challenges will require interdisciplinary solutions and the combined mind power of women and men working together. (Engineers Ireland, 2018b, p. 35)

However, none of the publications addresses this significant challenge in any meaningful way. It might be argued though that this contribution might be used by those within engineering education and practice to push for relevant change within programmes, whilst also accommodating other interpretations in the profession.

Currently, the silence in relation to interdisciplinarity in remaining publications has the effect of projecting professional elitism as opposed to promoting more inclusive and socially cohesive modes and methods. However, fostering social cohesion and inclusiveness are prerequisite factors towards addressing global sustainability challenges (Burns, 2015). It is in this regard that the lack of focus on inclusiveness within the publications critiqued is of concern.

2.3.4 Shaping the professional development of engineers

The *Engineers Ireland Continuing Professional Development Policy* (Engineers Ireland, 2017a) includes the following definition of what constitutes continuing professional development (CPD):

> The systematic maintenance, enhancement and development of knowledge and skill, and the development of personal qualities necessary for the execution of professional and technical duties throughout the practising engineering professional's career. (Engineers Ireland, 2017a, p. 3)

This publication is important in framing what *Engineers Ireland* believes to be of value in terms of the development of professional engineers. The policy document (Engineers Ireland, 2017a) includes the following rationale in explaining the need for CPD:

> CPD brings significant benefits to members and the engineering profession itself as well as employers and society as a whole. In an environment of rapidly changing technology, ever-increasing globalisation, more demanding consumers and greater scrutiny on professionals and organisations alike, CPD helps:
> - Demonstrate a commitment to maintaining and developing professional standards; to attain professional titles
> - Protect consumer; protect the public interest
> - Increase client satisfaction, increase effectiveness; deliver high performance
> - Improve employee motivation, adaptability and staff retention; enhance job satisfaction
> - Promote career advancement and career resilience and the reputation of the profession (Engineers Ireland, 2017a, p. 4)

The policy document notes the requirement to protect consumers and protect the public interest; however, it is then interesting to note that the public disappears from the policy guidance. For example, the *Engineers Ireland CPD Accredited Employer Standard* (Engineers Ireland, 2012) neglects to include the public as a key stakeholder or *player* in the CPD process (Figure 2-3).

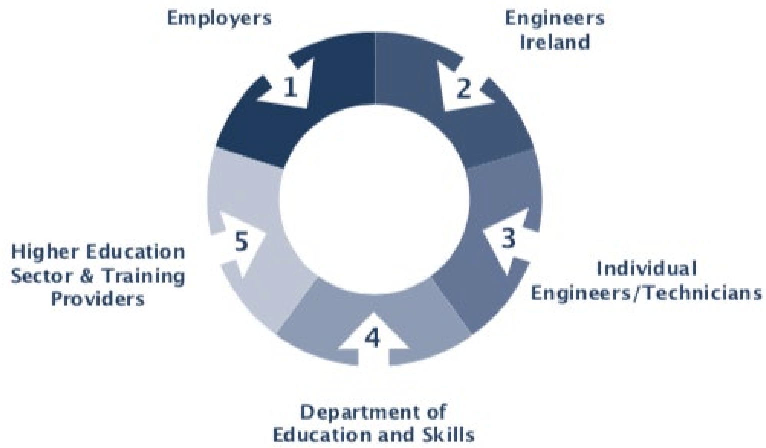


Figure 2-3 Key players in *Engineers Ireland* CPD policy
(Engineers Ireland, 2012, p. 5)

2.3.5 Professional body positioning in a sustainability context

Nicolaou *et al.* (2017) describe the underlying socio-cultural barriers preventing a holistic integration of education for sustainable development (ESD) in engineering education in their exploration of the placement of ESD within seven engineering degree programmes in Ireland. Nicolaou *et al*. (2017) further point to 'reinforcing mechanisms facilitating the provision of disciplinary education aimed at producing technically proficient, employable graduates in which the social dimension is marginalized' (Nicolaou *et al.*, 2017, p. 13).

This marginalisation of the social dimension is evident in the professional body publications; in its place, an authoritative voice emerges as is evident in the following quotation, included in the introduction of *Engineering 2018: A barometer of the profession in Ireland (Engineers Ireland, 2018b).* This positioning creates an unquestioning support for development as being of 'paramount importance' in the creation of the 'necessary' capital infrastructure to support increasing economic demands and to 'transform' the country (Ireland). There is no consideration of whether development is sustainable, whether there is the potential for unintended consequences or, indeed, whether such continuing development is to the benefit of society in the long-term.

> The last number of years in Ireland have brought significant change to our environment, society and economy…However, the country faces incredibly serious challenges relating to housing, health, climate action and Brexit[4]. To reinforce the economic recovery and to overcome these challenges, Government policy centres on the importance of skills to innovation, industry and infrastructure. … Also, the €116 billion National Development Plan 2018-2027 (as part of Project Ireland 2040) commits to the delivery of an ambitious programme of infrastructure to transform the country over the next ten years. It is of paramount importance that the country has the necessary capital infrastructure to meet economic demands within the coming years as well as the skilled labour force to create and fill the jobs of the future. (Engineers Ireland, 2018b, p. 1)

There is also a need to reflect on where engineering stands from a social responsibility perspective, in considering development in the context of sustainability. What requires consideration is whether a proponent of an activity posing uncertain risks to society bears the burden of proving that the activity poses no risk or an acceptable risk before the activity should go forward (Zandvoort *et al.*, 2013). There are an evident reflective silence and a lack of reflexive action in the professional body consideration of this important theme in contemporary society.

---

[4] Brexit represents the withdrawal of the United Kingdom (UK) from the European Union (EU). In a June 2016 referendum, a majority of voters voted to leave the EU. The UK parliament has voted on three occasions against the negotiated withdrawal agreement and, as a result, the deadline to leave has been extended twice. The current deadline is 31 October 2019.

2.3.6 The framing of *public welfare* within the publications

The ethical responsibility to maintain the welfare of the public, included in the *Engineers Ireland Code of Ethics 2018 (Engineers Ireland, 2018a)*, is bounded around health and safety concerns

> At all times in their relations with the public, Members shall apply their skill and experience to the common good and the advancement of human welfare with proper regard for the safety, health and welfare of the public. A Member shall not engage in any activity which he/she knows or has reasonable grounds for believing is likely to result in a serious detriment to any person or persons. (Engineers Ireland, 2018a, p. 3)

And:

> Members shall at all times be conscious of the effects of their work on the health and safety of individuals and on the welfare of society. While acting as designers, operators or managers on projects, members shall strive to eliminate risks to health and safety during all project stages. (Engineers Ireland, 2018a, p. 3)

It could reasonably be surmised that an engineer is complying with this clause if the actions of the engineer are not endangering the public. This interpretation is reinforced by the following reference in the *Engineering 2018: A barometer of the profession in Ireland* (Engineers Ireland, 2018b) publication:

> We believe that one of the reasons why the public holds such high levels of confidence in engineers is the role the profession plays in public health and safety. When we put this to the public, 77% of adults agreed that engineers are essential to reduce risks to public health and safety (only 3% disagreed). Agreement was strongest among those with young children in the household (81%) and those over 65 years old (80%). (Engineers Ireland, 2018b, p. 12)

Issues of societal concern from a social responsibility perspective do not necessarily arise as considerations, in terms of compliance with the referenced code of ethics. There appears to be a very narrowly framed interpretation of the *do no harm* principle referred to earlier in this chapter. In summary, the word tree depicted in Figure 2-4 (see also appendix 8) is representative of how ‘the public’ is represented in referenced publications:

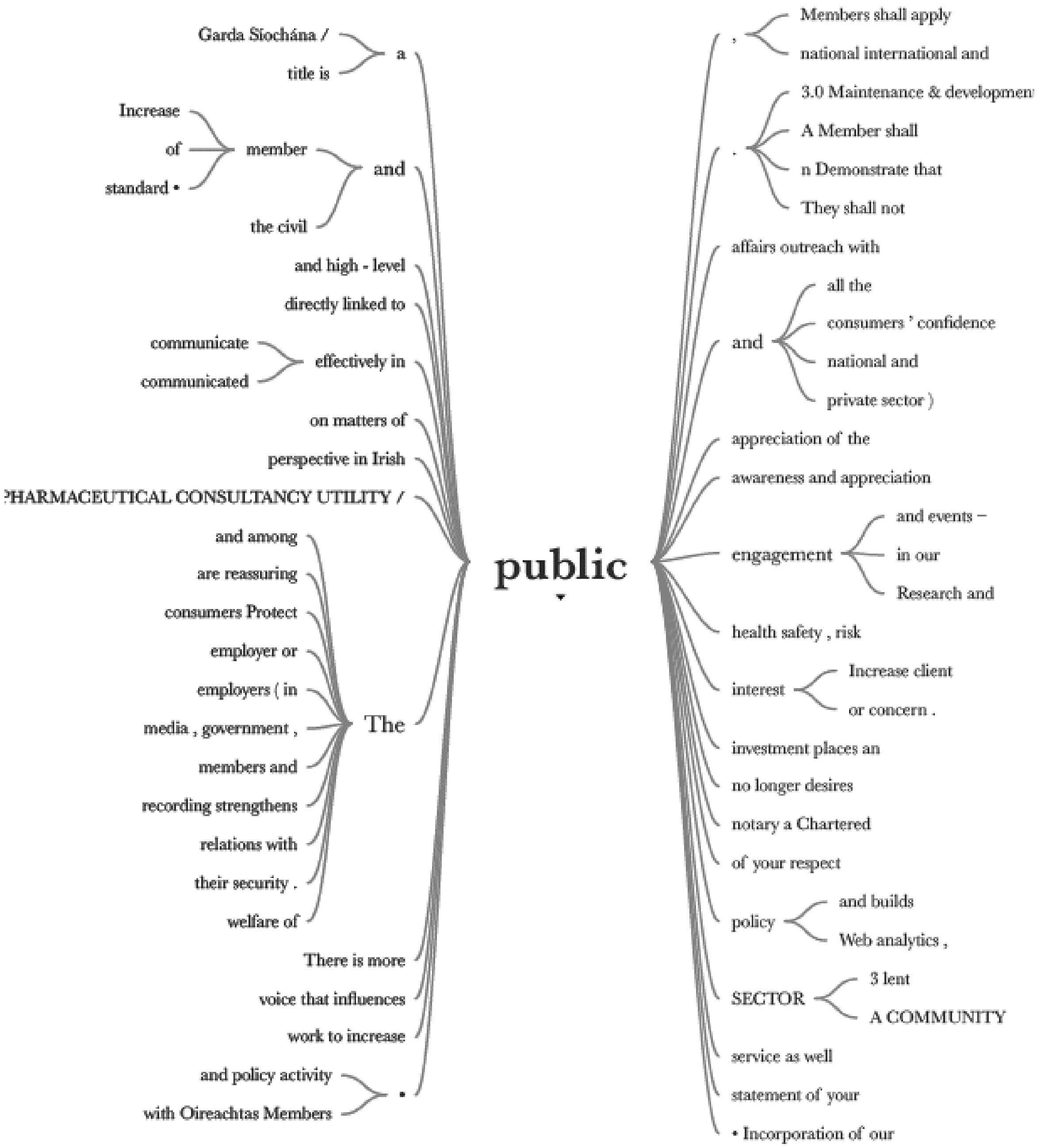


Figure 2-4 References to the ‘public' in *Engineers Ireland* publications

There is a visible lack of interactive public engagement in the above illustration. There is a sense of the expert/authoritative voice emerging in references such as ‘…public appreciation of the…’ and ‘…voice that influences public…’. There is also no real sense of participatory engagement with the public as might, for example, be required when considering sustainability-related concerns.

2.3.7 Professional body influences on engineering practice: the code of ethics

In this section, I turn to a consideration of ethics and social responsibility concerning engineering practice. I reflect in the opening chapter on how, as a practising engineer, I predominantly placed my focus on technical problem-solving. In a characterisation of engineering that mirrors my experience, Karwat *et al.* (2014) represent the engineer's role in society as being narrowly focused and one that involves the provision of technology to solve the problems of society. The examination of the social good that might be attributable to engineering practice has been a particular point of interest in much of this research. Given the current positioning of *Engineers Ireland* as a representative body, such an aspirational vision is lacking within the engineering profession in Ireland and indeed internationally at present. In writing on this theme, when comparing engineering to other professions, Riley and Lambrinidou (2015) point to how physicians aspire to promote human health, while the legal profession is dedicated to promoting legal justice. In contrast, they view engineering as lacking an aspirational vision in terms of the social good that might be attributable to the profession. Professional positioning is further explored, from a sociological perspective, in the next chapter.

In terms of the ethical positioning of the engineering profession, the ethical codes of practice of the public engineering representative bodies provide direction on the required code of ethical conduct for engineers. In Ireland, it is the *Engineers Ireland Code of Ethics* (Engineers Ireland, 2018a) that ethically guides that practice. Engineers who are members of *Engineers Ireland* are required to meet the standards of ethics and conduct set out in the code of ethics. The *Engineers Ireland Code of Ethics* (Engineers Ireland, 2018a) is divided into four parts:

- Relations with colleagues, clients, employers and society in general
- Environmental and social obligations
- Maintenance and development of professional conduct and standards
- Enforcement procedures and disciplinary action

In the opening chapter, I describe engineering as lacking an aspirational vision in terms of the social good that might be attributable to the profession; the *Engineers Ireland Code of Ethics* (Engineers Ireland, 2018a) is narrowly framed and professionally focused in this regard. For example, clause 2 of the code relates to the environmental and social obligations of professional members. Specifically relating to societal interaction, it includes the following statement:

> Members shall at all times be conscious of the effects of their work on the health and safety of individuals and on the welfare of society. (Engineers Ireland, 2018a, p. 3)

This reads as a foundational directive, as opposed to an aspirational vision, in a manner that is consistent with similar clauses in other engineering codes of ethics (Riley and Lambrinidou, 2015). Michelfelder et al. (2013) similarly note that professional engineering societies in North America do not put the engineer's responsibility towards sustainability on a par with commitments to public safety, health and welfare. Such responsibilities are often encapsulated what is referred to as the paramountcy clause. In addressing members obligations towards sustainability, the National Society of Professional Engineers (NSPE) Code of Ethics for Engineers (2019) describes those responsibilities in very different ways. For example, responsibilities relating to sustainability are referred to in a somewhat aspirational manner as follows:

> Engineers are encouraged to adhere to the principles of sustainable development1 in order to protect the environment for future generations (National Society of Professional Engineers, 2019, p. 1)

Contrastingly, the paramountcy clause is framed in this code as a mandatory compliance clause: ‘Engineers shall hold paramount the safety, health, and welfare of the public’ (National Society of Professional Engineers, 2019, p. 1). As Michelfelder et al. (2013) note, there is no doubting the hierarchical positioning of health, safety and welfare as compared to sustainability in the framing of both clauses.

It is also interesting to note how environmental and social obligations are described in generalised terms in the code. As a result, even if considered as a more narrowly framed foundational directive, it is difficult to determine whether code compliance or indeed, code violation has arisen. For example, the following clause is included under Section 2 of the code:

> Members shall promote the importance of social and environmental factors to professional colleagues, employers and clients with whom they share responsibility and collaborate with other professions to mitigate the adverse impacts of their common endeavours. (Engineers Ireland, 2018a, p. 4)

When reviewing the above clause with a *do no harm* ethical principle in mind, it warrants consideration as to what might represent an *adverse impact* and, who ought to be protected from such an *adverse impact*? In considering the dilemmas that can arise in this regard, Vesilind (2010) quotes an example of the choice faced by an engineer when confronted by a project requiring the conversion of apartments into luxury condominiums. When the engineer enquired as to what would become of the low and middle-income families living in the building, the developer ‘had no idea nor did he care’ (Vesilind, 2010, p. 75). The dilemma for this engineer was determining how to maintain the welfare of the public in this instance? Was it the interests of the project developer, the future building occupier or the evicted tenants? Unusually, the engineer resigned from his job and walked away from that particular project when informed of the eviction of the current building occupiers.

Also, in further considering this clause, it could be viewed that the requirement to 'mitigate the adverse impacts of their common endeavours' (Engineers Ireland, 2018a, p. 4) would only result in the impact of some incident being less severe, serious or painful. I hold the view that there is a need to avoid foreseeable adverse societal and environmental impacts of the common endeavours of engineers, as opposed to merely mitigating those impacts.

The lack of focus on societal impacts points to a key consideration concerning engineering practice; which is the lack of awareness of who benefits from and who loses out, due to engineering decision-making. The *Engineers Ireland Code of Ethics* (Engineers Ireland, 2018a) does not attempt to negotiate this contentious consideration.

In recent years, there have been many critiques of the practice of engineering concerning its limited societal engagement. Baillie (2009; 2013), Riley (2008; 2015) and Jamison (2009; 2012) are amongst several scholars who have completed useful research in this area. In place of the previously referred to paramountcy clause, Riley and Lambrinidou (2015) call for a clause with more of an aspirational vision. This call is problematic however due the lack of a commonly held understanding within the profession of what represents ethically sound and socially responsible engineering practice. However, in unusually adopting a more expansive approach towards the consideration of sustainability, the Australian Code of Ethics and Guidelines on Professional Conduct (Engineers Australia,

2019) includes the requirement to promote sustainability as one of its four foundational pillars. The code requires members to '[e]ngage responsibly with the community and other stakeholders, [p]ractise engineering to foster the health, safety and wellbeing of the community and the environment and; [b]alance the needs of the present with the needs of future generations' (Engineers Australia, 2019, p. 2).

The ethical positioning of the profession, in turn, influences the engineering curriculum, as it is the ethical standards at the core of the engineering profession that underpin the learning outcomes included in the engineering curriculum, concerning ethics as prescribed by the relevant professional body. This again relates to a lack of a commonly held understanding within the profession of what represents ethically sound and socially responsible engineering practice. It is perhaps unreasonable to expect that any code of ethics can provide clear and definitive guidance towards evaluating the potential societal impacts of engineering decision-making. Nonetheless, the argument here is that there is a requirement to provide directional guidance in this regard, for example in a manner similar to the approach adopted in the Australian Code of Ethics and Guidelines on Professional Conduct (Engineers Australia, 2019).

2.3.8 Programme accreditation criteria: an international comparison

In this section, I briefly compare the accreditation criteria that apply in the United Kingdom and North America with the *Engineers Ireland* accreditation criteria (Engineers Ireland, 2014a). I noted previously in this chapter, how the ethical and social responsibility themes are phrased in such an open manner in the framing of programme outcome 'E' by *Engineers Ireland* (2014a), as to be open to a range of interpretations. As a result, it warrants exploration as to whether such treatment of ethical responsibilities is also apparent in other accreditation criteria internationally.

Baillie and Levine (2013) describe how ethical codes are framed within the value system within which they were created, noting hegemonic influences in this regard and pointing to the dominant discourse within the profession, mirroring a dominant societal paradigm, as being key to how ethical codes are framed.

The review of the *Engineers Ireland* accreditation criteria in the previous section outlines the extent of that influencing role in the context of engineering education in Ireland, which then follows into engineering practice.

In the United Kingdom, the Engineering Council holds responsibility for engineering programme accreditation. The '[e]conomic, legal, social, ethical and environmental context' (Engineering Council, 2014) programme learning outcome addresses ethical considerations concerning engineering practice. The underlying description provided for this particular learning outcome provides a sense of what is expected in addressing this learning outcome:

> Engineering activity can have impacts on the environment, on commerce, on society and on individuals. Graduates therefore need the skills to manage their activities and to be aware of the various legal and ethical constraints under which they are expected to operate. (Engineering Council, 2014, p. 16)

The following additional guidance is provided (Engineering Council, 2014, pp. 16-17) concerning the definition of requirements to meet this learning outcome:

> Understanding of the need for a high level of professional and ethical conduct in engineering and a knowledge of professional codes of conduct
>
> Knowledge and understanding of the commercial, economic and social context of engineering processes
>
> Knowledge and understanding of management techniques, including project management that may be used to achieve engineering objectives

> Understanding of the requirement for engineering activities to promote sustainable development and ability to apply quantitative techniques where appropriate
>
> Awareness of relevant legal requirements governing engineering activities, including personnel, health & safety, contracts, intellectual property rights, product safety and liability issues
>
> Knowledge and understanding of risk issues, including health & safety, environmental and commercial risk, and of risk assessment and risk management techniques. (Engineering Council, 2014, pp. 16-17).

It is noteworthy that this learning outcome framing is very similar to the framing of the *Engineers Ireland* programme outcome 'E' (Engineers Ireland, 2014a).

Turning to North America, it is the Accreditation Board for Engineering and Technology (ABET) that holds responsibility for accrediting programmes in applied and natural science, computing, engineering and engineering technology. Student outcome 4 is of most relevance in the context of this research:

> 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. (Accreditation Board for Engineering and Technology, 2019, p. 5)

There are again similarities in terms of how this learning outcome is presented when compared to the *Engineering Council* version as applies in the United Kingdom (Engineering Council, 2014) and the *Engineers Ireland* accreditation criteria (Engineers Ireland, 2014a). The authoritative voice, the expert-oriented solutions provision and the relatively narrow framing, in a societal context, are features common to each set of the accreditation criteria considered. Bucciarelli (2008) describes the requirements as being misguided and misguiding in critiquing ABET's accreditation requirements. Bucciarelli (2008) further asserts that the presentation of ethical issues in a manner that focuses on the individual engineer acting alone and merely avoiding wrong-doing misrepresents the context of engineering practice and paints a false image of the engineer's role in society.

A key feature of the positioning of *Engineers Ireland*, however, is its overarching national influence, as both an accrediting body and as a national professional representative body for all engineering disciplines. By contrast, in the United Kingdom and North America, there are a series of discipline-specific professional representative bodies which operate separately from the programme accrediting bodies mentioned previously in this section. Given *Engineers Ireland's* powerful position of influence, the argument here is that this may present a potentially significant barrier when considering curricular change. Equally, it presents a potential opportunity, as given the professional body's influence, if there is a recognition of the need for change, the professional body could act as a powerful, agentic supporter of the need for change and change implementation.

2.4 Course Provision: Ethical Treatment Shaped by Accreditation Criteria

I describe previously how *Engineers Ireland,* as the representative accrediting professional body, holds a position of significant influence in shaping programme content. I note how it is programme outcome 'E' from the accreditation criteria (Engineers Ireland, 2014a) which sets the standard, from a programme outcome perspective. It is also the programme outcome that accreditation panels use in assessing ethical content in engineering programmes in Ireland. In this regard, it is instructive to review the treatment of ethics in the following representative group of (Level 8) honours degree civil engineering programmes in Ireland:

- ❖ CW478: Bachelor of Engineering (Honours) in Civil Engineering (Institute of Technology, Carlow).
- ❖ SG342: Bachelor of Engineering (Honours) in Civil Engineering (Institute of Technology, Sligo).

- ❖ DT066/DT027 General Engineering (common entry)/Bachelor of Engineering (Honours) in Civil Engineering (Technological University, Dublin)
- ❖ CK600: Engineering (common entry)/Bachelor of Engineering (Honours) in Civil Engineering (University College, Cork).
- ❖ LM116: Engineering (common entry)/Bachelor of Engineering (Honours) in Civil Engineering (University of Limerick).

Extracts from the prospectus with outline content for each of the above programmes are included in Appendix 10. What is clear from the programme extracts is that the treatment of ethics and social responsibility does not occupy a prominent position in the extracts. The treatment of ethics and social responsibility across the programmes is represented in Figure 2-5 below.

Institute	Programme	Module specifically mentioning ethics	Comment
Institute of Technology, Carlow	B Eng (Hons) in Civil Engineering	The Engineer in Society (year 4)	▪ Professionally focused, ethical considerations in referenced module.
Institute of Technology, Sligo	B Eng (Hons) in Civil Engineering	N/A	▪ No evidence of ethical considerations included in the course outline.
Technological University, Dublin	General Engineering (common entry, year 1)	Engineering in Society	▪ Consideration of macro-ethical principles including sustainable development and social responsibilities in the referenced module
Technological University, Dublin	B Eng (Hons) in Civil Engineering (years 2-4)	N/A	▪ No evidence of ethical considerations included in the course outline.
University College, Cork	Engineering (common entry, year 1)	Introduction to Energy Engineering and Engineering Ethics	▪ Consideration of some macro-ethical principles in referenced module.
University College, Cork	B Eng (Hons) in Civil Engineering (years 2-4)	Materials and Sustainability (elective module)	▪ The referenced module is included as an elective module in year 3.
University of Limerick	Engineering (common entry)	N/A	▪ No evidence of ethical considerations included in the course outline.
University of Limerick	B Eng (Hons) in Civil Engineering (years 2-4)	Learning from engineering mistakes of the past (expert witness practice)	▪ Reference to consideration of project failures from an ethical/legal perspective, including collaboration with law students.

Figure 2-5: Representation of ethics in programme outlines

In programme outlines included in Appendix 10, the references to ethics are very limited. Within each programme outlines included in Appendix 10, the focus is on the technical and employability aspects of the role. Indeed, none of the programme outlines provides a vision of engineering reaching beyond technocratic and micro-ethical perspectives. In programme content terms, there are very limited references to ethical considerations. Another feature of the consideration of ethics in the above programmes is that, at best, there is only one module that specifically addresses ethical themes within each programme. For example, the programme outline included in the Technological University Dublin website for their Bachelor of Engineering (Hons) in Civil Engineering programme (Technological University Dublin, 2019) includes reference to a year 1 '*Engineering and Society*' module which with the following learning outcomes:

- ❖ Describe the ethical and social responsibilities of a chartered engineer
- ❖ Identify the responsibilities of engineers as set out in the Code of Ethics
- ❖ Discuss the principles of sustainable development;
- ❖ Describe the communications process and the principles of good communication

In this context, these are the sole references to sustainable development and social responsibility in the programme outlines reviewed. Notwithstanding the limited treatment of ethics in each programme considered, it is interesting to note that all have met the accreditation criteria of *Engineers Ireland* (Engineers Ireland, 2014a).

2.4.1 The positioning of ethics and social responsibility within the engineering curriculum

It has been widely noted (Bucciarelli, 2008; Byrne, 2012; Conlon, 2013; Zandvoort *et al.*, 2013) that incorporating a focus on social responsibility and ethics within engineering programmes has been problematic. There are two main reasons for this; firstly, there is a lack of a commonly held definition of what social responsibility represents in terms of engineering practice (Zandvoort *et al.*, 2013) or indeed, what the boundaries of good ethical practice might be in the context of engineering work. Secondly, resulting from this difficulty concerning framing and definition, there is a further challenge in negotiating how to integrate ethical content appropriately and how to foster an appreciation of the societal impact of engineering decision-making into the engineering curriculum (Bucciarelli, 2008; Colby and Sullivan, 2008; Conlon, 2010).

In writing on engineering education in North America, Colby and Sullivan (2008) note that although there is some variation to the extent to which ethics is addressed in engineering faculties, the approaches commonly adopt a restricted range of options in the curriculum. Such arrangements include (Colby and Sullivan, 2008, p. 331):

- Stand-alone courses in ethics either within the engineering faculty or courses on ethics and philosophy provided by the philosophy department.
- Brief discussions about professional responsibility and ethics, framed around public safety, incorporated where the themes arise with the subject matter in the course in general.
- Specific modules focused on engineering ethics and professional responsibility.

Based on my experience as an accreditation panel participant, on behalf of *Engineers Ireland,* the latter two methods more commonly apply in Ireland. Firstly, the evidence is presented relating to discreet modules focused on ethics and social responsibility (consistent with Figure 2-5 above). Secondly, specific learning outcomes associated with other modules contained within the curriculum and discreet course work are put forward as providing supporting evidence. Graham (2012) asserts that radical curriculum change requires strong institutional support. I would further add, given the importance of programme accreditation when considering curriculum development as previously discussed in this chapter, that professional body support is also a key requirement in the curriculum change process. One of the outcomes of Graham's (2012) research into radical curriculum change in engineering education was to identify a series of key success factors to support change. Amongst the success factors identified by Graham (2012) is the need for embedding change into core institutional positioning, as opposed to being isolated within the curriculum and reliant on a small number of enthusiasts to deliver the unconnected flagship courses. Graham (2012) further adds that a strongly interconnected and coherent curriculum should underpin radical change and that there is a requirement for a wide pool of faculty willing and able to deliver the reformed courses.

2.4.2 Case studies fulfil a dominant instructional method

> The ethical cases used in many programs do not strike me as consonant with essential features of engineering practice. They may have their technical facts straight but they generally discount, or entirely neglect, the social nature of day-to-day engineering. In focusing solely on an individual agent's possible courses of action they oversimplify; they are not a valid abstraction. (Bucciarelli, 2008, p. 1)

As noted in Bucciarelli's quotation (2008) that opens this section, the dominant approach concerning the treatment of ethics within the curriculum is to use classic case studies. Such case studies tend to focus on micro-ethical dilemmas (Herkert, 2001), often relating to public welfare and safety, concerning engineering practice. This treatment of ethics, taking an individualistic object world approach

(Bucciarelli, 2008; Byrne, 2012), presents a falsely, simplistic treatment of ethical dilemmas in the context of engineering practice.

The case study will generally involve a discussion of scenarios in which an engineer is facing an ethical problem or dilemma involving individual engineering decision-making (Conlon, 2013). What is missed in this treatment of case studies is the broader context of the social, organisational and even political complexities of engineering practice (Bucciarelli, 2008). The larger macro-ethical concerns relating, for example, to the development of technology (Herkert, 2001) which misses the impact of technology on society. Context and complexity tend to lose out to objective realities within these scenarios (Byrne, 2012).

There is also a lack of social context in the situations, presented as part of the classic case study treatment. Many of the case studies focus on the impact of an engineer's decision-making concerning technology-related disasters. One frequently used case study scenario is the Challenger[5] disaster. This case study is often simplistically presented to students as a case of poor engineering decision-making when confronted by commercially driven management pressures, leading to a violation of safety rules with disastrous consequences. In a seminal work focusing on the Challenger disaster, however, Vaughan (1996) deviates from this overly simplistic account, characterising the disaster as a story of how 'people who worked together developed patterns that blinded them to the consequences of their actions' (Vaughan, 1996, p. 409). Vaughan (1996) notes that it is 'not that

[5] In 1986, the NASA space shuttle '*Challenger'* disintegrated soon after take-off because of a failure of a rocket booster joint at lift-off, caused by the failure of O-ring seals used in the joint. An investigative report published after the accident pointed towards flaws in the decision-making process, involving engineering and management, which led to the launch of the space shuttle although there were serious concerns relating to the design of the O-rings which subsequently failed.

individuals in organizations make mistakes, but that mistakes themselves are socially organized and systematically produced' (Vaughan, 1996, p. 394).

2.4.3 A consideration of micro-ethical versus macro-ethical approaches

Several scholars (Conlon, 2010; Jamison, 2012; Conlon, 2013; Jamison *et al.*, 2014; Kolmos *et al.*, 2016) assert that engineers are not being prepared to fully consider the complex global, socio-technological and environmental challenges awaiting them in practice. Herkert (2001) contrasts the currently dominant micro-ethical treatments, focusing on professional ethics, with an alternative macro-ethical approach reflecting the collective social responsibility of the profession and to societal decisions about technology. This dominant micro-ethical focus on professional ethics is very apparent in the programme outlines discussed above and included in Appendix 10. Where there is a reference to ethics, it is framed around micro-ethical perspectives. For example, in the Institute of Technology Carlow programme outline, there is a reference to the course promoting the requirement to 'understand the need for the highest ethical standards in the practice of [the] engineering profession' (Institute of Technology Carlow, 2019).

Herkert (2001) points to a need to consider how to integrate the micro-ethical with macro-ethical approaches to engineering ethics. Conlon (2013) further identifies a need to emphasise social responsibility together with greater community engagement within the engineering curriculum if 'engineering practice is to move beyond its present captivity by corporate interests' (Conlon, 2013, p. 1589).

Similar micro-ethical treatment tends to dominate in education for sustainable development (ESD) in an engineering context. In this regard, Nicolaou *et al.* assert that the current educational focus is predominantly on the environmental dimension of ESD, with the social dimension marginalised (Nicolaou *et al.*, 2017). As a counter to such dominant micro-ethical perspectives, Byrne (2012) proposes an approach which is unusual in an Irish context, in incorporating a broader engineering ethical framework concerning the ESD theme. Byrne's (2012) alternative approach relates to one first-year module titled, *Introduction to Process & Chemical Engineering*, included as a mandatory five-credit module within a common first-year engineering programme at University College Cork (UCC). The following module learning outcomes are of relevance when considering a macro-ethical dimension in engineering education:

> Expound the importance of safety, the environment and professional ethics in chemical process engineering and in the broader world. (Byrne, 2012, p. 237)

And:

> Advocate the roles and social responsibilities of engineers within society. Research information on an engineering topic and construct a case to defend one's position on technical grounds. (Byrne, 2012, p. 237)

Having adopted a teaching approach previously based on classical case study evaluations, Byrne (2012) incorporated a broadened macro-ethical perspective when considering sustainability issues in the context of engineering practice. Consistent with a theme raised earlier in the chapter, the macro-ethical dimension in this instance is based on the recognition that the engagement of engineering with the sustainability agenda implies a responsibility towards future generations which 'requires an enhanced level of commitment to social and ecological domains' (Byrne, 2012, p. 235). Byrne's (2012) problem-based learning approach required students to work in small groups, in considering particular sustainability challenges and broadly framed ethical dilemmas within an engineering context.

Working in groups, students considered solutions to dilemmas posed, prepared reports on their findings and formally presented findings and critiqued presentations of other groups. At the end of the module, students completed a questionnaire designed to determine how they perceived the treatment of ethics within the module. Feedback was broadly very positive, with students ranking material covered concerning the engineer's societal role, the environment, sustainability and health and safety, as the most enjoyable topic covered in the module. In one particular response, a student stated that they now 'realised the importance of imaginative, innovative solutions in the profession; and realised that the job does not revolve solely on science' (Byrne, 2012, p. 244). Another noted their increased enthusiasm as being due to 'knowing now that I can help change and make the world a better place for people to live in' (Byrne, 2012, p. 244). Byrne's (2012) proposed strategy is a useful means of integrating both micro and macro-ethical perspectives towards the ESD subject area, as it provides students with the opportunity to develop a holistic appreciation of the social responsibility principles and in particular the precautionary principle described in this chapter. The approach, however, is limited to one specific module representing only 8% of learner engagement within the first year of the programme. This is a common feature of many such add-on initiatives; the macro-ethical treatment of the subject matter is reliant on the enthusiasm and expertise of a pioneering individual academic in only one module, as opposed to a more widespread philosophical or directional approach at the faculty level (Spitzer, 2013).

This raises the point as to what might represent socially responsible engineering practice. Zandvoort *et al*. (2013) provide the following definition:

> [A]n activity or action within science and technology is socially responsible if it satisfies certain ethical principles, and socially irresponsible if it does not satisfy those principles. Similarly, the wider use of scientific and technological products in society could be labelled socially responsible if it does not violate such principles. A decision can be called socially responsible or not, depending on whether it leads to a socially responsible activity. (Zandvoort *et al.*, 2013, p. 1428)

While this is a useful definition in broadly framing the social responsibility principles associated with engineering, there is a requirement to add further context and content when considering how the definition might then apply, in a meaningful way, to specific cases in engineering practice. Zandvoort *et al*. (2013) attempt to negotiate this challenge when further adding some basic principles of direct relevance to science and engineering acts (Zandvoort *et al.*, 2013, p. 1429):

- The do no harm principle.
- The precautionary principle, i.e. a proponent of an activity posing uncertain risks bears the burden of proving that the activity poses no risk or an acceptable risk before the activity should go forward.
- The principle of informed consent.
- The principle of freedom of speech.

The above principles provide a very useful framework in considering social responsibility in the context of sustainability and sustainable engineering practice. In an approach to sustainable development, Qureshi and Nawab (2013) assert that a paradigm shift is called for within engineering, to move from control of nature to participation with nature, pointing towards the need for 'ecological' thinking, highlighting deep interconnectedness. In that regard, Qureshi and Nawab (2013) note that repositioning would move engineering towards an awareness of ecosystems and towards a mindset of the mutual enhancement of nature and humans that embraces sustainable development principles. The social responsibility principles proposed by Zandvoort *et al*. (2013) align with the directional shift called for by Qureshi and Nawab (2013). Again, the question returns to how to interpret the social responsibility principles outlined above. Ideological positioning, rationalities and influences of power then feature as influences in that interpretation.

2.4.4 The treatment of ethics in engineering programmes: an international comparison

As is evidenced by the review of engineering programmes in Ireland, the treatment of ethics is narrowly framed at best. In this section, I provide a brief review of the outline programme content provided in two universities in the United Kingdom and one university in North America. I do so to explore whether the limited treatment of ethics is evident in engineering curricula elsewhere in the northern hemisphere. Again, for consistency of comparison, I review civil engineering honours degree programmes. The programmes reviewed are as follows:

- ❖ Bachelor of Engineering (Honours) in Civil Engineering: Brunel University, London
- ❖ Bachelor of Engineering (Honours) in Civil Engineering: City University, London
- ❖ Civil Engineering Degree Major: University of California, Berkeley

In considering the positioning of ethics in the respective programmes, the treatment varies across universities. For example, one of the stated aims of the civil engineering programme provided by the City University London is as follows:

> …are aware of their professional and ethical responsibilities, the global and societal impact of engineering solutions, as well as the economic and political issues. (City University London, 2019)

The means of achieving this aim within the programme is unclear from the course outline, however. There is also the following reference to ethical considerations in one programme outcome within the civil engineering programme offered by Brunel University:

> Knowledge and understanding of risk issues, including health & safety, environmental and commercial risk, and of risk assessment and risk management techniques. (Brunel University, 2019)

From the outline documentation reviewed, there is no clear indication as to how this programme outcome is addressed in the curriculum.

By way of comparison, illustrating a contrasting approach towards engineering education in North America, the civil engineer major degree provided by the University of California, Berkeley (UC Berkeley) requires students to take some humanities and social science-based courses. The justification for doing so is described as follows:

> To promote a rich and varied educational experience outside of the technical requirements for each major, the College of Engineering has a Humanities and Social Sciences (H/SS) breadth requirement built into all of the programs of study. (UC Berkeley, 2019)

While this perhaps provides a rich and varied educational experience for engineering students, there appears to be no attempt to integrate the social dimension into the range of technical engineering subjects. The argument here is that this potentially further reinforces a sense of the separation of engineering endeavour from society.

Bucking the trend: challenging the established curricular status quo

Interestingly, however, in the international context, there are several examples of alternative ethical treatments within engineering education that adopt macro-ethical approaches. In endeavouring to open up the classroom in such a manner, there has been a focus in North America, in particular, on integrating Science, Technology and Society (STS) studies within engineering education (Bucciarelli, 2008). In doing so, there is an intention to simultaneously address professional/ethical responsibility with engineering's societal context (Herkert, 2005). One particular STS approach proposed by Herkert (2005) involves broadening the discussion of engineering ethics to include issues and concerns relating to public policy, risk and product liability, sustainable development and globalisation. Many of the areas of concern in Herkert's (2005) proposal mirror themes to be considered in the next chapter, including for example, the consideration of problematic bureaucratic influences as a sociological dimension that warrants further consideration within engineering. In this regard, scholars (Bucciarelli, 2008; Conlon, 2013; Zandvoort *et al.*, 2013) have proposed that engineering students should consider the social and the organisational complexities of engineering practice during their studies. In another STS approach, designed to address this concern, Lynch and Kline (2000) suggest that there is a requirement to consider 'culturally embedded engineering practices' (Lynch and Kline, 2000, p. 212) within engineering education.

Kline (2001) refers to the Challenger Disaster as being a case study that might benefit from the use of STS analytical tools in considering an anthropological account of engineering practice. Kline (2001) argues that such an approach, based on Vaughan's (1996) findings in her seminal work relating to this disaster, would more openly consider the social dimension, the blurring of engineering-management boundaries and the difficulties of clearly communicating technical information in bureaucracies. This proposed treatment brings to the fore a consideration of a key sociological dimension reviewed in the next chapter, relating to the diminishing of professional autonomy within engineering practice resulting from restrictive, bureaucratic organisational structures. Lynch and Kline (2000) propose an STS approach to the treatment of the *Challenger* case involving three distinct parts. Firstly, their proposal includes class discussion to consider the routine procedures and practices contributing to the disaster. Secondly, students would then undertake writing exercises to compare the features of this particular case with other disaster cases creatively. Finally, students would then engage in role-playing exercises to better appreciate the constraints within which disaster participants acted and, as a result, consider possibilities to address these constraints (Lynch and Kline, 2000). Such an approach to the consideration of disaster cases, from an ethical perspective, would provide an enhanced, reflexive and more engaging learning experience when also linked to the more commonly applied micro-ethical treatment that is underpinned by moral philosophy (Kline, 2001). The approach proposed by Lynch and Kline (2000) is useful as a diagnostic tool. Although useful in directing a focus towards developing a more nuanced awareness of the precautionary principle organisational cultural failings, Conlon (2015) argues that such proposals fall short of specifying how engineers, who become aware of the normalisation of deviance, might then change that organisational practice.

By way of another example, an STS course was introduced in Bilkent University in Ankara, Turkey in the mid-1990s as a compulsory component of engineering majors. The course dealt with the ethical, social, cultural, political, economic, legal, environment and sustainability, health and safety, reliability dimensions of science, technology, and engineering (Ozaktas, 2013). Ozaktas (2013) tasked groups of students with considering particular problems within the local community in a manner that required a deep engagement with those problematic issues, together with active engagement with the communities concerned. Ozaktas (2013) observed significant educational value in the learning experience which required deep student commitment, together with individual and collective action and reflection on the consequences of that action. The proposed approach promoted an appreciation of the social responsibility principles referred to previously in this chapter. As a result of dealing with a class population that rose to 500 and owing to financial constraints, Ozaktas (2013) was unable to obtain management backing to support the student group sub-divisions required for effective ongoing implementation of the course. The lack of backing perhaps results from the proposal of the course as an add-on strategy, led by an individual academic. It was perhaps seen as dispensable at the institutional level given that it was not a core element of the programme and therefore vulnerable within a constrained financial programme support model.

A further approach involved the introduction of an *Engineering and Society* course in 2011 at Clarkson University, New York, which provided students with the opportunity to explore how non-technical factors influence the development and integration of technology with society (DeWaters *et al.*, 2015). The students explore engineering through an STS lens, thereby developing an appreciation for the macro-ethical issues associated with engineering decision-making. The stand-alone course again offered as an add-on strategy, addresses societal context and contemporary issues, alongside engineering topics, in a manner that emphasises the former (DeWaters *et al.*, 2015). Concerning the teaching and learning approaches adopted, students explore concepts through extensive readings, supplemental assignments together with interactive class discussions and activities. Students also engage in role-playing, risk assessment, value conflict resolution and debate the benefits and risks associated with emergent technologies. Based on post coursework feedback gathered, 'students felt more confident about problem-solving and teamwork, a stronger sense of 'belonging' in an engineering career, and a better understanding of the role of ethics and societal factors to engineering design and decision making' (DeWaters *et al.*, 2015, p. 4).

An *Engineering, The Environment, and Society* course provided at University of California, Berkeley, also challenges students to look beyond the technical elements of their work and to recognize the deeply social and political nature of engineering questions (University of California, 2018). Students engage in projects affecting diverse communities that address a range of environmental and social justice issues, including contaminated drinking water, industrial pollution, and air pollution. Again, this provides students with an opportunity to develop a deeper appreciation of the social responsibility principles referred to earlier in this chapter.

2.5 Conclusion

Burns (2015) asserts that for sustainability teaching, learning must move beyond traditional styles of education in which individuality, intellectual rigour, (instrumental) rationality, and transfer of knowledge are privileged in the educational process. The argument here is that this assertion has implications for the treatment of ethics and social responsibility in the engineering curriculum

(Bucciarelli, 2008; Byrne, 2012; Conlon, 2015). The evidence presented in this chapter suggests that the current engineering curriculum, framed by the traditional approaches alluded to by Burns (2015), is ill-equipped to address global sustainability challenges and lacks a balanced consideration of micro and macro-ethical perspectives (Herkert, 2005). Given the potential for negative long-term effects such as global warming, engineers with broader perspectives and skills are needed to create socially responsible solutions (Canney and Bielefeldt, 2015). In the chapter I note, the assertion of Qureshi and Nawab (2013) that repositioning is required to move engineering towards an awareness of ecosystems and towards a mindset of the mutual enhancement of nature and humans, embracing sustainability principles. While the social responsibility principles proposed by Zandvoort *et al*. (2013) potentially align with the directional shift called for by Qureshi and Nawab (2013), it is dependent on the interpretation of those principles. In an international context, approaches adopting STS studies, broaden the discussion of engineering ethics to include issues and concerns relating to public policy, risk and product liability, sustainable development and globalisation (Herkert, 2005). However, it warrants consideration as to whether such approaches, limited to single modules or elective courses, lead to the marginalisation within the curriculum of the social dimension of engineering practice, further cultivating the sense of the technical and non-technical being incompatible as alluded to by Riley and Lambrinidou (2015).

Given the overarching role upheld by *Engineers Ireland* as evidenced in the chapter, their support for any directional shift in engineering education and engineering practice will be essential. In this exploration, there is the question as to whether or not this will require a transformational change in professional body positioning from being the purveyors of expert, authoritative knowledge towards promoting a sense of the interlinking and interactions between engineering disciplines, non-technical fields and society (Qureshi and Nawab, 2013)? The next chapter includes an in-depth discussion concerning sociological influences within engineering education and engineering.

Chapter 3: A Sociological Analysis of Engineering Ethics

3.1 Introduction

In the previous chapter, I consider the treatment of ethics in engineering education and engineering practice. In this chapter, the focus turns to a sociological exploration of the ethical positioning of engineering within modern society. Thematically, what is under consideration in the chapter is the evolution of an apparently unsustainable modern capitalist society, the positioning of contemporary engineering within that societal construct and, the crucial implications of that positioning from a sustainability perspective.

Giroux (2006) argues that capitalism, as an economic system, with its intense fixation on market-driven growth, has evolved to a point where it has become so normalised in society that any possibilities of an alternative is difficult if not impossible to see, resulting in a hegemony of capital over all other domains of life. There is a resulting hollowing out of society, with human needs subordinated to the dictates of the market. Any means of social amelioration or conceptions of a sustainable future are difficult to envision from within the constraints of this system. This is a crucial point when considering a potentially sustainable future for society and the ethical place for engineering within such a future society.

In order to explore this theme further, a number of key discourses of modernity, each of which is set thematically within modern capitalism, are critiqued in the chapter. In this regard, the chapter critiques how a market-driven societal paradigm has taken a profound hold within modern society and considers too the ideological entrapment of engineering practice and education within that societal paradigm. The ideological entrapment I am pointing towards relates to the dominant societal forces and influences controlling the perpetuation of knowledge within the educational curriculum in general and, in the context of this research, within engineering education in particular. From an ideological standpoint, Apple (2004) asserts that the curriculum serves to preserve and distribute, what is perceived by those in positions of power as being 'legitimate knowledge', recognising a cultural legitimacy of knowledge by those specific groups upholding power within the larger political and economic arena. As a result, power and culture are not static entities but become attributes of existing economic relations within society (Apple, 2004). Indeed as Giroux (2010) argues, higher education institutes are now largely defined through the corporate demand that they provide the skills, knowledge, and credentials to build a workforce to support market-driven economic realities. As was evident in the previous chapter, such effects are particularly apparent in the engineering curriculum.

The importance of this critique within the study is best understood in the consideration of alternative approaches towards securing a sustainable future. The argument being that there is a need to take account of the powerful forces which work towards perpetuating the societal status quo. In looking towards challenging this societal construct from a sustainability perspective, there is a requirement to pay attention to the 'dialectical realities of political power and the capabilities necessary to fashion a political praxis of educative liberation and ideological emancipation' (Blewitt, 2012, p. 2). As a result, in considering those dialectical realities, underlying factors and discourses which act towards supporting this societal paradigm are critiqued in the chapter. With these underlying considerations in mind, the chapter begins with an exploration of certain rationalities viewed as reaching their fullest potential in modernity (Schafer, 2018). The importance of these rationalisation effects becomes apparent in the later critique of the key discourses associated with modern capitalism.

The chapter then turns to an exploration of contemporary engineering ideology and how ideological positioning shapes the engagement of engineering with society. What becomes apparent within this critique is the alignment of contemporary engineering and modern capitalism from a cultural perspective. In this exploration, there is a particular focus on globalization and neoliberalism, together with contrasting reflexive modernity discourses. From an ethical perspective, the challenges presented to engineering within each of the discourses is explored in the chapter. For example, engineering is often considered as being a key driver of globalization (Riley, 2007) and, as a result, the review of ethical positioning of engineering within this particular discourse is particularly important in the context of this research.

Finally, there is an exploration of discursive representations of sustainability and sustainable development concepts, with their contrasting ideological perspectives. The exploration of engineering engagement within the sustainability domain also provides a useful lens through which to view how modern sociological influences have a (mis)shaping effect on contemporary engineering education and practice. Having problematised current engineering ideology and societal positioning, the chapter then begins the work of reimagining an engineering education with a view towards repositioning engineering within the sustainability domain.

3.2 Rationality and the Evolution of the Modern Capitalist Society

A key consideration in this study is the importance and significance of particular influences of rationality in shaping modern society and, in turn, the resulting implications of these rationalisation effects in considering the ethical positioning of contemporary engineering. As a result, this section provides a critique of the broad-ranging concepts of rationality within modernity as a thematic precursor to the remainder of the chapter. In the context of the sustainability debate, as will become evident later in this chapter, the consideration of the prominence of instrumental rationality within modernity is of particular importance.

Schafer (2018) identifies certain aspects of rationalization as having reached their fullest expression in modernity and, in particular, points to two related, but distinct, forms of rationality: instrumental/means-ends rationality and formal/rule-governed rationality. Both involve a transformation of society into a rational form governed by principles or formulas that allow for the prediction and control of human action (Schafer, 2018). In that context, Scott (2005) notes how the transition from a traditional to a modern society is best understood as a process of rationalisation within which value standards show an increasing degree of 'formal' rationality. Scott (2005) further asserts that the rationalisation of value standards involves 'a process in which key social institutions are transformed in the direction of a greater 'formal' rationality in the standards by which they operate' (Scott, 2005, p. 162).

The proliferation of instrumental reason is manifested in the development and spread of capitalism, and indeed in what might be regarded as unreflective technical progress. In this regard, Scott (2005) notes how cultural modernity involves an increasing reliance on scientific knowledge, forged through the application of formal principles of rationality and applied in technologies that are judged solely by their practical success. As will become evident later in this chapter, the unreflective adherence to the principles of technical progress is an important contemporary consideration for engineering.

In further exploring the theorising of rationality, it is important to first develop the historical context, given that the history of rationalization, in all its forms, is coextensive with the history of human culture (Schafer, 2018). In this regard, I first turn to a consideration of Weberian rationality, given the importance of Weberian theory in influencing future variants of rationality. Four types of rationality are theorised by Weber (1968): practical, theoretical, substantive, and formal rationality. Of these four rationality types, it is formal rationality which legitimates an instrumental means-end rational calculation by reference back to universally applied rules, laws, or regulations (Kalberg, 1980). Formal rationality, at the expense of the other types of rationality, was the rationalising effect that was considered by Weber as being a defining problem of modern society (Ritzer 2011). The key differentiation being that formal rationality ‘refers primarily to the calculability of means and procedures whereas substantive rationality [refers] primarily to the value (from some explicitly defined standpoint) of ends or results’ (Brubaker, 1984, p. 36). Thus, according to Weber, while the values behind substantive rationality can be internalised in individuals, so that they want to act in a certain way, within formal rationality people are forced to act in the manner required by an administrative body (Ritzer, 2001). The rules and regulations of formal rationality dictate actions and, as a result, there is a resulting quelling of autonomy and individual choice-making. Weber noted that formal rationality took hold within the capitalist economies and bureaucratic organisations that predominated in the Occident (Ritzer, 2001). According to Weber (1968), capitalism and bureaucracies were derived from the same sources and, as a result, acted to reinforce one another in a manner that reinforced the rationalization of the Occident. Whilst formal rationality is in essence value-neutral, Brubaker (1984) notes how the formal rationalization of modern society is not neutral, given that it is imbued with the values and interests of those who are in a position to perpetuate the rational approaches. In stark contrast, substantive rationality exists as ‘a manifestation of man's inherent capacity for value-rational action’ (Kalberg, 1980, p. 1155). In characterising Weber’s (1968) substantive rationality, Kalberg (1980) notes that ‘a radical perspectivism prevails in which the existence of a rationalization process depends on an individual's implied or stated, unconscious or conscious, preference for certain ultimate values’ (Kalberg, 1980, p. 1156). This results in the systematization of his or her action to conform to these values.

Particularly pertinent in the context of this research, is the exploration of the shaping effects of market-driven cultural influences on contemporary engineering education and practice. Indeed Weber theorised a relationship between culture and the economy in taking the cultural realm of values and ideology as a social force that interacts with and influences other aspects of society (Scott, 2013). So for example, in cultural terms Weber identified elements of theology as providing Protestantism with a cultural affinity with the economic demands of early market capitalism (Hayward and Kemmelmeier, 2011). Indeed, Weber sets the birth of modern capitalism in an economically rational context, founded on the substantively rational value systems of Calvinism which gave rise to this economic system (Kalberg, 1980; Ray *et al.*, 1994). According to Weber, the distinguishing characteristics of modern capitalism can be identified by the underlying attitudes informed by Calvinistic ethics and value systems (Giddens, 1971). Weber based his theory on statistical evidence that prominent leadership and ownership positions within the modern capitalist system were upheld by Protestants, who aligned their work with a rational conduct of life, seeing capital accumulation as a spiritual calling (Giddens, 1971).

Given this historical context, it is inappropriate to consider a Weberian basis for the perpetuation of capitalism, as an apparently ‘value free’ and formally rational process, without reference to its cultural origins, founded based on a Calvinistic value system. Nonetheless, Weber’s consideration of cultural influences and underlying attitudes underpinning modern capitalism is useful in continuing the exploring of the evolution of modern capitalism and its associated cultural influences, and indeed the placement of contemporary engineering within that dominant societal paradigm. It is important too, to note the influence of Weberian concepts of rationality in providing a basis for redefinition by critical theorists. In this regard, Ritzer (2011) notes how the critical thinkers were shaped not only by Marxian theory but also by Weberian theory, as reflected in their focus on rationality as the dominant development in the modern world. Indeed, fundamental to an understanding of the Frankfurt School’s[6] view of social theory is its critique of instrumental reason (Giroux, 1983). Feenberg (2017) notes the assertion of major critical theorists, including Adorno, Horkheimer, and Marcuse, that society became colonized by technical rationality. Indeed, Marcuse (2013) asserts that technology transforms nature into a mechanical and infinitely malleable order, a transformation underpinned by technological rationality, representing a pure version of instrumentality incapable of formulating substantive end goals (Marcuse, 2013). In further arguing that technology primarily serves powerful

[6] The Institute for Social Research, officially created in Frankfurt, Germany in 1923, was the original home of the Frankfurt School. It was formed under the directorship of Max Horkheimer and under his directorship, most of the members who later became famous, including Erich Fromm, Herbert Marcuse and Theodor Adorno, joined the institute. Giroux, H.A. (1983) *Theory and resistance in education: a pedagogy for the opposition*, Exeter, New Hampshire: Heinemann Educational Books.

interests, Marcuse (1989) asserts that it is naïve to conceptualise the development of modern science and its applications in isolation from the development of capitalism. Indeed technology, in modern societies, is shaped to meet the requirements of capitalism. Ultimately, technological rationality is characterised by a passive acceptance of reality and identification with technical achievements, thereby impeding ideas and actions that could identify and support the development of a qualitatively different society (Gunderson *et al.*, 2019). As a result, the assertion here is that because technological rationality reduces the world to goals of capital, it also blocks avenues for substantive social change that could bring about a better and more ecologically sound society. In considering this colonisation of society by technocratic rationality, Giroux (1983) notes how the Frankfurt School linked a crisis of reason with the general crisis in science and society as a whole and further points to two crucial aspects of Frankfurt School thought:

> First, it argues that the only solution to the present crisis lies in developing a more fully self-conscious notion of reason, one that embraces elements of critique as well as human will and transformative action. Second, it means entrusting to theory the task of rescuing reason from the logic of technocratic rationality or positivism. (Giroux, 1983, p. 13)

In this regard, Ritzer (2011) notes how the critical school adopted the Weberian differentiation between formal rationality and substantive rationality, which the critical theorists developed towards a theory of 'reason'. Ritzer (2011) further posits that for the critical theorists, formal rationality is concerned unreflectively with the question of the most effective means for achieving any given purpose, viewed as 'technocratic thinking'. Technology is mediated by society and vice versa with the interests and values of society embodied in technical achievements.

There is a clear contrast here with the theoretical conception of 'reason', which according to critical theorists, is the hope for society (Ritzer, 2011). Reason being an ideal involving the assessment of means in terms of the ultimate human values of justice, peace, and happiness. Ultimately, technological rationality is characterised by a passive acceptance of reality and identification with technical achievements, thereby impeding ideas and actions that could identify and support the development of a qualitatively different society (Gunderson *et al.*, 2019). As a result, the assertion here is that because technological rationality reduces the world to goals of capital, it also blocks avenues for social change that could bring about a better and more ecologically sound society.

Giroux (1983) conceptualises the idea of the 'problematic' in addressing the distinctness of the boundaries surrounding the theoretical framing of any mode of rationality. According to Giroux (1983), the problematic of any theoretical approach 'refers not only to the questions that govern its mode of social enquiry but also to the questions not asked' (Giroux, 1983, p. 48). In the remainder of this chapter, there is an attempt to reveal the questions not being asked from an engineering perspective when considering the rational underpinnings of key discourses of modernity. As will become evident in the chapter, there is a clear alignment between a currently dominant engineering ideology and the rational underpinnings of these discourses of modernity. Ultimately, for engineering, in considering the means towards bringing about a better and more ecologically sound society, there is a question of how to rescue 'reason' from the logic of technocratic rationality. There is also a consideration of the role played by engineering in supporting these rationalising effects utilising apparently 'value-neutral' engineering endeavours. The argument offered here is that this apparent 'value-neutrality' is actually a false premise and that this misunderstanding creates important ethical implications for contemporary engineering education and practice.

3.3 Ideological Formations in Contemporary Engineering Education and Practice

In this section, in an attempt to reveal engineering positioning in modern societal debates, I consider influences shaping contemporary engineering ideology. In particular, what is explored here are the interconnecting influences of expertise, professionalism, rationality, bureaucracy and the significance of institutional power in the context of the societal positioning of engineering.

Engineers' ideas are logically related and can be arranged in sequences to form systems of thoughts from major premises; the systems being materialistic and framed around scientific laws and business-related principles (Layton, 1986). Traditionally, engineering has been represented as a technical profession that serves the status quo, a profession that remains largely unresponsive to public concern (Riley, 2008). As Heywood (2017) notes, engineers are taught to 'prioritize technical ingenuity over helping people' (Heywood, 2017, p. 72). With these considerations in mind, I first consider briefly the development of engineering as a profession from a historical perspective. I then critique the prominence of expert-based perspectives and professionalism, turning then to a consideration of bureaucratic influences and the effects of instrumentally rational thinking.

3.3.1 Engineering and professionalism: a historical perspective

In this section, in adopting a critical neo-Weberian perspective, I explore the cultural influences and values that have shaped engineering historically. I also critique ethical positions and their shaping effects within that professionalisation process. The sociology of professions has been considered in a number of different ways over time. Wilensky (1964) describes the process of professionalization as involving the creation of a full-time occupation, the establishment of a higher education award pathway, the formation of a professional association, rules to exclude the unqualified and the establishment and implementation of a code of ethics. The process of professionalization described by Wilensky (1964) is reflective of how engineering has been shaped as a profession. Saks (2012) describes professions as having a diverse range of attributes which differentiate them from other occupational work. He identifies the differentiators as knowledge and expertise and notes the requirement to make a positive contribution to the community as another key differentiator. In terms of professional identity, as was evident in the previous chapter, engineers hold a position in society as purveyors of expert technical knowledge. The requirement to make a positive contribution to the community that Saks (2012) identifies is a key professional attribute that is not always apparent in engineering practice. This may be as a result of the contextual deficit relating to the cultural/human dimensional meaning of engineering (Jamison, 2009).

Abbott (1988) identifies a tendency of modern communities to institutionalise expertise in the form of professionalism thereby creating a distinctive way of controlling and organising work. Focusing on the evolution of the profession in the United Kingdom, ‘an apprenticeship continued to be the standard means of learning engineering’ (Rae and Volti, 2001, p. 180) through to the middle of the twentieth century. In North America, Wilensky (1964) identifies civil engineering as the first branch of engineering to meet the criteria to qualify as a profession. A full-time civil engineering occupation was established in the 18th century in North America and a code of ethics subsequently established in 1910. In describing the positioning of engineering at that time, Lucena et al. (2010) note the discipline's focus on transforming nature, leading to the formation of organisational structures that might profit from such transformations economically whilst also modernising communities using technology.

In 1955, the British government commenced the development of higher technological education in the technical education sector (Heywood, 2016), based on the belief that the part-time release of students from industry to technical colleges would not provide sufficiently high quality engineers for industry. In transitioning from an apprenticeship-based training model to full-time college-based engineering programmes, the responsibility for the ethical formation of students transferred from the guidance provided by the supervisor of the apprentice to the programme content to which the full-time engineering students were exposed.

In identifying a distinguishing characteristic of the engineering profession when compared to other professions from the first half of the nineteenth century onwards, Larson (1979) notes how the average engineer emerged from this period as a salaried employee. So, as opposed to independent consultancy and entrepreneurial practice, Larson (1979) remarks that engineers typically worked for 'large-scale economic enterprises in a capitalist society' and introduced 'a principle of heteronomy at the very core of the engineer's role' (Larson, 1979, p. 27). The result of that employment relationship compromised their professional autonomy.

3.3.2 Engineering expertise, authoritative perspectives and professionalism

The authoritative professional representative voice of *Engineers Ireland* is particularly evident in the critique of professional body publications in the previous chapter. There is a sense of expert knowledge being applied by the discipline of engineering for the self-evident and unquestioning benefit of society. This non-reflexive positioning resonates throughout the publications, perhaps best represented in how the professional body represents its societal rule as being '[a] community of creative professionals delivering solutions for society' (Engineers Ireland, 2017b, p. 1). In terms of professional identity, Saks (2012) observes that engineers commonly view their societal role as being the purveyors of expert technical knowledge.

What is also apparent in the critique of professional body publications in the previous chapter, is a sense of one-way expert-based communicative practices. Expert-based positioning based around objectivity, then shapes how engineers communicate outside of their disciplinary boundaries. In this regard, Leydens *et al.* (2012) assert that such positivistic outlooks then 'result in communicative actions that destabilize effective collaborative relationships' (Leydens *et al.*, 2012, p. 71). As a result, actions become immune from criticism, given that such positioning is founded on expertise and objectivity. The reference that '[m]embers shall use appropriate opportunities to outline and explain the contribution of the engineering profession in enhancing society's well-being ...' (Engineers Ireland, 2018a, p. 5) being a particularly apt example in this regard. This contribution appears blind to the potentially beneficial impact of collaborative community engagement. In its place, an expert-based approach is apparent in identifying the need to explain the self-evidently beneficial impact of engineering decision-making. There is also a consideration of status in this contribution, with the inherent power associated with being the custodians and purveyors of expert opinions. In this regard, Brante (2011) notes how professions obtain their social standing and trust due to their position as 'inter-mediators and appliers of the *highest knowledge* within specific social domains' (Brante, 2011, p. 9).

Such positioning can then lead to problematic engineering outcomes. It is with this consideration in mind that several writers (Riley, 2007; Robbins, 2007; Baillie, 2009; Nieusma and Riley, 2010) have noted how many engineering projects have proved contentious in terms of their societal impacts. This is particularly evident in developing countries, due to a predominant non-reflexive focus on managerial processes and expert-based technological perspectives. With the focus on developing expertise, there is also evidence, within engineering education, of knowledge increasingly becoming compartmentalised within engineering disciplinary boundaries (Cumming-Potvin *et al.*, 2013). This is apparent in the representative programme outlines, critiqued in the previous chapter and included in Appendix 10. There is little if any evidence, for example, of the presence of cross-disciplinary learning practices in any of the programmes reviewed. Students remain captive within their discipline-specific siloes. This then becomes problematic as the challenges confronted by engineers become increasingly multidimensional (Cumming-Potvin *et al.*, 2013). For example, this is the case within the sustainability domain, with multidimensional interconnectedness being apparent within many of the challenges encountered (Ryan and Murphy, 2018). It is beyond question, given the increasing level of importance and urgency associated with sustainability concerns (Stern, 2007; Borne, 2010; Zandvoort *et* *al.*, 2013), that engineering students will confront these kinds of challenges in their future careers.

Such expert-based approaches then inform the professional positioning of engineering. In writing on professional responsibility, from a broadly-framed professional context, Brint (2015), tracks an ideological shift from social trustee professionalism towards expert professionalism, with a resulting enhanced focus on the value of specialised skills development in higher education. This was apparent in the critique of engineering education in the previous chapter, within which it was evident that the educational focus is predominantly placed on students acquiring advanced technical skills within the narrowly framed programme accreditation process. In also considering the theme of key professional attributes, Saks (2012) identifies the differentiators as knowledge and expertise, but importantly, also notes the requirement to make a positive contribution to the community as being a key professional attribute. Again, in the critique of professional body publications, and the review of sample educational programme content in the previous chapter, there is no evidence forthcoming of such values-based approaches or perspectives.

Another key defining characteristic of professionalism, identified by Saks (2012), is professional autonomy. In this regard, Riley (2012) notes that autonomy, and the ability to make independent values-based ethical choices, is an essential element of what defines professions in sociological terms. In exploring the need for autonomy in engineering practice, Riley (2012) identifies the contribution of the individual engineer as being a mark of professionalism, further adding that engineers tend to abdicate responsibility for problem definitions. Riley (2012) asserts that if the profession of engineering does not exercise such choices individually and collectively, it may cease to be regarded as a profession in one important sense. On a similar note, Baillie and Levine (2013) point to the responsibility of a professional engineer to see beyond what ethics means, within the boundaries of contemporary pressures and measures of success, and to know what the morally justifiable choices are before deciding on any new direction. It is with these considerations in mind that I now turn to the critique of bureaucratic control and rationality within contemporary engineering; the argument being that such control curtails professional autonomy.

3.3.3 Bureaucracy and its limits: rationality in engineering education and practice

While the effects of expert-based positioning and professionalism are evident within engineering, there is also a consideration of how bureaucratisation and rationality are both highly influential in shaping both engineering education and practice. In writing on the formative development of professions in the Occident, Weber (1968) establishes a relationship between professionalization, bureaucratization and rationalization recognising that 'professionalization, like bureaucratization, is an aspect of the rationalization of society' (Ritzer, 1975, p. 627). This theoretical perspective has since influenced the neo-Weberian theorising of the rationalisation of contemporary professions. For example, Ritzer (2001) conceptualises a more contemporary, but parallel, process to Weber's theorising of bureaucracy as the paradigm of the rationalization process. In addressing the dimensions of Weber's formal theory, Ritzer (2001) proposes the McDonald's business model with its focus on providing consumers, workers, and managers with efficiency, calculability, predictability and control as a rationalisation paradigm, which he names *McDonalization* (Ritzer, 2001). Ritzer (2001) defines the paradigm as follows:

> The process by which the principles of the fast-food restaurant are coming to dominate more and more sectors of American society as well as the rest of the world. (Ritzer, 2001, p. 174)

The key aspects of the rational approach as characterised by McDonald's, focusing on efficiency, calculability, predictability and control, are also present in many engineering companies and particularly so in the larger multinational companies. This brings to the fore a consideration of the dominant societal paradigm which privileges control and efficiency over resilience and redundancy, however, it can be argued that such thinking and action is not sustainable (Byrne *et al.*, 2016). Similar procedures, processes and hierarchical regimes appear in regional companies in multinational organisations, with repeatability and predictability being highly valued. This leads to an erosion of professional autonomy within engineering similarly to Ritzer's (2001) conception of the *McDoctor* when considering similar developmental changes in the medical profession. Though *McDonaldization* offers obvious and distinct advantages from the rational, repeatable and predictable perspectives, it also has inherent flaws. One of the flaws is characterised by Ritzer (2001) as the fifth dimension of *McDonalization* or the irrationality of rationality, the concept being that rational systems will almost certainly lead to irrational consequences.

In addressing the forms of rationality considered previously in this chapter, it is formal (or instrumental) and technocratic rationality, as opposed to substantive (or value) rationality, that has increasingly influenced the development of the engineering profession, as evidenced by the exploration of engineering education and engineering practice in the previous chapter. Indeed, it might be added that such effects have been experienced within higher education more generally. Such instrumental and technocratic rationality underlines the thinking of *Engineers Ireland*, as evidenced by the critique of a range of their publications. As alluded to previously, such thinking is also aligned with the dominant societal paradigm. The dynamics that serve these processes are also shaped by national policies together with institutionally contingent variables (Byrne *et al.*, 2016). Returning to professional body positioning, it begins with how the institution sees one of its primary purposes as being the 'setting up and maintaining *proper* standards of professional and general education and training for admission to membership or any category of membership of the Institution' (Engineers Ireland, 2014a, p. 3). The 'proper' standards referred to are informed by ideological perspectives, informed by authoritative, expert knowledge, with standards then enforced within a strictly controlled bureaucratic framework. This is evident in the critique of engineering programme accreditation processes and professional development frameworks critiqued in the previous chapter. On this point, in writing on the rationalisation of engineering education, Nieusma (2015) notes the relentless advancement towards instrumental rationality within higher education generally and, in particular within engineering programs. In describing how engineering standards are influenced by formal/instrumental rationality, Bucciarelli (2008) notes:

> If you accept the vision of engineering practice promoted and sustained by the object- world notion - that the work of engineers is instrumental and value free - then it seems to follow that the profession is "value neutral", that we are all but "guns for hire". (Bucciarelli, 2008, p. 13)

A similar degree of instrumentally rational thinking is evident in higher education in general. In writing on this subject, Murphy (2009) notes how managerial auditing processes drive for accountability and maintain high levels of instrumentally rational control over higher education within closely controlled bureaucracies. In this instance, it is those groups upholding positions of power within higher education that effectively control the instrumentally rational approaches being adopted. As would be evident from the previous chapter, it is the professional body influence, in shaping engineering education, via their accreditation process, that bureaucratically upholds the institutional power in dictating the accreditation criteria to be adhered to in engineering education in Ireland. The type of knowledge, informed by ideological positioning and focused on the development of technocratic expertise in narrowly framed disciplinary boundaries, is the knowledge that is validated in this instrumentally rational accreditation process. Hence, the values incorporated within engineering education, and those of most influence in the development of engineering student perspectives, are largely externally imposed.

Brubaker (1984) also notes the tension between formal and substantive rationality as being behind many of the social conflicts of our time. Indeed, such tension between formal and substantive rationality is also emergent in engineering education, as can be evidenced in the previous chapter by the alternative micro and macro-ethical treatments being adopted within engineering education, with micro-ethical approaches dominating currently. What is worthy of consideration, however, is whether the status quo, in educational terms, is fit for purpose when considering the multidimensional aspects of the challenges faced by engineering in the sustainability domain.

When considering engineering practice, the narrowly framed engineering focus on the desired ends, associated with instrumental rationality, concerning economic development, does not place sufficient focus on non-economic consequences (Riley, 2007). In writing about projects in the developing world, Riley (2007) asserts that the non-economic consequences of an instrumentally rational approach, adopted on such engineering projects, support economic development but that this support has led to detrimental impacts on society. According to Evetts (2013) this is supported by key structures which are characteristic of organisational professionalism, leading to standardised procedures and managerial control, domination and a resulting autonomy deficit at the individual practitioner level. This can lead to what Conlon (2015) describes as the captivity of engineering to corporate and managerial agendas, given that engineers are just one of many contributors within the complex, organisational and technical decision-making process. As a result, engineers become captive to social, organizational, and economic forces that 'define the problems engineers are to address as well as the terms of acceptable solutions.' (Newberry, 2007, p. 113). The bureaucratic managerial hold maintained on engineering, with the values incorporated within, and most influential to engineering, are largely externally imposed (Newberry, 2007). There is an alignment here between the instrumental rationality and bureaucracy that engineers experience in their education and what their experiences then are in practice, similarly constrained by bureaucratic and instrumentally rational influences.

To summarise, the currently dominant engineering ideology is objective, instrumentally rational, founded on expert-based knowledge which is then manifested within bureaucratic settings. The core ideological components are represented in Figure 3-1 below:

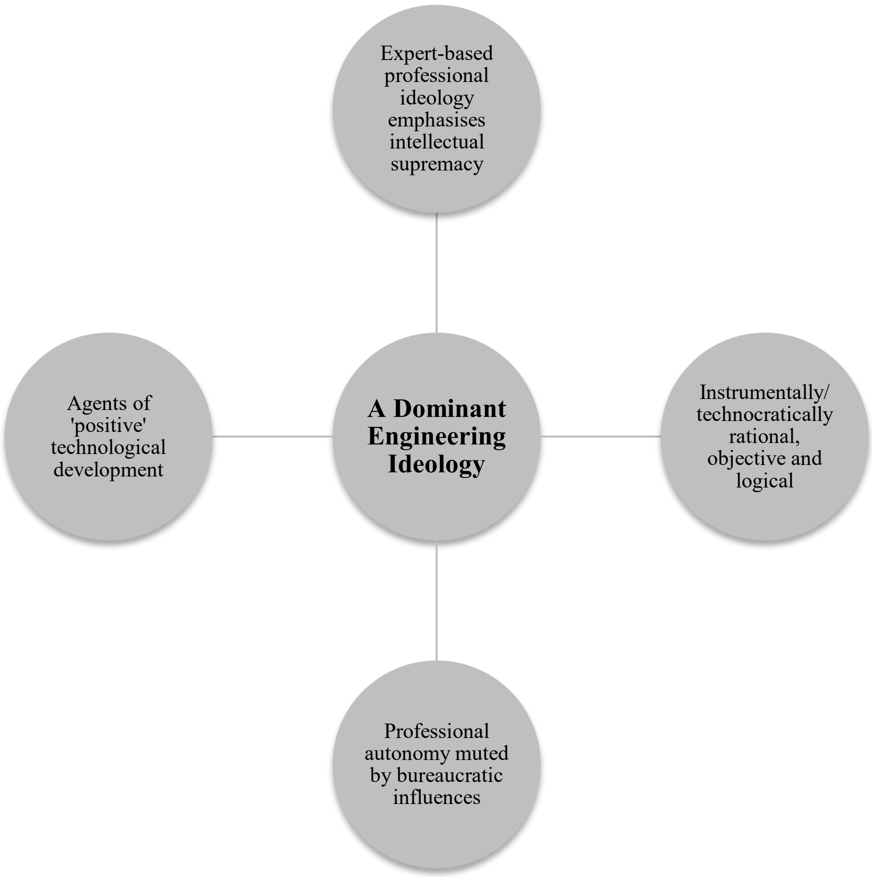


Figure 3-1: A dominant engineering ideology
(Author's own figure)

Such positioning then prioritises a certain engineering vision, informed by authoritative expertise, and privileging micro-ethical perspectives. This perspective views engineers as fulfilling a narrowly framed technocratic role in society.

3.4 The Interaction of Engineering with Key Discourses of Modernity

Having considered ideological formations within engineering, I now turn to an exploration of engineering engagement with key discourses of modernity. The discourses considered in this section include globalization and neoliberalism. Globalization being constitutive to capitalism and neoliberalism representing a phase of modern capitalism within which instrumental rationality has become particularly prominent. This is followed by a consideration of reflexive modernity which acts as a critique of the dominant societal paradigm. Finally, there is an exploration of discursive representations of sustainability and sustainable development concepts with their contrasting ideological perspectives when compared to other modernity discourses. As will become apparent in this exploration, while these discourses overlap structurally, there is a very clear divergence ideologically (Bakari, 2013), with that ideological divergence potentially signposting a pathway towards a sustainable future.

3.4.1 Engineering engagement with the discourse of globalization

The application of engineering has become increasingly globalised, with engineering providing essential support for global economic development (Riley, 2007). What is evident here is the alignment between the ideology underpinning globalization and the dominant engineering ideology considered in the previous section, which it will be recalled is also based on instrumental rationality, expertise and authoritative positioning with dominant bureaucratic influences also evident. In this critique, neoliberalism is considered in tandem with globalization; the argument being that both are maintained by instrumentally rational perspectives (Ritzer and Dean, 2015), with both being prominent within modern capitalism. As was apparent earlier in the chapter, instrumental/technocratic rationality is a key aspect of the contemporary engineering ideology. In this regard, the exploration reveals a clear alignment, in terms of rational motivations and perspectives, between contemporary engineering and the discourse of globalization.

In addressing this subject, while recognising the potential for significant engineering impacts to society, both locally and globally, Beever and Brightman (2016) note how globalization brings with it complex and multifaceted contextual issues that are challenging to engage with. Globalization involves the 'intensification of worldwide social relations and interactions such that distant events acquire very localised impacts and vice versa' (Held and McGrew, 2007, p. 2). In defining globalization, Ritzer and Dean (2015) use imagery of liquids and fluidity in characterising globalization as involving the free flow of people, objects, places and information:

> Globalization is a transplanetary process or set of processes involving increasing liquidity and the growing multidirectional flows of people, objects, places and information as well as the structures they encounter and create that are barriers to, or expedite, those flows. (Ritzer and Dean, 2015, p. 2)

This particular definition provides an effective metaphorical representation of globalization in its portrayal of free-flowing interconnectedness, which is also now representative of global engineering practice. Held and McGrew (2007) further characterise globalization as involving a series of processes including the stretching of social, political and economic activities across political frontiers, the intensification of interconnectedness, the accelerating pace of trans-border interactions and the growing intensity and velocity of global interactions. Ultimately, globalization involves a structural shift in the organisation of human affairs from 'a world of discrete but interdependent national states to the world as a shared social space' (Held, 1990, p. 3). Globalization involves the idea that 'power, whether hard (economic or military) or soft (political and cultural) is often organised and exercised at a distance' (Held and McGrew, 2007).

In considering the economic backdrop to globalization, it is also important to note that global engineering has been based predominantly on North American and European perspectives (Johnston, 2001). There is a sense of expert knowledge from the Global North being imposed on the Global South. It is in this privileging of technical rationality, within engineering practice, in the context of development work (Nieusma and Riley, 2010), allied to the economically driven globalization model, that creates the conditions for the problematic societal impact of engineering in such instances. As a result, issues of social responsibility can be missed. In critiquing engineering development work, Nieusma and Riley (2010) identify some of the challenges associated with the non-technical aspects of such development work, including the problematic social power relations with local communities and structural constraints, including neoliberal economic policies and questions of project sustainability. As a result, globalization is often approached with indifference, or indeed, arrogance towards cultural sensitivities, with the net effect being 'the destructive attenuation of one set of cultural values in the wake of a collision with a more aggressive set of values' (Newberry, 2004, p. 31).

As the magnitude, diversity and complexity of the process of globalization (Ritzer and Dean, 2015) increases, so too do the occurrences of problematic engineering dilemmas. As a result, engineers are exposed to a range of sociological factors that create and perpetuate the globalization phenomenon in navigating these dilemmas (Riley, 2007). It is in the use of objective, expert-based technological approaches, informed by instrumentally rational perspectives and positioned within bureaucratic procedural practices, that there is a diminution of the macro-ethical considerations conceptualised by Herkert (2001), as alluded to in the previous chapter. With that enlargement and widening of global support, aligned with neoliberal economic policies, comes an expansion in the types of problems, constraints and environments encountered by engineers (Newberry, 2004). In reflecting on this theme, Lucena *et al.* (2010) assert that, on many such projects, engineers are guided by commitments to top-down planning, design, development, and project implementation in the absence of appropriate community consultation. There is an apparent disregard for the social responsibility principles, considered in the previous chapter, in the lack of engagement with the communities affected by technological solutions and innovations.

Johnston (2001) further asserts that much of the political context for the contemporary global engineering practice is being set by three ideological constructs, namely, globalization, economic rationalism or neoliberalism and corporate managerialism (Johnston, 2001). There is a synergy between globalization and neoliberalism and indeed, between both and global engineering practice. As with engineering practice, a driving force behind neoliberalism is an apparently 'value-free', means-end instrumental rationality. Whilst the instrumentally rational implementation of neoliberal policies might be 'value-free', the underlying values encoded in neoliberal policies worldwide align with the free-market values of modern capitalism.

Neoliberalism emerged during the Depression-era[7], in part as a reaction to Keynesian economics, whereby markets, entrepreneurs, and corporations came to be limited by a number of social and political and regulative constraints (Ritzer, 2011). Hay (2004) describes how the institutionalization and normalization of neoliberalism have been defended in largely technical and rationalist terms and 'in a manner almost entirely inaccessible to public political scrutiny, contestation and

[7] The Great Depression was a severe worldwide economic depression that took place mostly during the 1930s, beginning in the United States. The timing of the Great Depression varied across nations; in most countries it started in 1929 and lasted until the late-1930s. John, A. (1986) 'Garraty, The Great Depression', *An inquiry into the causes, course, and consequence of the worldwide depression of the nineteen-thirties, as seen by contemporaries and in the light of history (San Diego/New York/London 1986).*

debate' (Hay, 2004, p. 523). There is a natural alignment between the ideological positioning of contemporary engineering practice and the (instrumentally) rational and expert-based defending position of neoliberal perspectives as alluded to by Hay (2004).

When considering global engineering, for example, the reduction in state intervention and regulatory constraint is particularly pertinent. In describing the detrimental global impacts associated with the implementation of a neoliberal ideology from an engineering perspective, Riley (2007) points to policies and outcomes including 'increased economic inequality, environmental devastation, violations of human rights, oppression of women, widening technological divides, and suboptimal engineering solutions' (Riley, 2007, p. 12.1240.14). In this regard, in focusing on the poor record attributable to a neoliberal approach to globalization as represented by the exploitation of natural resources, Harvey (2005) contests that the 'preference for short-term contractual relations puts pressure on all producers to extract everything they can while the contract lasts' (Harvey, 2007, p. 174). Neoliberalism involves a political commitment to individual liberty and devotion to free-market economics, with an attenuation of the influence of the state in that market (Harvey, 2005). In considering neoliberalism as a theory, and its focus both on political positioning and economic practices, Harvey's (2007) definition is particularly appropriate:

> [H]uman well-being can best be advanced by the maximization of entrepreneurial freedoms within an institutional framework characterized by private property rights, individual liberty, unencumbered markets, and free trade. The role of the state is to create and preserve an institutional framework appropriate to such practices. …Furthermore, if markets do not exist (in areas such as land, water, education, health care, social security, or environmental pollution), then they must be created, by state action if necessary. But beyond these tasks, the state should not venture. (Harvey, 2007, p. 22)

This definition provides a very clear presentation of the key characteristics of neoliberalism: the privileging of entrepreneurial freedoms, the curtailment of state-led regulatory interventions and the utilisation of unencumbered markets, acting as a driving force for economic development. The portrayal of neoliberalism has been morally justified by its inference of freedom, an ideal with which those in North America, in particular, have been heavily socialised (Wrenn, 2015). The definition is particularly apt in its alignment with the critique of the positioning of engineering in the previous chapter.

Harvey (2005) links neoliberalism with globalization in a number of ways. As a system, neoliberalism manifests global fluidity in a similar manner to globalization. It is also a global phenomenon as it has become an economic and political system that is now commonly in place throughout the world and, as a result, has become a particularly prominent feature of modern capitalism. Finally, the influential organisations, often seen as a driving forces of a neoliberal ideology, including the International Monetary Fund (IMF) and the World Bank, are dominated by neoliberal ideas and are imposing them, in the form of various demands for restructuring, on several societies throughout the world (Harvey, 2005). According to Giroux (2006), with neoliberal globalization, capital is removed from control and regulation by the state and power then becomes disconnected from ethical and social responsibility considerations.

Coupled with, and following on from, this economic approach, are policy perspectives that include the removal of regulations on industry and trade and the privatisation of public goods. Hay (2004) describes how rationalist assumptions have played a 'crucial role in consolidating, normalizing and, above all, depoliticizing a neoliberal economic paradigm which is disingenuously presented as a simple and necessary accommodation to global economic realities' (Hay, 2004, p. 521). Economic development, for example, is seen as self-evidently necessary when viewed through an instrumentally rational and expert-oriented lens. States are then encouraged to leave economies to the efficiencies of market forces, and state-led development is deemed to be inefficient (Kiely, 2005); the intention being that freeing of market forces from state restrictions promotes rapid growth and improved living standards for all. This drives gross domestic product (GDP) performance improvement and debt reduction but often with very detrimental impacts on society (Ritzer, 2011). The performance improvement is often driven by reforms introduced via shock therapy (Ritzer and Dean, 2015) with a resulting 'dismal reality of inequality, corruption and environmental degradation' (Klein, 2007, p. 280).

Prior to concluding this critique however and in viewing globalization through a macro-ethical lens, it is important to note that a case can be made for globalization having the capacity to have a positive, beneficial impact and provide enriching societal benefits. However, this can only occur where there is a values-based sensitivity to whose particular preferences and interests are being promoted in the globalization process (Newberry, 2004). Such sensitised awareness is not readily forthcoming, however. In writing about the creative destructive force of global neoliberalism for example, Harvey (2007) writes that '[f]or any system of thought to become dominant, it requires the articulation of fundamental concepts that become so deeply embedded in common sense understandings that they are taken for granted and beyond question'(Harvey, 2007, p. 24). This adds significantly to the difficulty of challenging such processes which are seen as self-evidently necessary in fuelling further economic development. In this regard, Riley (2007) identifies the need for a deep awareness of underlying assumptions and values that accompany globalised neoliberal trends amongst engineering educators and the need to incorporate awareness of neoliberalism and globalization in engineering curricula, in a manner that supports the development of student awareness and promotes appropriate student action. Such reasoned sensitivity is at the centre of the thinking of many anti-globalism movements.

3.4.2 Anti-globalization movements and implications for engineering

Globalization has recently been under sustained attack politically, environmentally and economically and, as a consequence, instrumentally rational thinking on what is deemed as progress in the context of modernity. Indeed, anti-globalism has emerged in reaction to the detrimental impacts of modernity, as manifested via globalization. From an engineering perspective, Riley (2007) characterises those detrimental impacts as 'increased economic inequality, environmental devastation, violations of human rights, oppression of women, widening technological divides, and suboptimal engineering solutions' (Riley, 2007, p. 12.1240.13). Vallero and Vesilind (2007) further assert that no engineering project can be regarded as being complete until matters of justice and social responsibility are addressed. In referring to environmental projects by way of example, Vallero and Vesilind (2007) posit that questions focused on the impact on communities, close to projects, need to be addressed in more depth. Often, however, in the context of that global development work, as Vallero and Vesilind (2007) note, these impacts are understated or missed completely. There is an apparent misalignment here, between the dominant ideological positioning previously considered in this chapter, and the call here for a more nuanced consideration of the societal impacts of engineering decision making. Considering this theme, Riley (2007) argues that engineers should resist neoliberalism in global development, given that neoliberal ideology has led to policies and outcomes including economic inequality, environmental devastation, together with other human rights violations and engineering solutions that have proven suboptimal. In this regard, in writing on anti-globalization movements, Schlosberg and Coles (2016) note how circulations, practices and relationships, both within society and across the human/non-human divide, are being increasingly challenged. Schlosberg and Coles (2016) further add that movement groups see current practices as weakening human capacities together with human-ecological systems and, as a result, begin to question the participation in social and material practices leading to the current status quo. This, and similar critiques of modernity, are addressed in the next section under the sustainability theme that underpins this study.

3.4.3 Reflexive modernity: engineering responsibility in a risk society

What has become apparent in this exploration is that modernity has given rise to a series of unintended and potentially dangerous consequences. There are a number of ways of conceptualising this. From an ecological perspective, two particularly influential and contrasting theories have been developed. Ecological modernisation theory acknowledges the need for fundamental transformations in the modernity project but addresses this need from a position of technological optimism and as a techno-economic management strategy (Mol and Spaargaren, 2000). A contrasting means of conceptualising this subject is offered in Beck's (1996) risk society theory, with the criticism of science and technology being one of the core elements of Beck's (1996) analysis of the risk society. The expert-based imposition of technocracy on society is illustrated in Beck's (1996) work in the manner in which he illustrates how science engages with environmental risks, by adhering to ‘technical and scientific procedures to defend their monopoly on the diagnosis of hazards, even when this position is challenged both from within and from 'outside' society because of the new hazards that have arisen’ (Spaargaren, 1997, p. 107).

In considering these contrasting conceptual positions, I have chosen to develop the argument around Beck's (1996) risk society theory, given its positioning as a response to the detrimental impacts of expert-based technocracy, a critique which resonates with my critique, earlier in this chapter, of the colonisation of technical rationality within modernity. The contention here is that, in adopting instrumentally rational and expert perspectives, as alluded to in the previous section, engineering is placed centrally and at odds within the risk society debate, with its inherent preference for, and uncritical support of, technological development and innovation as being self-evidently necessary.

The concept of the risk society arises as a result of a phase of development of modern society whereby the social, political, ecological and individual risks created, as a result of innovation, elude the control and protective institutions of industrial society (Beck, 1992). Giddens (1999) contrasts two types of risks, *external risks* and *manufactured risks*. External risks are characterised as events that may strike individuals unexpectedly, but that occur sufficiently regularly in a whole population of people as to be broadly predictable. External risks may include, for example, events such as sickness, disablement or unemployment (Giddens, 1999). Manufactured risks, on the other hand, are marked by the high level of human intervention required in both producing, and mitigating such risks (Giddens, 1999). As manufactured risks are the product of human activity, proponents of risk society theory (Beck, 1992; Giddens, 1999) assert that societies can assess the level of risk being created, or that might be created. This societal assessment of manufactured risks leads to the concept of reflexive modernisation, characterised 'as much by *reflex* as it is by *reflection*' (Lash *et al.*, 1996, p. 6). In theorising the concept of *reflexive modernization*, Beck (1996) and Giddens (1999) assert that modernity turns on and critiques itself in response to phenomena, such as climate change, and a variety of other societal issues (Schlosberg and Coles, 2016). The increased critique of modern industrial practices, in turn, leads to reflexive modernisation. In other words, a reflex action or reaction that invokes concepts such as sustainability and the precautionary principle focusing on preventive measures to decrease the levels of risk. Risk is always related to security, safety and responsibility and, 'as the world becomes dominated by manufactured rather than external uncertainty, there is a renewed discussion of the nature of responsibility' (Giddens, 1999, p. 7). Given its influence in shaping the technological landscape of modernity, it warrants exploration as to whether engineering ought to be more engaged within this debate. In turn, it calls to question as to whether or not there ought to be space within the engineering programme accreditation process to address this requirement. By way of example, Giddens (1999) points to the Brent Spar[8] incident, whereby it became apparent that the company which had erected the oil platform had not adequately reflected on the full platform life cycle, which should have involved a consideration of the means of safe end-of-life disposal.

[8] Brent Spar was a North Sea oil storage and tanker loading buoy in the Brent oilfield in the East Shetland Basin of the North Sea, operated by Shell UK. Brent Spar became an issue of public concern in 1995, when the British government announced its support for Shell's application for its disposal in deep Atlantic waters.

Beck's (1997) representation of applied technological science, a principle that governs bureaucratic organisations, operates logically as [instrumentally rational] cause-and-effect and means-to-an-end thinking (Loon, 2002). For Beck, this is a key aspect of the risk society, in which the instrumental rationality of bureaucracy, a characteristic feature of most organizational settings of modern institutions, 'drives a vicious circle between risk and risk management, and between complexity and ambivalence' (Loon, 2002, p. 189). Because of such ambivalence, there is a link to instrumental rationality, with a singular focus on apparently 'value-neutral' and means-end thinking thereby aligning with the currently dominant ideology within contemporary engineering, as alluded to earlier in this chapter. In a global risk society, with the uncertainty of science, the knowledge base of experts is equally uncertain. The following quotation from Beck (1997) represents this dilemma succinctly:

> [E]xperts can never provide anything but more or less uncertain knowledge and information on the probabilities of events; they cannot answer the question as to whether a risk is still acceptable or not. All statements on risk contain built-in standards of tolerance and acceptance relying on morality, cultural standards and perceptions, which ultimately come down to the question: how do we want to live? This is a question that can never be answered by experts alone. (Beck, 1997, pp. 23-24)

The limitations of expert-based approaches identified by Beck (1997) implies a need for more open societal engagement and communication practices within engineering in considering how best to negotiate societal risks. Technological innovation begins with engineering design concepts, leading to the development of new technical ideas of potential value to society. However, the democratic input into the consideration of the introduction of technological innovation is often very limited. It is often restricted to either voting for elected government representatives, who can influence budgetary priorities or to potentially influencing a regulatory agency decision (Hess, 2007). In writing about the difficulty of avoiding unintended consequences of engineering design, Grasso and Martinelli (2007) remark on how this has become increasingly difficult ‘as population soars and technology, ever more complex, becomes increasingly embedded in human experience’ (Grasso and Martinelli, 2007, p. 1).

I now turn to a consideration of climate change which represents a particularly important and urgent contemporary societal concern. While most nations now recognise the need to move to a low-carbon economy, it is widely recognised that such reductions may achieve too little and too late (Shepherd, 2009). Efforts to address climate change have primarily focused on mitigation, through the reduction of greenhouse gas emissions. However, in recent years, in considering methods to combat climate change, more reactive, interventionist geoengineering[9] measures have been proposed. In this regard, it is interesting to note that there was a reluctance to consider geoengineering in the early years of this century. The reluctance stemmed from a concern that the proposed technical solutions might create a moral hazard and encourage risky behaviour (Preston, 2013) and potential unintended consequences associated with such interventions in highly complex systems. This was based on a balanced consideration of the technical complexity of some of the emerging technologies and their associated risks. Also, in further exploring unintended consequences in the context of the climate change debate,

---

[9] Geoengineering has been defined as ‘the deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change.’ Shepherd, J.G. (2009) *Geoengineering the climate: science, governance and uncertainty*, London: The Royal Society Publishing. The risk imposed on society as a result of the introduction of such expert-deployed technological innovations warrants careful consideration from an ethical perspective.

this brings to the fore a consideration of the Jevons Paradox[10] whereby energy efficiency policies can become counter-productive (Alcott, 2005). Technological progress and government policy resulting in the promoting of efficiency measures creates a reduction in unit energy usage but results in the potential for the unintended consequence of the rate of consumption of that resource rising due to increasing demand within a modern society fixated on economic growth.

Gunderson *et al.* (2018) point to capitalism's inability to overcome the contradiction between the need to accumulate capital, on the one hand, and the need to maintain a stable climate system on the other. In reflecting on the inequitable global risks evident in late modernity, Beck (1997) imagines responsible modernity, coming into view framed around *technological citizenship.* Beck (1997) envisions that this would involve a society that debates the consequences of technological and economic development before the crucial decisions are made. In such a scenario, Beck (1997) asserts that the burden of proof for future risks and hazards ought to lie on those creating them, and no longer on those potentially threatened by them. There is, as a result, a call for open and reasoned engagement with society in negotiating risk. In such a scenario, the expert embraces societal engagement and interaction in a shared negotiation and mitigation of societal risks.

There have been criticisms of Beck's (1997) risk society thesis. In one particularly noteworthy case, Ormrod (2013) analyses the inadequacies of Beck's accounts of economic power and subjectivity. Ormrod (2013) suggests that Beck's optimism

---

[10] In economics, the Jevons paradox occurs when technological progress or government policy increases the efficiency with which a resource is used (reducing the amount necessary for any one use), but the rate of consumption of that resource rises due to increasing demand Polimeni, J.M., Mayumi, K., Giampietro, M. and Alcott, B. (2012) *The jevons paradox and the myth of resource efficiency improvements*, London: Earthscan.

about the emergence of a cosmopolitan public sphere, applying a standard as to how we might wish to live when considering scientific plans and hazards, is misplaced given the economic interests that keep uncertainty about such risks away from the public. Effectively, in analysing Beck's risk society thesis, Ormrod is drawing on the current dominance of instrumental rationality in modern society. In addressing Ormrod's (2013) criticism, however, one can further make a case for a values-based societal response, informed by substantive rationality, as a reaction to the dominating economic interests that Ormrod (2013) believes tend to have a muting effect on public participation in risk societal consultation. In a further critique, Ritzer (2011) draws attention to the unremitting pessimism of Beck's work, noting how his substantive work on rationalization and domination 'indicated that we are trapped in an increasingly meaningless and disenchanted world' (Ritzer, 2011, p. 156).

The risk society debate also provides a potential sociological basis for reimagining how engineering might engage ethically with society. There is a call for participatory engagement in considering societal risk. In invoking reflexive modernisation, Ritzer (2011) notes how it is often the victims of the risks that begin to reflect on the risks and, as a result, become experts, who, in turn, come to question advanced modernity and its dangers. Ritzer (2011) notes that they do this, in part, because they can no longer rely on scientists to do it for them. This aligns with Beck's (1996) criticism of scientists for their role in the creation and maintenance of the risk society. In this observation, there is a criticism of the instrumentally rational deployment of expertise in contemporary engineering practice. Writing on this subject Lucena *et al.* (2010) note how the power held by engineers over technological development lies in their knowledge, skills, attitudes, and beliefs towards technology, but that some of these attributes are problematic when it comes to developing technological solutions for communities.

While risk societal theory provides a potentially useful framing towards promoting substantive/reasoned approaches within engineering, instrumentally rational thinking still dominates. For example, within the European Union[11] (EU), the response to such environmental challenges has been to understate the social and cultural aspects of the challenge. Instead, such challenges, are formulated as instrumentally rational constructs, as either technological challenges focused on energy supply, or, by standard Europe-wide measures, such as energy taxes 'whose hugely different meanings, impacts and ramifications across the social and cultural heterogeneity of Europe are ignored' (Lash *et al.*, 1996, p. 5). It is worthy of reflection as to how risk society might meaningfully be addressed within the engineering curriculum, for example in reflecting on the relative pros and cons of technological 'advances' and the criteria and value sets which would suggest whether they are worth pursuing or not.

3.5 Sustainability Discourses within Modernity

Whilst there is broad agreement that the present state of the Earth is unsustainable, conceptually sustainability and sustainable development are very much contested terms. In this section, I explore the discursive representations of the sustainability and sustainable development concepts. I first critique the evolving sustainable development discourse. This is followed by a contrasting conception of

[11] The European Union (EU) is a political and economic union of 27 member states that are located primarily in Europe.

sustainability, framed as an aspirational means to support human and other life flourishing (Ehrenfeld, 2000; Grant, 2012).

As was evident in the previous section, globalization is powered by seemingly 'value-neutral' instrumental rationality, privileging entrepreneurial freedoms and curtailing state-led regulatory interventions. In contrast, sustainable development seeks to address the daunting challenges faced by global society in the economic, social, environmental and cultural realms (UNESCO, 2012). An 'official' sustainable development definition first appeared in the *Brundtland Report* (1987). The report was written on behalf of the United Nations[12] (UN) and called for a transformation in global socio-economic development approaches. The following commonly referenced definition of sustainable development is included in the report: 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (Brundtland, 1987). This definition has subsequently underpinned the framing of the *Sustainable Development Goals* (SDGs) which emerged from a United Nations Conference on Sustainable Development in Rio de Janeiro in 2012. The SDGs include seventeen interconnecting goals, providing a sustainable development blueprint intended to address global challenges, including those related to poverty, inequality, climate change, environmental degradation, peace and justice (UNESCO, 2020). The SDGs frame sustainable development as an instrumentally rational/technocratic management process, managing economic development so that the Earth will continue to support future generations, as it has done both current and past

[12] The United Nations is an international organization founded in 1945. It is currently made up of 193 Member States. The mission and work of the United Nations are guided by the purposes and principles contained in its founding Charter United Nations (2000) *The Millennium Development Goals*, available: http://www.unfoundation.org/what-we-do/issues/mdgs.html [accessed 28/05/2017].

generations. In critiquing the discourse of sustainable development and related concepts, Ehrenfeld (2008a) notes their firm placement within the present dominant social paradigm within the industrial world. Whilst development is not the objective, Ehrenfeld (2008a) questions what specifically the aspiration might be, apart from avoiding unsustainability. The problem orientation is also reductionist in focusing on the elimination of symptoms, but often overlooking root causes (Grant, 2012). In this regard, Ehrenfeld (2000) argues against a representation of sustainability as a technological characteristic of the global system or indeed the appropriateness of it being reduced to some deterministic set of characteristics and rules. Unsustainability becomes the unintended consequence of patterns of modern life, underpinned by consumerism and the dominant market-driven/capitalist economic paradigm. This returns us to a core risk societal theme, namely the avoidance of unintended and unsustainable consequences in this technocratic management process. As Ehrenfeld (2008b) notes, unsustainability is an unintended consequence of modernity and will likely remain with us until the beliefs and norms that drive industrialized economies are exchanged for new ones aligned with sustainability.

In contrast to the sustainable development discourse, Ehrenfeld (2008a) offers an alternative conception of sustainability which envisions 'the possibility that human and other life will flourish on the planet forever' (Ehrenfeld, 2008a, p. 6). In writing about sustainability, Grant (2012) espouses a similar flourishing philosophy and identifies the approach as contrasting with the more dominant sustainable development paradigm in its pursuance of what will support life thriving as opposed to merely surviving. Ehrenfeld (2008b) proposes flourishing as a normative vision and as a quality 'that encompasses all three legs of sustainable development because it conjures up a vision of a desirable future state' (Ehrenfeld, 2008b, p. 2) and because it 'can be assessed as being present or not and as a metaphor for many things, but always connotes aliveness, joy, health and many other qualities related to being' (Ehrenfeld, 2008b, p. 2). Ehrenfeld (2008b) further notes that if the possibility of flourishing is to be realised, the cultural system must be transformed at its roots., starting by exchanging the dominant model of determinate objective reality for one of complexity, 'accepting that the world and its subsystems cannot be reduced to a set of mathematical or analytic rules' (Ehrenfeld, 2008b, p. 3). Indeed, as will become evident in this exploration, the sustainability-as-flourishing philosophy, aligns with the critical theorists' conception of 'reason', which as I noted earlier involves the assessment of means in terms of the ultimate human values including those of justice, peace, and happiness (Ritzer, 2011).

In considering the scale of the challenge, it is evident that there will be a requirement for transformational as opposed to incremental change to foster a sustainability-as-flourishing philosophy. Such a transformational change would require a fundamental change in society's culture and collective consciousness, enabling the creation of new collective beliefs and values (Ehrenfeld, 2008a). In further developing the sustainability-as-flourishing concept, Ehrenfeld (2008a) identifies a series of characteristics that might be required to support such a culture (Figure 3-2). The letters in parentheses in Figure 3-2 point to the source of inspiration for these new elements: "n" to nature as the source, and "b" to Being.

Cognitive	Worldview	Contemporary Norms	Psychological
Interconnected (n)	Holistic (n)	Equity/justice (b)	Remembrance (b)
Distance (b)	Organic (n)	Qualitative (n)	Avowal (b)
Complexity (n)	Bio-centric (b)	Enchantment (n, b)	International (b)
Indeterminacy (n)	Intuitive (b)	Other-directedness (b)	Accurateness (b)
Graduality (b)	Communitarian (b, n)	Techno-skepticism (n)	Sensitization (b)

Figure 3-2: Characteristics of a sustainability culture

It is noteworthy that the characteristics of such a sustainable culture, including interconnectedness, complexity, indeterminacy, holistic, organic, and communitarian all spring from observable characteristics of natural systems. As a result, the sustainability-as-flourishing approach sets out an idealised and 'reasoned' approach, by providing a framing of the assessment of means in terms of ultimate human values. From a cultural standpoint, this contrasts very starkly with the dominant instrumental and technocratically rational approaches within contemporary engineering education and practice and, indeed within broader society as became evident in the earlier critique of discourses of modernity.

3.5.1 An analysis of the development of sustainability education

In the opening chapter, I note how obligations to promote sustainability principles are rarely embedded in engineering programmes in Ireland although professional body codes of ethics require engineers to promote these principles (Byrne, 2012). This is also evident from the critique of engineering programmes in Chapter 2. In considering this theme, it is important to note that sustainability and sustainable development create a call for enhanced levels of commitment, within engineering, to the social and ecological domains, in avoiding practice which may result in passive neglect or future negative consequences, unintended or otherwise (Vesilind, 2002). There is also a need for engineers to recognise their responsibility towards future generations (Byrne, 2010) given their ethical duty within the sustainability domain.

From a historical perspective, within the past three decades, sustainability education has emerged and evolved from marginal beginnings towards a more prominent position, perhaps indicating the possibility of fundamental change in collective views of the purposes and nature of education and learning in this regard (Sterling, 2004a). Several terms are commonly used as being representative of sustainability education. The most commonly used of those terms include environmental education (EE), education for sustainable development (ESD), education for sustainability (EFS) and education for a sustainable future (ESF). As was apparent in the consideration of the limited presence of sustainability within engineering education in the previous chapter, ESD currently represents the most commonly adopted term within that limited treatment. As will be recalled from the previous chapter, this is due primarily to current dominant educational approaches tending to reinforce 'mechanisms facilitating the provision of disciplinary education aimed at producing technically proficient, employable graduates in which the social dimension is marginalized' (Nicolaou *et al.*, 2017, p. 13). On this point and in considering ESD methods, Nicolaou *et al.* (2017) observe that dominant approaches supplement the focus on the development of technical proficiency with primary sustainability focus on the environmental dimension of ESD. Crucially though, in considering the macro-ethical dimension of engineering, Nicolaou *et al.* (2017) assert that the social dimension is marginalised in many such approaches currently.

As explored in the previous section, ESD has sought to encompass the social, economic and environmental dimensions of change and alternative futures within an instrumentally rational framework. As also became evident in the previous section, the term 'sustainable development' is perhaps unhelpful, given its inference of a technocratic process that in turn manages the process of economic development to support future generations in the same way it has for us. In policy terms, for example, the dominant societal paradigm tends to emerge. For example the following quotation included in Ireland's National Strategy on Education for Sustainable Development in Ireland, 2014-2020 (Department of Education and Skills, 2014), taken from The UNECE Strategy for Education for Sustainable Development (UNECE, 2009) establishes the motivation for the approach, which appears to be placed firmly within the dominant social paradigm within the industrial world (Ehrenfeld, 2008a):

> It [sustainable development] can promote a shift in people's mindsets and in so doing enable them to make our world safer, healthier and more prosperous, thereby improving the quality of life (UNECE, 2009 cited in; Department of Education and Skills, 2014, p. 7)

The self-evidential linkage between prosperity and an improvement of quality of life helps to reinforce this point aligning with the privileging of 'having' over 'being' (Ehrenfeld, 2000), thereby aligning with the all-pervasive consumer culture that has colonised society within modernity. This point is further reinforced in the following quotation included in the report referred to above, linking economic vitality with sustainability taken from the same report:

> It is a region characterized by sustainable development, including economic vitality, justice, social cohesion, environmental protection and the sustainable management of natural resources (UNECE, 2009, p. 15)

Educational approaches, prompted by such structural thinking, and commonly including traditional methods of lecture and assessment, tend to oversimplify complex issues and trade-offs into right or wrong answers while emphasizing individual achievement at the cost of positive societal outcomes (Redman, 2013). This is also evident in the previous chapter in the critique of sustainability-related educational approaches within engineering. However, as McGhee and Grant (2019) note the 'wicked'[13] problems often associated with sustainability dilemmas necessitate collaborations between a broad range of stakeholders, to ensure that all relevant knowledge and interests are taken into account. On this note, Gough and Scott (2006) contrast the dominant technocratic, paradigmatic and task-based perspectives that have been proposed in the context of sustainability-related education with a preferred socially-framed paradigm shift perspective, which seeks to address the failure of technology and science to solve sustainability-related problems. Gough and Scott (2006) further assert the need for debate about sustainability and education in the context of globalization, which requires the development of learner reflexivity, as a key to living sustainably in a globalized world. In other words, a shift in the way engineers work and think is required, in response to the macro-ethical problems of technological sustainability (Herkert, 2001; Conlon, 2013).

The proposition explored here is the need to bridge micro-ethical and macro-ethical (Herkert, 2001) perspectives, as referred to in the previous chapter, becomes increasingly important in empowering engineering students to negotiate these contemporary societal issues in their future practice. As a result, in identifying the need to consider the inner dimensions of valuative psychological

[13] As opposed to types of 'tame' problems that science has developed to address and for which an exhaustive formulation can be provided containing all the information needed to solve the problem, Rittel and Webber note that 'wicked-problems' have no definitive solutions or objective answers. The information needed to understand the problem depends upon one's idea for solving it Horst, W.J.R. and Webber, M.M. (1973) 'Dilemmas in a General Theory of Planning', *Policy sciences*, 4(2), 155-169, available: http://dx.doi.org/10.1007/BF01405730.

and perceptual change (Sterling, 2004a), the exploration here focuses on educational approaches that foster a sense of 'being', as represented by the sustainability-as-flourishing concept. The contention is that in engineering education, a framework is required to encourage students to identify solutions in the social, cultural, ecological, and political spheres of life (Stephens *et al.*, 2008). This requires an integrated approach to carefully and critically reflect on societal concerns, be they social or environmental, in contrast to the presently narrowly defined solutions to ill-defined/'wicked' problems (Bacon *et al.*, 2011).

In considering the growing emergence of ecological worldviews, Sterling (2004a) notes the need to move beyond the root metaphor of mechanism that is still at the heart of the modernist project and towards a new 'organicism' based on a 'living systems', 'co-evolutionary' and 'participative' views of the world. According to Sterling (2004a), such thinking transcends the limits of mechanism and goes beyond the blind alley of relativism. In essence from an educational perspective, Sterling (2004a) asserts that this would entail an extended and participatory epistemology, a connective ontology and an integrative praxis. In this regard, Redman (2013) identifies four specific competencies to foster transformative action and empowering students to be change agents in this transition to sustainability. The competencies identified by Redman (2013) include (1) systems thinking and an understanding of interconnectedness, (2) long-term, foresighted reasoning and strategizing, (3) stakeholder engagement and group collaboration, and (4) action-orientation and change-agent skills. The first competency acknowledges the complexity, array and interconnectivity of 'wicked' global problems and impacts, thereby identifying the need for the development of systems thinking capabilities of learners. Secondly, Redman (2013) proposes the development of foresighted long-term and future thinking to foster learner understanding of consequences of actions taken today for future generations, thereby promoting intergenerational equity. Thirdly, collaborative practice is identified as a key competency, thereby accounting for diverse values and normative perspectives. Finally, given that at its core, sustainability is a call for change from our current trajectory, Redman (2013) notes a need for learners to foster the ability and confidence to become active participants whilst shaping their future within the sustainability domain.

What is evident from the above brief exploration of sustainability education is the consistent need to mount a deeper critique of the culture of mechanism, modernism and instrumental rationality that largely still informs most educational policy (Sterling, 2004a). The implications are profound and far-reaching for engineering education within the sustainability domain. What becomes apparent, in considering ethical engineering education and practice within the sustainability domain, is the need for what Conlon calls a critical examination of 'underlying generative mechanisms and their impacts on engineering practice' (Conlon, 2015, p. 7). However, evidence of such a critical examination is not apparent from the critique of current engineering educational provision in the previous chapter. In their research, drawing on critical realism, Nicolaou et al. (2017) identify problems in the ways that sustainable development is understood within engineering education. Nicolaou et al. (2017) assert that this arises from the underlying paradigm shaping engineering education, with the evidence in their research suggesting that this results from sustainability and engineering being decoupled discourses. Based on their research, Nicolaou et al. (2017) identify a difficulty for teaching staff within engineering courses to link sustainability, in its broadest sense, to their discipline. As was apparent in the exploration of engineering education within the sustainability domain in the previous chapter and the critique of the ideological positioning of engineering, there is an evident need for a redefinition of engineering to include a broad social purpose if engineers are to meet the challenge of sustainability. Indeed, as Nicolaou et al. (2017) assert, without engagement with the culture and structures that support current practices and without a challenge to market and science-driven models of education, deeper change is unlikely to occur and be sustained.

3.6 Conclusion

What is considered in this chapter is the powerful shaping effects of instrumental/technocratic rationality within modern capitalist society and, in turn, how ideological positioning profoundly influences the societal engagement of engineering within that dominant societal paradigm. In terms of ideology, the dominance of bureaucratic influences and instrumental rationality (Weber, 1978; Ritzer, 2001), with a prioritising of the expert voice (Hay, 2004) creates a close positional alignment between engineering and key discourses of modern capitalism, and in particular the globalization and neoliberalism discourses. Engineering is inextricably linked with the interaction of expert knowledge, globalization and development. This resonates with the outcome of the critique of *Engineers Ireland* publications in the previous chapter. Such approaches, informed by a reductionist, instrumentally/technocratically rational engineering ideology, have been identified as being problematic from a sustainability perspective (Bucciarelli, 2008; Conlon and Zandvoort, 2011). In focusing on contemporary engineering practice, a key consideration is the unforeseen consequences associated with that practice, which links to risk society theory (Beck, 1996;

Giddens, 1999), and its subsequent consideration concerning environmentalism and (Loon, 2002; Pellow and Brulle, 2005).

The chapter explores a range of education for sustainability teaching practices, with ESD approaches focusing on eliminating unsustainable practices, contrasting with selected EFS approaches more closely aligning with a sustainability-as-flourishing philosophy. What is explored here is whether there is a call for alternative educational approaches to create a basis for critiquing and challenging dominant and unsustainable ideological perspectives, that might then also address the cognitive, social/emotional and behavioural interrelated dimensions of sustainable education. As evidenced in the previous chapter, this brings to the fore a consideration of the need for the adoption of substantively rational and reasoned perspectives, informed by criticality, together with the integration of micro and macro-ethical approaches, within engineering education and engineering practice (Herkert, 2005). As Herkert (2001) notes in writing about ethics in engineering education, while important work remains to be done in addressing micro-ethical issues within engineering ethics, little has been done in relation to macro-ethics, and even less still concerning developing integrated approaches to addressing micro-ethics and macro-ethics within engineering. As is evidenced by the contributions of several scholars (Bucciarelli, 2008; Byrne, 2012; Conlon, 2013; Jamison *et al.*, 2014), in both this and the previous chapter, this remains the case in contemporary engineering education. The contention here, aligning with the consideration of Zandvoort *et al.* (2013), is that educational activities that support the formation of cultural traits and focus on social responsibility, need to be normalised in the sense that they become integral to engineering education.

Chapter 4: Research Methodology

4.1 Introduction

In this chapter, I describe my research approach and also outline how my chosen research methodology evolved. The chapter opens with an outline of my ontological and epistemological positioning. I also describe how my positioning, in turn, influenced my research approach and the selection of my research methodology. I explain in the chapter how critical theory as an ontological position has informed the research. I note my epistemological perspective, in reflexively adopting both positivist and social constructionist approaches. Both approaches have supported me in bridging the engineering and the sociology worlds in my research.

In conducting the study, I have intentionally adopted a qualitative approach as the kind of knowledge that I have prioritised is qualitative insofar as it relates to the understandings, experiences and imaginings (Mason, 2002) of research participants in their consideration of research themes.

The approach that I adopted during the field research stage required engagement and interaction with a wide range of research participants from the engineering community, each of whom was purposively selected. My chosen approach was highly informed and influenced by my extensive experience in engineering practice, a practice that is very much team-focused and consultative. I adopted a reflexive approach throughout my research, consistent with my critical and social constructionist positioning.

4.2 Positioning informed by a Critical Perspective

> …the adoption of a critical perspective…that is, a concern with revealing the operations of the social world, and the political

> apportioning of power that is often accomplished unawares, so as to change these operations and replace them with something that is more just. (Lock and Strong, 2010, p. 8)

The above reference encapsulates for me the critical and social constructionist perspectives that influence my positioning as a researcher. The remainder of this section provides an outline of that ontological and epistemological positioning.

As I describe in the opening chapter, in reflecting on formative learning experiences within my family, my vision of reality, in social and political terms, was shaped by those family discussions and debates and, in particular, in discussions with my father. Societal issues informed discussions and political events of the day, as reported in the paper of choice in our house, *The Irish Times.*

Ontological positioning has been defined as what is seen as the 'very nature or essence of things in the social world' (Mason, 2002, p. 12). Guba and Lincoln (1994) describe a paradigm as a set of basic beliefs that deal with 'ultimates or first principles and represent a worldview that defines for their holders the nature of the world' (Guba and Lincoln, 1994, p. 107). For me, from an ontological perspective, critical theory represents the paradigm that I align with most closely. The need to uncover the hidden assumptions underpinning the construction, reading and interpretation of narrative accounts (Creswell and Miller, 2000) is a key motivator for me. In the context of my research, this inspires me to consider and critique underlying assumptions that might influence the ethical positioning of engineering education and engineering practice. I share Creswell and Miller's (2000) view that social, political, cultural, economic, ethnic, and gender factors relating to my research inform my critical perspective and those of my fellow research participants.

Those factors then inform collective perspectives, and, in turn, these have influenced my research findings. As a result, in conducting my research, I saw the need for validity to be continually questioned, interrogated and challenged and this required me to remain reflexive in my research and the analysis of my research findings.

The contrast in theoretical perspectives between critical inquiry and an alternative interpretivist approach has been characterised as the difference between 'a research that accepts the status quo and research that seeks to bring about change' (Crotty, 1998, p. 13). I am attracted by the transformative potential of critical inquiry and critical reflection and by its ability to bring about change in both teaching and research practice. Brookfield (2005) describes critical theory as being based around a vision of a society whereby people see their state of wellbeing linked with that of the collective. In further framing the positioning of the critical paradigm, Brookfield (2005) considers critical theory as envisioning a society within which people are sensitive to the presence of injustice, inequity, and oppression. As a result, it challenges ideology that attempts to 'portray the exploitation of the many by the few as a natural state of affairs' (Brookfield, 2005, p. 39). Such a vision of society aligns with my political philosophy as outlined in the opening chapter.

4.2.1 Adopting Dual Epistemological Perspectives

In considering societal 'realities', my thinking is informed dialectically in my analysis of historical perspectives. It is also informed dialogically in my consideration of other viewpoints and, in exploring hypothetical perspectives directed towards reframing current societal norms. Guba and Lincoln (1994) describe how for a critical theorist 'the investigator and the investigated object are assumed to be interactively linked, with the values of the investigator (and situated 'others') inevitably influencing the inquiry' (Guba and Lincoln, 1994, p. 110).

Objectivism is the dominant epistemological approach in engineering with educational preferences underpinned by a positivistic paradigm. Engineers are trained to interpret the world from a positivistic position. Crotty (1998) characterises objectivism as 'the epistemological view that things exist as *meaningful* entities independently of consciousness and experience' (Crotty, 1998, p. 5); and, that 'careful (scientific?) research can attain that objective truth and meaning' (Crotty, 1998, p. 6). In my view, this approach supports decisive decision-making, given that it is based on the *apparent* certainty of the scientific knowledge base. While engineers might be decisive in their decision-making capacity, it is my experience that they tend not to be reflective or indeed reflexive in that decision-making process and, in particular, in assessing the societal impact of those decisions. Many of the themes raised in Chapter 2 reflect such thinking. The argument here being that this results from their intellectual positions being rigidly fixed around apparent scientific certainty and that this positioning partly results from how engineers are trained to interpret the world and their societal engagement. I hold the view that meaning is constructed as a result of my interaction and engagement with the world; I also believe that it is as a result of socially constructive processes that shared understandings can be yielded with others, as noted by Gergen (1985):

> Social constructionist inquiry is principally concerned with explicating the processes by which people come to describe, explain, or otherwise account for the world (including themselves) in which they live. (Gergen, 1985, p. 267)

Importantly for me, that dialogic interaction is framed by a dominant critical perspective focused on effecting meaningful change in society. Constructionism, as an epistemology, provides a view of human knowledge, whereby 'truth, or meaning, comes into existence in and out of our engagement with the realities in our world' (Crotty, 1998, p. 8). Creswell (2000) notes how this qualitative paradigm assumes that reality is socially constructed and that particular reality is what participants perceive it to be. This paradigm deviates significantly from the broadly objectivist positioning that dominates engineering practice. There is a relationship between the object and the conscious being experiencing that object.

I draw a distinction here between constructivism, focusing on the activity of the individual mind and constructionism where the focus includes cultural and social influences and shared meanings (Crotty, 1998; Gergen and Gergen, 2004). In addressing this theme, Gergen and Gergen (2004) note that the social constructionist is likely to favour 'forms of dialogue out of which new realities and values might emerge' (Gergen and Gergen, 2004, p. 21).

I noted earlier my belief that engineering education follows a predominantly objectivist approach. In contrast, there is a call for critical and constructionist perspectives in tackling some of the key societal concerns faced by engineers and particularly so within the sustainability domain. For example, the challenge of securing future sustainable supplies of energy calls for that radical spirit of openness that Crotty (1998) describes and the endless invitation to innovate referred to by Gergen (1985). In my view, the engineer is called to identify a societal need and then co-construct a solution for that need with society, based on sustainability principles. A key question which then arises is to what extent engineers might engage in open consultation with those in society who are potentially impacted by their decisions? Such an open, consultative and dialogic approach would follow a critical and constructionist philosophy. Such an approach aligns with my preferred positioning alluded to earlier in this chapter; supporting Riley's (2012) call for the co-construction of technological innovation with society.

My engagement with sociology has provided a stark contrast for me from the positivist approach that currently dominates within the discipline of engineering. I see a need to embrace both the positivist and social constructionist approaches reflexively. This positioning enables me to bridge the engineering and the sociology worlds in my dual roles in education and research. I negotiate these dual epistemological perspectives in my work as an educator, working within the constraints of the narrowly framed programme accreditation criteria, while looking towards ways of implementing interdisciplinary practices and enhanced community engagement within programmes.

This dual epistemological environment reflects the tensions that arose between the opposing sides at the workshop described by Leydens *et al.* (2012), as referred to in Chapter 1. This tension has been a recurring theme in my research, particularly reflected in my review of the literature in this area in Chapter 2 and my analysis of research findings in Chapter 6.

As a result, I believe that I bring novel insight to this area of research, having experienced that dual epistemological environment in engineering practice. For me, praxis (Freire, 1996) creates the foundation for how I negotiate that dual epistemological environment. In the opening chapter, I describe the cyclical laboratory-based experiential learning, which was similar to my exposure to Kolb's learning cycle (Kolb, 1984) in my undergraduate engineering education. This exposure provided a rich and meaningful learning experience for me. In considering why this was the case, it was the combined thinking, putting thinking into practice and then reflecting on the outcome to adjust future practice that created the rich learning experience. This learning experience, in turn, led to a reflexive response following my reflection on engaging in that learning experience. In the context of my research, praxis as a process of reflection and reflexive action (Freire, 1996) informs my thinking in considering a transformation in the approach adopted towards the treatment of ethics in engineering education. Equally, praxis is a process that I have adopted in negotiating my dual epistemological positioning in engineering practice. The practice was followed by reflection which, in turn, was followed by reflexive action. For example, in my engineering practice, I followed the codes and guidelines; I adopted the bureaucratic rules and structures. On reflecting on that practice in the opening chapter, I noted some of the ethical dilemmas that I had confronted in my work, such as the societal injustices that became most apparent to me on projects that I completed in the Middle East. The consideration of ethical dilemmas, in turn, led me to reflexive action in engaging in this area of research.

4.2.2 A Critical Approach with Social Constructionist Influences

Earlier in this chapter, I describe how I viewed the knowledge that I wished to explore in my research as being subjective. I also identified critical inquiry, supported by social constructionism, as my preferred epistemological approach. Denzin and Lincoln (2011) describe qualitative research as being a situated activity, involving an interpretive, naturalistic approach to the world and further add that 'qualitative researchers study things in their natural settings, attempting to make sense of, or to interpret, phenomena in terms of the meanings people bring to them' (Denzin and Lincoln, 2011, p. 3). This qualitative research approach supported my objective to develop an appreciation of the meaning that engineering students and engineers derive from their engagement with engineering education and practice. I realised, however, that such meaning is subjective and, as a result, I understood that I would encounter different viewpoints and perceptions in how those involved in the discipline would make sense of that involvement.

I describe in the opening chapter how, informed by my political beliefs, I perceive the world to be unequal and that engineers are exposed to social inequalities in their professional engagement with society. In my field research, I was interested in exploring the individual perceptions of those engaged in engineering education and professional practice. In particular, I wished to develop an understanding of how they each viewed the interaction of engineering practice with society in the context of my research themes.

I referred earlier to the dual epistemological environment that I embraced in my engineering work and how this has provided me with a novel insight into this particular area of research. My background in engineering practice and engineering education has also provided me with a deep awareness of the role fulfilled by each of the participants that engaged in my research. I have experienced life as an engineering student, albeit in a very different Ireland in the 1980s. I practised as an engineer for many years, and I am now involved in engineering education and engineering-related research. As a result, I designed my field research approach to dialogically co-construct research findings with a diverse range of research participants from within the engineering community.

4.3 Research Methodology: Interpretation and Evaluation

The first stage of my field research included a critical interpretation of the existing situation as it applied to the research theme, both within engineering education and engineering practice. The second field research stage then included an evaluation of field research findings within a focus group setting. The focus group also considered an agenda for change based on those findings.

Adopting a qualitative approach in my research, and informed by my epistemological perspective, I believed that any consideration of the positioning of ethics within engineering would require a social/dialogic interaction within the engineering community. In so doing, I intended to unveil shared meanings and understandings concerning my research question and, indeed, to create space for the emergence of potential new realities (Gergen and Gergen, 2004). Equally, in considering a possible agenda for change, I approached this dialogic interaction from a critical perspective. I did not wish to just understand shared ethical perspectives within the engineering community; I wished to critique the underlying assumptions leading to the current status quo, concerning the positioning of ethics both in engineering education and engineering practice. This approach to critiquing underlying assumptions also influenced my literature review. Together with reviewing the literature, including previous related research and relevant policy documentation and critiquing documentation at the *surface* level, I also adopted a critical perspective in an attempt to reveal underlying sociological discourses and assumptions in the literature.

I was interested in exploring how participants viewed the interaction of engineering with society. I wished to explore how participants viewed current engineering practice in the context of societal engagement and what participants perceived to be good ethical practice in engineering. Specifically, I was interested in considering the following research question:

> *What are the challenges and opportunities associated with adopting a social responsibility approach to engineering education and practice?*

This foundational research question also led to exploring ideological thought formations relating to engineering and how they, in turn, might influence the societal positioning of engineering. As a result, the kind of knowledge that I was seeking was best supported by a qualitative approach, given that such an approach allowed participants to share their understandings, experiences and imaginings with me, in line with the approach proposed by Mason (2002).

In devising this research methodology, I also drew upon my experiences in engineering practice, a practice that frequently calls for consultative and dialogic approaches to engineering problem-solving. I was interested in developing a shared understanding with research participants, supported by a critically informed constructionist approach. I was also interested in participants, in turn, dialogically challenging my views.

As described by Ryan (2015) the interview is 'a process during which meanings and insights are not only brought forth or uncovered but also sometimes produced or generated' (Ryan, 2015, p. 124). I saw the use of open or semi-structured interviews as creating the opportunity to discuss and consider lines of thinking introduced by the interviewee.

As I noted previously, I envisaged that the nature of my research would create the potential for challenging my worldviews and my views on my research theme. I held this belief in the realisation that my history within engineering education and practice has been one of reflective engagement and interaction, followed by reflexive responses. As I note in the opening chapter, I experienced a diverse career in engineering practice, completing projects in several international locations and different cultural settings. I note in the opening chapter, the narrow framing of my undergraduate engineering education, in a manner that undervalued the social domain of engineering. My exposure to differing cultures, meanings and interpretations of engineering practice during my career, informed by my ontological perspective and my political belief system, has led me to this conclusion. It has also informed my view on effective teaching and learning practices, preferring the use of interactive and reflective learning practices as a reflexive response to my previous exposure to the banking system of education (Freire, 1996).

I continue to reflect and reflexively adapt over time, and this has continued throughout my research. In my field research, for example, there was a particular point during the focus group discussion, which challenged my reflexivity considering the ethical dilemmas which my work in the Middle East had presented for me. When I recounted how some of the work in which I was engaged, while in the Middle East, was a challenge for me personally, from an ethical standpoint, some focus group participants pointed towards this being a professional body issue, as opposed to one of individual concern. I describe this encounter in more detail in Chapter 5. In hindsight, in reflecting on this point, while that ethical dilemma sparked my interest in this area of research, the focus group input led me to further reflect on those dilemmas and to question my thinking. It led me to consider whether similar ethical dilemmas are best addressed by the autonomous action of the individual engineer. Alternatively and perhaps, more appropriately, responses might be prompted by autonomous action, supported by appropriate professional body directives, to influence the practice of all engineering members when confronted by similar ethical dilemmas.

In completing my research in this manner, I saw my role as a researcher as being an integral part of the interpretation offered (Ritchie *et al.*, 2013). Because I saw myself as 'inevitably and inextricably implicated in the data generation and interpretation processes' (Mason, 2002, p 149), I, therefore, sought to critically read and interpret the research data in a manner that captured and expressed those relationships. In adopting a critical approach in my research, I also explored potential ideological influences in engineering education and engineering practice. In this regard, Cech (2013) posits that cultural ideologies shape how engineers understand and interpret their work and their role in society:

> An integral part of the culture of engineering is the promotion of particular ways of understanding society and engineers' roles and responsibilities therein. These specific cultural ideologies shape how engineers understand their own work, their responsibility to the broader society, and what counts as engineering work and what is superfluous to that work. (Cech, 2013, p. 69)

I sought to reveal how engineering education and engineering practice might be positioned to maintain the status quo in terms of the engagement of engineering with society and whether this positioning might be ideologically framed. In considering ideological influences, Cohen *et al.* (2000) characterise the curriculum as being 'ideologically contestable terrain' (Cohen et al., 2000, p. 33). Cohen *et al.* (2000) further assert that ideologies can be treated either as, sets of commonly held beliefs or as, sets of beliefs 'emanating from powerful groups in society, designed to protect the interests of the dominant' (Cohen *et al.*, 2000, p. 33). I was interested in exploring how ideological influences within engineering might shape how engineers understand their work and their responsibility to a broader society.

4.3.1 Pre-Field Research Stage: Critical review of professional body publications

A key aspect of the research is the critical review of professional body publications. Given the importance of the role of *Engineers Ireland,* the professional representative body for engineers in Ireland, my review of pertinent literature included a critical review of documentation produced by the professional body. This critical review involved using NVivo qualitative data analysis software to extract content from the documentation that aligned with the research themes to emerge from my field research.

In reviewing the selected *Engineers Ireland* publications, I viewed them as standardized artefacts, intended for a defined circle of legitimate and involved recipients (Wolff, 2004). In this regard, Wolff (2004) notes that a major part of the reality that is relevant to modern societies is available via documents. In this instance, the intended and involved recipients are members of the *Engineers Ireland* professional body or those aspiring towards professional body membership.

Scott (1990) recommends four specific criteria when reviewing documents in qualitative research:

- Authenticity: as evidenced by documents being both genuine and of unquestionable origin.
- Credibility: that selected documents are free of error and distortion.
- Representativeness: that selected documents reveal evidence of typicality in context.
- Meaning: that documents provide evidence of clear and comprehensible meaning.

I critically reviewed selected publications produced by *Engineers Ireland* utilising the above criteria. Each publication selected is both authentic and credible when measured against the above selection criteria. Each is also representative of a key aspect of *Engineers Ireland* policy, as follows:

- The *Engineers Ireland Code of Ethics 2018:* in becoming a member of the professional body, engineers are required to comply with this code in guiding their practice ethically. As a result, it is an important artefact for consideration.
- *Continuing professional development (CPD) related policies*: the selected CPD policies are instructive in terms of revealing what the professional body perceives to be of importance in framing the professional development of engineers.
- The *Regulations for the registered professional title of chartered engineer:* these regulations provide a reference point in defining the professional attributes that *Engineers Ireland* perceives to be of importance in the formation of the professional engineer.
- The two selected reports, *Engineering 2018: A barometer of the profession in Ireland* and *Engineers Ireland Strategy 2017-2020: A community of creative professionals delivering solutions for society* are both useful in illustrating how the professional body views the profession currently and as a portrayal of how the professional body envisions the future of the profession strategically.

My analysis focused on critiquing how the engagement of the engineering profession with society was represented in these selected publications. Using NVivo qualitative data analysis software, I explored references to societal and community engagement within the range of publications. I also explored the overall direction of policy, in the contexts of ethical positioning. In doing so, the ethical positioning of the professional body and its approach to societal engagement became clear. The contention here is that it was particularly important to develop such an appreciation of professional body positioning, given professional body influences within engineering education and practice. These publications provide a barometer as to how *Engineers Ireland* envisions the appropriate engagement of the profession with society. My objective in critiquing the selected publications was to consider how *Engineers Ireland* might be guiding the professional development of engineers and how the publications might be informing the development of an appreciation amongst engineers of the societal impact of their engineering practice. I include the resulting critique of the *Engineers Ireland* publications reviewed in Chapter 2.

4.3.2 Field Research Stage 1: a critical exploration of the existing situation in engineering education and practice

The first stage of my field research involved interviewing research participants, with interviewees being purposively selected, in an attempt to make sense of the status quo concerning the positioning of engineering in society. I selected eleven research participants with each having a role in either engineering education, engineering professional body representation or in engineering practice (refer to Figure 4-1 below).

Participant Ref.	Role	Location	Gender
Participant #1	Undergraduate Student	Ireland	Male
Participant #2	Academic	UK/Ireland	Male
Participant #3	Academic	Ireland	Male
Participant #4	Practitioner	Ireland	Female
Participant #5	Institutional Body	UK/Ireland	Male

Participant #6	Practitioner	Ireland	Male
Participant #7	Postgraduate Student	North America	Female
Participant #8	Academic	North America	Male
Participant #9	Practitioner	Ireland	Female
Participant #10	Practitioner	Ireland	Male
Participant #11	Undergraduate Student	Ireland	Male

Figure 4-1: Interview Participant Selection

I invited research participants to contribute to my research, based on my judgement of their typicality within the profession (Cohen *et al.*, 2000). I purposively selected participants with a view of the features or characteristics that each brought to the research. I include a brief biography for each participant in Chapter 5. I was interested in exploring views from a wide range of participants, intending to develop a shared understanding with those participants of the ethical positioning of engineering in the context of contemporary societal engagement.

This exploration included a development of understandings from both engineering education and practice in Ireland and also, with international participants, to develop a wide appreciation of perspectives in this regard. In the selection process, I wanted to ensure balanced student and academic participation from within engineering education together with obtaining contributions from engineering practitioners. Gender representation was reflective of the current gender breakdown within engineering and, as a result, the majority of participants were male.

I conducted a series of semi-structured interviews with the selected research participants to gain an understanding of how each perceived the societal positioning of engineering. I entered the field with a series of open questions (Appendix 2), informed by my dialectic understanding of the positioning of engineering in society. Each of these interviews was a dialogic interaction, openly and reflexively considering the thoughts and ideas of each participant and the themes which emerged in that dialogic interaction. I was interested in co-creating a shared understanding of the societal awareness of engineers and also, in revealing any potential deficiencies in terms of that societal engagement. In the interviews, I also focused on exploring the potential influences of power and ideology within engineering.

4.3.3 Focus Group Participation

On completion of stage 1 of my field research, including the coding of interview findings (refer to Section 4.4.1), I convened a focus group to consider these initial research findings (field research stage 2). I met with focus group participants to evaluate key findings from the first stage of my field research. Together with evaluating the initial research stage findings, I also asked the focus group to consider whether there might be a need to realign engineering education to respond to the themes raised in the initial research findings.

My reasoning in creating the focus group to support this research stage was to afford participants the opportunity to interact with each other rather than with me as the interviewer (Cohen *et al*., 2000). My intention in using a focus group setting was that the focus group would generate discussion and, in so doing, reveal both the meanings that participants read into the discussion topic and how they individually and collectively negotiated those meanings (Flick, 2009). My further expectation was that, in that dialogic interaction, insights might be revealed that would otherwise not have come to light (Cohen *et al.,* 2000). The nature of the focus group discussion and insights revealed as a result of that discussion are further explored in Chapter 7.

The focus group was composed of five academics engaged in engineering education within the higher education community in Ireland. Participants were again purposively selected to broadly consider the initial findings from the first stage of my field research. The focus group was composed of male and female academics, all of whom have experience relating to engineering education in higher education in Ireland. A brief biography for each participant is included in Chapter 5.

I chose to engage academics in this field research phase as I see academics as the agentic change drivers within engineering education. Academics provide a direct line of influence between students and management and, as a result, they were well-positioned to consider key findings from the first field research stage. They were also well-placed to propose potential change initiatives within engineering education, given their positioning as both teachers and potential co-creators of curriculum change.

My objective was to again dialogically engage with focus group participants to consider the themes that emerged from the initial field research stage. I was also interested in exploring whether the group might then consider whether research findings provided a basis for considering an agenda for change within engineering education.

The themes that arose from the initial stage of my field research pointed towards the need to embrace a more integrative philosophy within engineering education and to more openly acknowledge and embrace the interaction of engineering practice with society. Allied to this was an identified need to develop a more holistic learner awareness of the impact of engineering decision-making on society. I was interested in openly exploring whether focus group participants might share these views and, if so, whether we might collectively envision an agenda for change to address these perceived deficiencies in engineering education.

4.4 Research Data Gathering and Coding

Interviews were held interviews either online, via a *Skype* platform, which included video and audio linkage, or were conducted face-to-face. In reflecting on those interviews, it is interesting to contrast the face-to-face and the online interviews. Mason (2002) describes the exchange of dialogue in qualitative interviews as involving one-to-one or group interactions, with face-to-face interviewing being conducted in a relatively informal conversational style, as opposed to a formal (written) question and answer format. Based on my field research experience, I would go further in distinguishing between my face-to-face and online interviews. In what was a surprise to me, I found that the Skype interviews introduced a further informality to the process which, at times, actually promoted more open and engaging conversation.

Following each interview, I then prepared a transcript directly from the audio recording of each encounter. I viewed it as particularly important to personally transcribe all interviews. In this regard, I share the view expressed by Cohen *et al.* (2000) that this is a crucial step as, given that each interview is a social encounter, there is the potential for data loss, distortion and the reduction of complexity during the transcription process. Committing the time to transcribe each interview provided me with an opportunity to engage deeply with each recording. In this regard, I concur with Flick's (2009, p. 302) view that documenting an interview 'detaches the events from their transience' and that 'the researcher's style of noting things makes the field a presented field'. As a result, I endeavoured to protect the richness of each interview, respecting each as a dynamic social encounter.

As I noted previously, I believe that within a qualitative paradigm, reality is socially constructed. As a result, I concur with Creswell's (2000) assertion that it is important to check on how accurately research participants' realities have been represented in the final account. As a result, I shared transcripts with each participant soon after conducting each interview. I commenced the coding of a transcript following the review and acceptance of that transcript by the research participant. I include a table presenting the timelines between interview invitations, interviews, transcriptions and acceptance of transcripts in Appendix 1.

4.4.1 Coding and categorisation: thematic coding

I used thematic coding as a method of identifying, coding and interpreting patterns of meaning or themes within my research findings. As a method, Braun and Clarke (2006) note how thematic coding can provide a systematic procedure for generating codes and themes from qualitative data. Braun and Clarke (2006) also note that thematic coding can be conducted within both realist/essentialist and constructionist paradigms, with a different focus and outcome in each instance. With the former the experiences, meanings and reality of experiences are reported, whereas with the latter, account is taken of the ways in which events, realities and meanings are shaped by discourses operating within society.

This form of coding has been identified as an appropriate method for analysing a research issue focusing on the social distribution of perspectives on a phenomenon or a process (Flick, 2009). My underlying assumption is that a reality that was once plastic can be captured with time as it is 'shaped by social, political, cultural, economic, ethnic, and gender factors' (Guba and Lincoln, 1994, p. 110). In that sense I was also interested in exploring shaping influences on participants as a means of developing a deeper understanding of their positioning in relation to the research themes being considered.

I collected research data using methods to permit comparability while, at the same time, remaining reflexively open to expressed views relating to those topics. I prepared a standard list of research questions in advance for each participant grouping. I formed specific questions for engineering students, academics involved in engineering education, engineering practitioners and, engineering professional body representatives (Appendix 2).

In coding the qualitative data gathered, I saw my role as one of interpretation, viewing that interpretation as being more of a reactive interaction with the decontextualized data (Cohen *et al.*, 2000) as opposed to a completely accurate representation of that data. I coded the transcriptions both individually and then collectively to identify the emerging themes that I had interpreted as being present across the data. I categorised this as the open coding stage of my field research. In adopting this approach, I was aligning with Cohen *et al.* (2000) and their interpretation of coding as being a means of translating interview question responses and respondent information into specific categories for analysis.

I used NVivo qualitative data analysis software in coding my research findings. I applied thematic coding in multiple stages. The first stage was to define the participant group; to do so, I first prepared a short biography for each participant. This provided information concerning each research participant as it related to my topic of research. In this summary, I included noteworthy contributions provided by each participant concerning the research question. As a result, this then facilitated a detailed exploration and understanding of the central research themes

(Ritchie *et al.*, 2013). In particular, I was interested in exploring the specific experiences of participants both individually and then collectively and thematically as those experiences related to my research question.

I coded participant interview transcripts, and in the process, created a series of open codes, preserving the meaningful relations that the respective participant addresses in the topic of the study (Flick, 2009). I coded each participant interview on a line by line, sentence by sentence basis to break down and understand the text and to attach and develop categories (codes) and put them into an order (Flick, 2009). I also similarly coded the focus group transcript. A copy of the codebook, including the open coding categories to emerge from this research stage, is included in Appendix 3.

Open codes emerging from the coding of participant interview and focus group transcripts were then arranged thematically (Appendix 4). In presenting field findings, thematic coding provided the corroborating evidence collected via interviews and focus group findings, with themes emerging from my research findings thematically linked back to my research question. In taking this approach and in aligning with social constructionist principles, I intended to generate ideas, propositions and theories from the data (Mason, 2002).

4.4.2 Triangulation and validating the data

I used triangulation as a validity procedure in seeking convergence amongst the different sources of research information that I had gathered, to form research themes (Creswell and Miller 2000).

I sought convergence in findings in the research data by gathering that field data in sequential stages. Findings from stage 1 of my field research, represented by the series of semi-structured interviews, were first open coded and then thematically coded. The themes to emerge from stage 1 were then further considered by the focus group in stage 2 of my field research (Appendix 5).

Considering the stage 1 findings in a focus group setting provided an opportunity for me to determine if there was convergence in seeking an agenda for change in the context of the positioning and treatment of ethics in engineering education. The focus group openly discussed and reflected on the findings to emerge from the first field research stage in considering that possible agenda for change.

4.5 Reflections on the Limitations and Delimitations

I note in the opening chapter, how I commenced this study with the aim of creating an agenda for real change in engineering education and practice, intending to recognise the social dimension of engineering as a response to the problematic aspects of engineering education and practice alluded to in the study. While I had not developed a full theoretical perspective to frame my positioning, I held a view, informed by my practice, that engineering was narrowly framed in a manner aligned with the traditional engineering ideology considered in Chapter 3. I noted in that chapter how this appeared to be so self-evidently apparent to me that I assumed that others would hold similar views. As a result, within the shift in trajectory in the study lies an inherent limitation. The study outcome now creates the basis for continuing an important conversation as opposed to, what I would have initially predicted, as being the basis for a change agenda. However, this does not diminish the significance of the research; as it creates a basis for continuing an important and potentially influential conversation, in shaping the future of engineering and its engagement with society. As a result, the importance of the outcome of this explorative study remains undiminished.

Finally, the approach to my study included one particularly noteworthy delimiting characteristic, with the focus being intentionally directed solely towards engineering education and practice in Ireland. I make no generalised claims to the international applicability of the findings.

4.6 Ethical Considerations

Consistent with my overall research theme, it was important to me to ensure that there was a rigorous ethical underpinning to my research. As a result, I placed a key focus on carrying out my data generation and data analysis and on ethically framing my research questions. I share the view expressed by Mason (2002) that this is easier said than done, as I saw that my research project involved a range of competing interests which I describe below. In negotiating this challenge, I found it useful to consider the core purpose of my research and those parties that would potentially be affected by my research. I also considered what the implications might be for those parties when framing my field research (Mason, 2002, p. 41).

In considering the purpose of my research from the ethical, moral and political standpoints, I was conscious of the positioning that I brought to my research. I was interested in engaging in this area of research because, based on my experience in engineering practice, I observed that the impact of engineering decision-making on society was undervalued or misunderstood within the profession. However, as I noted in the opening chapter, this is a contested idea within the profession. As a result, I was sensitive to the fact that research participants may have regarded the advancement of my philosophy as being overtly political, given the potentially divergent range of participant beliefs and interests. In the event, no participant raised this as a concern. I regarded it as important, therefore, to frame and pose my questions as neutrally as possible, in order to openly encourage authentic participant responses and to reflexively consider those responses. I include the research questions posed to each representative group in Appendix 2.

4.6.1 Conflict of interests and power relations

As I fulfil a management role in academia, I saw that there was the potential for me to create a potential conflict of interest, given that I would be interviewing students and lecturers. To avoid that potential conflict of interest, I did not invite any lecturing staff with whom I interacted from a management perspective or any students with whom I engaged from a teaching perspective, to participate in the semi-structured interviews.

I recognise the potentially distorting effects of power and, as the interviewer, I recognised that I was potentially exercising power over the interviewees in and after the interview (Mason, 2002). I framed the interview agenda, prepared and posed the interview questions and then controlled the data gathered. As a result, I recognised the responsibilities that I held towards research participants in considering those power-related influences. That required me to think through the ethical implications of the interaction with research participants, from beginning to end, to mitigate the effects of those potential sources of power insofar as was possible.

In mitigating the potential impact of power associated with venue selection for interviews and the focus group, I conducted each in a neutral location, with a neutral meeting room venue selected for this purpose. Additionally, after I had completed the transcription of each interview, the transcript was shared with the interviewee.

Ritchie *et al.* (2013) note that, together with the researcher's conduct being of relevance, ‘a broader cross-perception between participant and researcher also takes place’ (Ritchie *et al.*, 2013, p. 65). As a result, Ritchie *et al.* (2013) point towards a need for the researcher and participant to be 'matched' on key socio-demographic criteria. In response to this consideration, each research participant had some engagement with the engineering profession and had some experience of the research issues under consideration.

4.6.2 Informed consent and confidentiality

Mason (2002) points to the difficulty in ensuring that participant consent is informed consent and based on the inherent difficulties in obtaining consent from participants. As a result, Mason (2002) notes that researchers should ‘take the issue of informed consent more rather than less seriously, in ensuring that they adopt a stringent moral practice’ (Mason, 2002, p. 82).

In adopting the stringent moral practice that Mason (2002) advocated, I approached my research intending to respect the dignity and rights of fellow research participants fully. In adopting this moral stance, I saw my approach as being aligned with my research theme, advocating that engineering practice should similarly respect the dignity and rights of all in society.

I regarded it as important to ensure that sufficient and adequate information was provided in advance to prospective research participants to provide a basis for informed and voluntary consent. All research participants received an information sheet and a consent form (Appendix 9) before their research participation. Before then commencing the interview, I reviewed the consent form and information sheet with the participant. In each instance, the form was then signed by both parties once I had conducted that review.

In discussing the right to privacy within research, Cohen (2000) describes this right as one which ‘may easily be violated during the course of an investigation or denied after it has been completed’, as ‘at either point the participant is vulnerable’ (Cohen *et al.*, 2000, p. 61). To ensure the maintenance of a right to privacy for each participant, specific details, including names, addresses, institute names, etc. were redacted from my thesis. To further protect the identities of research participants, this information, together with any other information that might impact on participants’ right to privacy, was anonymised in interview transcripts.

4.6.3 Follow up with participants

The principle of informed consent arises from the research participant’s right to freedom and self-determination (Cohen *et al.*, 2000). I see this right to freedom as being a key condition of living in a democracy. I share the view expressed by Cohen *et al.* (2000) that when restrictions and limitations are placed on that freedom, they must be justified and consented to within a research environment. In respecting each participant’s right to freedom, each could withdraw their contribution to the research up to, during and after their participation. They were each reminded of their ongoing right in this regard when requested to review their interview transcript.

On completion of the interview or focus group, each participant reviewed the transcript and was allowed to change any aspect of the transcript or to redact any information with which they were not happy. As it transpired, there was no requirement to change transcripts and, all participants continued to stay engaged with the research. Also, they were encouraged to ask questions about the study at any time during and following the interview or focus group session. It was also made clear to all participants that they retained the right to have their transcript withdrawn; as a result, the data could be removed from the study at any time throughout the research.

4.6.4 Data management, storage and retention

Research data are stored in a safe, secure and accessible form. They will be held for an appropriate length of time, to allow (if necessary) for future reassessment or verification of the data from primary sources, as outlined in *Maynooth University's Research Integrity Policy*. Only my supervisor and I have access to the personal information and data collected from research participants. Electronic Information sheets and consent forms and data collected have been encrypted and stored on a secure server at Maynooth University. Hard copy information sheets/consent forms and data collected are now held securely on campus at Maynooth University.

Primary data have been anonymised and will be retained for ten years from publication. This information is reflected in the consent form and information sheet. Aside from primary data, paper-based data have been destroyed by confidential shredding or incineration, and electronic files will be deleted by overwriting.

4.6.5 Observance of ethical codes

A key part of my research was the conducting of a critical analysis of the *Engineers Ireland Code of Ethics 2018* (2018a). As a result, I viewed it important to fully adhere to the requirements of that code of ethics in my research. The code requires that 'members behave with integrity and objectivity in their relationships with colleagues, clients, employers, employees and with society in general' (Engineers Ireland, 2018a, p. 2). This ethical requirement has guided my research approach throughout.

In conducting my research, I also followed the Code of Ethics produced by AERA (American Educational Research Association, 2011). I have fully supported the primary goal of this code of ethics in my research by maintaining 'the welfare and protection of the individuals and groups' (American Educational Research Association, 2011, p. 146) who participated in my research.

4.7 A Note on the Research Journey

In perhaps mirroring what I am calling for in terms of engineering repositioning, as I allude to earlier this study has been informed by a praxis-based approach (Freire, 1996). I reflexively approached my review of the literature, conscious of my role in the interpretation of the data (Mason, 2002); an interpretation heavily influenced by my career in engineering practice. My engagement with the literature and my exploration of professional body positioning informed my developing perspective, aligned with my experience in practice that the engagement of engineering with society was problematic and potentially provided a basis for a change agenda. There is perhaps, in that, a sense of the positioning adopted by default by engineering, aligning with the *traditional engineering* ideology conceptualised in Chapter 2. Perhaps, in hindsight, I commenced the fieldwork informed by an expert-based authoritative perspective, entering the field with the outlines of an answer to hand. This quickly changed however in the dialogic engagement with research participants.

My reflexive positioning continued throughout the field research stage: as a qualitative researcher, I was aware of the fact that I could not be an objective, authoritative, politically neutral observer standing outside of my research (Denzin and Lincoln, 2011). My views changed over time as I commenced fieldwork and engaged dialogically with research participants. I adopted a reflexive approach in responding to the evolving conversation. I allude to this changing perspective in some detail in the opening chapter. I note how, in setting out to complete this research, I had anticipated that it would be a relatively straightforward dialogic engagement within the engineering community, in considering a reframing of the ethical positioning of engineering education and engineering practice. However, the challenges and barriers encountered at an early stage of the study transformed the nature of the research. Indeed, those challenges and barriers might be regarded as symbolic of the current positioning of ethics within engineering education, as will become apparent in the analysis of the data in Chapter 6.

Stage 1 findings are represented openly and transparently in Chapter 5. As I considered how to present findings, I reflexively remained faithful to the context of my research and, to the views of the research participants, I was representing in the findings. It posed the challenge to ensure that the interpretation of findings represented, not only my views and interests as a researcher but also the interests of those who participated in the research (Denzin and Lincoln, 2011).

In adopting this reflexive approach, the trajectory of the study has changed considerably over time. I note in the opening chapter, how I commenced my research convinced that there was a self-evident need to reposition engineering towards adopting a social responsibility approach to engineering education and practice, to engage actively with global risk society dilemmas. However, a tension emerged in the field research between participants, whose contributions were more heavily influenced by substantively rational positions and those, particularly in the focus group, whose views appeared to be informed primarily by instrumental rationality (Weber, 1968; Ritzer, 2001). In recognising this tension, the trajectory of the study changed, leading to the research becoming more explorative.

4.8 Conclusion

In this chapter, I have explained the rationale for my selected research methodology and methods. I describe how I viewed the knowledge that I wished to explore in my research as being subjective. As I note in the chapter, I adopted a qualitative approach in conducting the study as the kind of knowledge that I prioritised related to the understandings, experiences and imaginings (Mason, 2002) of research participants in their consideration of the research themes. This approach was particularly important given the nature of the conversations; I was seeking a wide range of viewpoints and perspectives concerning the treatment of ethics within engineering under the sustainability guise which underpins this research.

I explain in the chapter how critical theory is the ontological position that has informed the research. I describe the importance, in my epistemological approach, of maintaining a reflexive position, by embracing both the positivist and social constructionist approaches in bridging the engineering and the sociology worlds in my research. This has been a key feature of this study; the changing nature of the research challenged my reflexivity. But the contention here is that the research has been enriched in the reflexive engagement with the challenges presented.

In the next chapter, I consider findings to emerge from the first and second field research stages, represented by a series of semi-structured interviews followed by a focus group, convened to consider themes to emerge from the individual interviews. Findings are collated thematically and the research themes to emerge from this analysis form the structural basis of the data set then analysed in Chapter 6.

Chapter 5: The Treatment of Ethics in Engineering - views from the field

5.1 Introduction

This chapter presents the findings to emerge from the first and second field research stages. The first field research stage involved completing a series of interviews with a range of participants involved in a variety of roles in engineering education and engineering practice. The second field research stage then involved a consideration of the themes to have emerged from the first stage, within a focus group setting.

In Chapters 2 and 3, I consider literature covering the treatment of ethics and social responsibility themes in engineering education and practice. In this chapter, I present research participant contributions relating to these themes. I begin the chapter by providing a brief biographic outline for each research participant. As previously mentioned, I purposively selected participants representing a wide range of viewpoints within engineering. The participant cohort selected included (3) engineering students, (4) engineering practitioners, (8) academics and a professional body representative.

The first field research stage focused on exploring how research participants viewed the treatment of ethics and social responsibility, within engineering education and engineering practice. This exploration also included a consideration of participant views on adopting what might amount to a more expansive social responsibility approach within both areas. This field research stage was then followed by a focus group consideration of the initial emerging themes.

5.2 Research Participant Profiles

PT01: Student, Ireland:

PT01 was a final-year male student in the field of civil engineering in an Institute of Technology (IoT)[14] in Ireland. This participant brought an interesting insight to the research and particularly highlighted the importance to him of a work placement he completed within his course, in terms of providing him with an insight into the potential impact of his engineering practice on society:

> Just in relation to the work placement then I was working in [city name redacted], I know that there was a big regeneration project going down there and [company name redacted] were involved. There was a master plan or something going on there like, and I know that they had to deal with people, trying to get them out of their houses that they had been in all their lives trying to re-house them I suppose or put them somewhere to re-generate a bad neighbourhood leading to a lot of crime and things like that. I suppose it's always conflict there when there are people involved in it.

PT01 noted that ethics was broadly covered within his course, in a module called '*The Engineer in Society*' and that the ethics theme was also referenced in other modules throughout the course. In a further contribution, PT01 noted his assertion that ethics was narrowly framed around engineering practice and the regulatory environment within which engineering operates.

> No, it would come in a lot of places. We've talked about ethics in things, good practice regulations construction regulations, the environment, in highways, in structures it's always there really not just in *The Engineer in Society* module.

[14] An Institute of Technology or IoT is a type of higher education college found in the Republic of Ireland. There are currently a total eleven colleges that use the title of Institute of Technology. IoTs were created from the late 1960s and were formerly known as Regional Technical Colleges.

PT 02: Lecturer, United Kingdom/Ireland

PT 02 is an experienced lecturer based in a higher education institution in the United Kingdom/Ireland region. This academic is engaged in engineering education and bought a very interesting insight into the engineering educational experience, based on his background in sociology and his extensive research in this area:

> But I have a very strong sense that there is an overriding culture within engineering, which pretty much shapes how all the disciplines act and how the people within those disciplines are educated. It's very much focused on things like the technology, the maths, the science and so on and I think that the social dimension doesn't feature enough in all of that you know.

This participant was particularly interested in considering a reframing of engineering education, which he believed to be too scientific, to introduce a more integrated approach linking the scientific, the enterprise/business and the social paradigms.

PT 03: Lecturer, Ireland

PT 03 is a relatively new entrant to academia and lectures in an IoT in Ireland. Having worked as an engineer in mainland Europe, he has recently returned to Ireland to focus on his preferred career pathway in teaching and research:

> It feels good to get good professional experience to keep everything relevant. Also, international experience gives a good broad perspective. But fundamentally, I prefer the academic side.

This participant highlighted the distinction between the various professional imperatives within engineering practice and the dominant technical focus in engineering education:

> The students, in the execution of their courses, they emphasise more on the technical aspects. So they are here to do technical subjects and then the kind of, professional modules take a secondary aspect.

PT 04: Engineer with broader STEM-related interests, Ireland

PT04 is a qualified Irish engineer who has chosen to combine creativity with science-related topics in her professional work. Her family background was a significant influencing factor when she chose to study engineering as she may not have opted for engineering otherwise:

> Yes, so I grew up in a very technical family, science and information was very much a big part of who we were in terms of how we communicated together. Dad was in engineering, he didn't have a degree but that in effect, that was what his job was. He worked in manufacturing for many years…We were a big science fiction family, very confident around science and numbers. I probably wouldn't have done engineering if he hadn't highlighted that we could do it.

With her diverse range of interests, this participant noted how she felt stifled within engineering at times:

> And I did enjoy it, but sometimes I would be a little bit overwhelmed by the lack of any sort of personal input into anything. You know it was always very much results-focused in terms of…there was a number usually and that was usually all you ever had to do in an exam or, you know, if you were writing up lab results or something it was just that.

She describes herself as being drawn towards the arts after finishing her engineering studies because she could not see somewhere in the middle between both disciplines. She also noted the importance of that arts background in supporting an appreciation of the human interface within engineering:

> I was doing one of these graduate programs relating to space, and I was dealing with engineers and scientists. I was there to cover the arts aspect even though I am more than qualified as the engineer. But it was funny that they were putting me in a box, well they couldn't hear me!...they resisted and resisted and it was only when we put the presentation together that they all came forward and really appreciated what I had shown them…they had never understood how important it is to be

> human within a context if you were trying to communicate technical information, so that was a big learning for a lot of them. But it's kind of incredible how far they had to come in order to let me do that!

PT05: Engineering Professional Body Representative, UK/Ireland

Having practised as an engineer previously, this participant now fulfils a role within a professional engineering body in the United Kingdom/Ireland region. The participant brings an interesting insight into engineering education and engineering practice, as a result. He defined the role of the engineer as follows:

> The role of the engineer in society is bound up as to what people think engineers do and there's not a huge understanding, I think in general of that. So, I think the role of the engineers is to make life better. And I know that that's a very general term, but if you do that; if you are a civil engineer or electronics, if you just make life better and to use the medical term, do no harm, then I think that's a good starting point.

While pointing towards the improvement in addressing ethical themes in engineering education, PT05 also pointed to engineering as potentially having forgotten the human dimension of engineering practice.

PT 06: Practising Engineer, Ireland

This participant has had an extensive career in engineering practice having qualified in civil engineering in the 1980s. In his current role, he focuses on community engagement within a large engineering organisation. PT06 provided an interesting insight into a recent initiative to raise societal awareness within his company:

> I think actually on something that this company is doing…starting out to do is to try and align our business with the United Nations SDGs you know the Sustainable Development Goals… recently we produced a paper; I haven't even managed to read it yet, it was produced out of [city name redacted], on developing cities that are child-friendly.

In the interview, he drew an interesting distinction between ethical practice and morality when discussing the theme of ethical dilemmas:

> People will defend the interests of the institution that they are working for and they may be willing to kind of bend their own moral principles slightly more than they would if it was their own dealings, you know what I mean? There are dozens of examples of that where people who are probably good people, are definitely not because they're trying to protect the institution. They are, you know, when they go to bed at night, they must realise that what they are doing isn't really morally right. Now they can probably defend it from an ethical point of view technically, but morally that isn't the right thing to do.

PT07 Postgraduate Engineering Student, North America

This research participant is a PhD student in civil engineering at a university in North America. She is currently based in the Global South and is conducting a research study to understand and mitigate risk for infrastructure projects in developing countries. In describing her postgraduate studies, she points to the focus on engineering within society:

> Our whole focus is like social impacts and making sure that the social aspect is there and building it within engineers because a lot of engineering disciplines typically do not include any social aspects, just technical.

Later in this chapter, in pointing to the impacts of engineering on society, this participant provided an interesting example of how a straightforward engineering project can have wide-ranging societal impacts.

PT08: Academic, North America

This participant is an experienced lecturer in a university in North America. Together with teaching within the mainstream engineering curriculum, this participant also teaches courses relating to global poverty and politics, and in other related subject areas. In talking about his work, he noted how he straddles the social sciences and engineering worlds:

> So, I have this sort of split identity and the institutions that I worked within don't have a lot of good capacity to handle such interdisciplinarity. They love it, they talk about it, and they are interested in it; but they have a really hard time, and I will say that I suspect that this is a somewhat exacerbated problem in America versus the rest of the world. But I think that they have a really hard time mixing, you know, some of the things that we're going to talk about; ethics and whatnot with more technical fields.

Similar to PT02, pointing towards the need for a more integrated approach to engineering education and practice, this research participant suggests that the conventional segregated approach is problematic:

> I think that our identities as members of society need to be integrated with our identities as engineers. I think often they get segregated. Like here's where I do my engineering work and here's where I do my volunteering work at the local, you know, homeless shelter. And I think that that segregation is causing problems in the way that we carry out our professional work. Because we don't think about our professional work as being tied to those things, we treat them as separate.

PT09: Engineering Practitioner, Ireland

This research participant is an early career practitioner working within the energy sector in Ireland. She pointed to the benefit of a work placement that she completed during her course, in counterbalancing what was for her a very academic course. It also provided very useful insight for her concerning engineering practice, as she had no family influences in this regard:

> And it was good as well during the four years I was able to do a work placement, all really organised and pushed by the university. So that was quite useful for someone who doesn't have any connections in engineering prior to that, it was good for me. And, you know, I got a job from that internship, so that was very useful.

In pointing towards the important need for positive community engagement in her work, this participant highlighted the need to be respectful in that engagement process:

> I suppose I touched on it already, it is becoming more and more important in my work for community engagement. And I suppose there is a kind of an ethical and moral backing to that as well. That is having respect for that engagement with the community on energy projects.

PT10: Engineering Practitioner, Ireland

This participant is a highly experienced engineer and entrepreneur and holds a leadership role in a company operating in the energy sector in Ireland. In contrasting the positive and negative aspects of engineering practice, he highlighted creativity and innovation as the positives, with financial constraints being a source of frustration:

> I don't know about the financial pressures that we had. But from the innovative and the creative part of the work and that and even right the way down to path laying and getting stuff ready. Yeah, if I was doing it all again, I would be…I have to admit that I wouldn't want to be anywhere different.

In speaking of morality and ethical dilemmas in engineering practice, this participant describes how he walked away from engineering contracting during the boom years in Ireland for what he believed to be a highly unethical practice that he witnessed, at the time:

> During the boom here, the amount of rigging of tenders and all of this was crazy. Actually, it became the norm, and some of the engineering consultancy practices would be…would have been some of the drivers behind that. So, you knew that you had to engage in that to get work and stuff. It was crazy; I am just telling you it was just…I stepped out of it.

PT11: Student, Ireland

PT11 is a civil engineering student in an IoT in Ireland. This participant pointed to having had an aptitude for mathematics from an early age. He indicated that although computer programming was his first choice, he switched to civil engineering, as computer programming proved too abstract for him. In contrast, he believed that civil engineering provided an opportunity for him to see the direct effects of what he was doing. This participant conveyed an awareness of the challenges of making good ethical decisions as an engineer:

> But realistically, in the real world, you're going to come into situations that are a lot of hazy grey. There might be situations where there is no good answer, and you have to choose between the lesser of two evils.

He also conveyed an aspirational sense of wishing to use his talents to benefit society in general:

> And I think it might need to be highlighted more, that perhaps the role of the engineer is not to just get a good job with loads of money. I think it should really be viewed as more…this job benefits everyone. I think like personally when I was working in practice; I was working on a lot of public projects. I was working on social housing and schools, and I felt great because I felt like this is actually going to help people. I mean I am only doing a little bit of it, but the little bit that I do is definitely going to help somebody somewhere.

Focus Group Participants

The focus group, purposively enlisted to consider the above themes, was composed of male and female academics, all of whom have experience relating to engineering education within higher education in Ireland:

PT12: Academic, Ireland

PT12 is a chartered engineer in the field of civil engineering. She has an extensive background in teaching and practice in civil engineering and now teaches full-time in higher education within the IoT education sector.

PT13: Academic, Ireland

PT13 is an early career academic with a background in structural engineering and hydrology. He has an extensive research background and now combines teaching practice with his research interests within both the university and IoT education sectors.

PT14: Academic, Ireland

PT14 is an electronics engineer with an extensive background in research, teaching and practice in this field. He has an extensive research background within both the university and IoT education sectors and now combines teaching practice with his research interests within an Irish IoT.

PT15: Academic, Ireland

PT15 is a chartered civil engineer with extensive experience, spanning Ireland and international locations, both in practice and in academia. He now teaches within both the university and IoT education sectors.

PT16: Academic, Ireland

PT16 is an early career electronics engineer with a background in research and teaching in this field. Her experience, from a research and teaching perspective, spans the university and IoT education sectors.

5.3 Thematic Analysis of Participant Interviews

In the manner described in the previous chapter, research participant transcripts provided a basis for open coding. A copy of the open codebook representing the output of this initial coding phase is included in Appendix 3. I then arranged the open coding thematically and the research themes to emerge from this analysis form the structural basis of this chapter. The themes to emerge (Appendix 3) from the open coding stage included:

- ❖ ***The Exploration of Ethical Arrangements in Engineering Education*** [participant insights concerning engineering education and specifically relating to the treatment of ethics and social responsibility in their education].
- ❖ ***Ethics within engineering practice*** [commentary on how participants perceived how ethical considerations might inform their engineering practice].
- ❖ ***Community engagement and societal awareness in practice*** [participants' perceptions of social responsibility positioning and community engagement of engineering].
- ❖ ***A consideration of alternative educational approaches and potential barriers to change*** [a consideration of opportunities for curriculum change to foster a heightened awareness of the broader ethical dimension of engineering practice together with an exploration of potential barriers that might prevent change].

The positioning of ethics and social responsibility in engineering, both from the educational and professional practice standpoints, is explored within each of these thematic domains in this chapter.

On completion of the thematic coding of participant interviews, the themes to emerge were then considered by the focus group. In the views expressed within both research stages, there was an evident contrast between those who would call for a more aspirational vision for engineering, in terms of embracing a broader ethical approach, with those who would envision a less expansive approach. The contrasting contributions from individual interviews and focus group participants are considered jointly under the above themes, thereby revealing these diverging views.

5.4 The Exploration of Ethical Arrangements in Engineering Education

As will be recalled from Chapter 2, the literature reveals a narrow framing of the treatment of ethics, defined in a manner that reveals narrowly framed ethical perspectives. There is also a focus on compliance with a narrowly framed professional body codes of ethics, with a resulting negating of the broader societal context in which engineers perform their work. In exploring this theme, research participants shared their views regarding the treatment of the ethics and social responsibility related themes.

I first considered the professional body influence in shaping engineering education in Ireland. In considering this point, and in describing the position of power assumed by the professional body*,* in being the single professional representative body for engineers in Ireland, PT02 commented on its influence on engineering programme accreditation in the country:

> *Engineers Ireland* is like a God. I find this really remarkable as an outsider! It has such value, and it's only...it works in contradictory ways because obviously without the accreditation, your programme is in trouble, right, in terms of marketing and getting students and so on, and so forth. But how seriously do they actually take the endeavour of some of the things that *Engineers Ireland* is saying? How seriously they are actually taken on board is another issue I think you know. But they do realise that without *Engineers Ireland*, they're in trouble you know.

By comparison, in discussing the less powerful positioning of accreditation bodies in North America, PT08 noted how their influence is somewhat weakened when interfacing with larger universities:

> …from the accreditation boards, they have requirements around ethics. I don't understand how [name redacted] gets away with it, because they don't do them and yet they aren't getting, you know, pulled back. But I think it's hard for those boards to push on a university like [name redacted] to make those demands. So, there's that challenge, there are these ethics classes in electrical engineering, computer science and bioengineering but again, universally understood as just not real classes.

This comparatively weakened positioning may result from the presence of several professional representative bodies for engineering in North America. In contrast, *Engineers Ireland* fulfils an overarching role, as the sole representative body for professional engineers in Ireland.

While the professional body influence is strong, the direction in terms of the treatment of ethics and social responsibility in the curriculum is somewhat vague. In describing how ethics might be addressed in engineering programmes, from a professional body perspective, PT05, who fulfils a role within a professional engineering body in the United Kingdom/Ireland region, noted the preference for it being addressed across programme content:

> And I think that our education system has helped a lot. I mean that it has been in the accreditation criteria for about fifteen years now. We are starting to see that it's becoming more…like you can't teach ethics in the same way as you can't teach presentation skills in a module. You've got to have it right across the course, creeping in at all levels. So, it

> becomes ingrained in behaviours. And I think we're starting to see the fruits of that now coming through the system.

In exploring this idea, PT02 notes that higher education institutions are aware of the learning outcomes but are unsure as to how to address them:

> Well, you have this contradictory thing going on in that the schools understand that *Engineers Ireland* requires this ethical learning outcome to be addressed. But they're not really sure how to do it. So, what you find at times of accreditation is you suddenly become important.

PT02 further pointed to confusion within his institution in preparing for a professional body accreditation visit. He noted how he perceived the demonstration of compliance with the accreditation criterion concerning ethics, as being more of a box-ticking exercise:

> And in fact, was it last January 12 months, the [school of engineering name redacted] asked me to organize a training seminar really about ethics and what it was and so on. So, we did that, but there has been no follow-through on that really. I think that there is a considerable degree of 'tick boxing' going on, you know.

PT02 further notes that adhering to the non-scientific accreditation criteria proves most challenging for higher education institutions:

> I mean, let's be honest about it, there is no issue in accreditation with the first three requirements that I can see in terms of the scientific, design and technological content of the programme. I think most of the issues tend to arise in relation to the other three or is it four now. I think there are seven criteria now aren't there? I think that three of them are called non-technical. Although I don't like this language of 'hard' and 'soft' and so on that people talk about, I think that that's very problematic. Most of the accreditation problems I think seem to arise around those three. Because I think the scientific and technological basis of engineering is well established, it seems to me.

While this might be the aspirational vision, at the professional body level, evidence in this research points to the wide adoption of a less integrated approach within engineering education in Ireland.

In considering the treatment of ethics within the curriculum, PT05 pointed to the need for the ongoing adaptation and development of the engineering curriculum, to ensure that the fostering of an appreciation of ethics and social responsibility is not restricted or 'compartmentalized' within one module:

> Again, like I said, it's not something that can be compartmentalized. The problem with ethics and social responsibility is that it is continually changing with creep. So, what was good last week isn't necessarily good this week. So, we just need to equip the students and graduates to know…to be adaptable and that, especially whatever situation they find themselves in to ask themselves a hard question, and if they can answer them, then they can go ahead.

In considering this remark, a contrasting view was expressed by focus group participant PT16 when reflecting on the treatment of ethics, in response to *Engineers Ireland* accreditation requirements, in her particular discipline of electronics engineering:

> But I know in electronics now, *Engineers Ireland* has a requirement that we have ethics as a part of all modules. Basically, they need to be ethics-based. So, we need to consider the ethics in everything we do and how that will impact society.' (Focus Group, PT16)

This consideration suggests that there is a desire to integrate ethical and social responsibility themes across programmes, although the evidence suggests that this is not occurring. In further focusing on the limited treatment of ethics in a particular engineering programme, offered by an IoT in Ireland, PT03 described how, given the workload to be covered in the programme, the ethics content is somewhat restricted, and its significance is potentially missed by first- and second-year students:

> Yeah, so I think that at the moment, because it is quite a heavy workload in the undergraduate course, that it's probably covered sufficiently, but it could be a bit more comprehensive. So, in first and second year, they touch on it, and I've noted that it's a primary learning outcome in one of their main modules; 'Technical Communications'.

> The learning outcome is [to] make ethical and informed decisions regarding the presentation of technical material. But I've also noted that such ethical decisions are linked to maturity. And also, in…there're more in line with executive decisions, so it's hard for the first-year students to grasp this. They see it as just another subject that they are not really interested in because it's not technical. They want to do maths or CAD or projects. So, they are like; this isn't engineering in a sense.

A variety of views emerged concerning the relative benefits of standalone modules versus integrated approaches to the treatment of ethics in the curriculum. In considering the potentially beneficial impact of a standalone module focusing on ethics, PT02 noted the following:

> In relation to the ethical stuff I do think that there is value in having standalone [module] where they are actually exposed to the history as I just talked about, I think that there's a value of exposing them to theoretical ideas about these things, that they are just not applied, that there's a background to these things. They understand…the concept of sustainability, for example, is very poorly understood amongst engineers. So at least, there would be a discussion about what the concept means, and I think that there is a value in that you know, in having standalone modules where that is discussed, whether it's called the History of Sustainability or whatever, Sustainable Development or whatever right. I think that there's a value in doing that.

In this context, PT02 further noted that while there was potential value for engineering students in introducing integrated cross-disciplinary engagement, this did not happen in his institution:

> …the other point I was going to make was this, our system is so structured in a sense, and there is a sort of problem with the way engineers see what engineering students need to cover. There's all this stuff that they have to do sort of thing, you know. So, we have very few optional modules or modules that the students could actually do with other students. To take a module with the social science students or the business students or whatever. And then, as you said a minute ago, then they are interacting with other kinds of people who maybe think differently than they do. But that doesn't really happen around here, you know.

In expressing the opinion that exposure to ethical themes is more useful in later years of study, PT03 noted that, in Year 4, he perceived the students to be more open to engagement with ethical concerns in the context of engineering practice:

> Yes, so I've also noted that in Year 4 in both Mechanical and Civil Engineering, it comes back to some content of ethics in Professional Studies and in the module, 'The Engineer in Society'. And it is a full learning outcome also. And I think at that level it's more appropriate for them to go more in-depth into ethical concerns. Then just following on from that I think there is the question of how the subject of ethics is delivered throughout the programmes.

5.4.1 Programme delivery considerations

In terms of delivery models, PT03 further pointed to a classic lecture delivery model focusing on a review of professional codes of ethics and case studies, as a means of treating the subject content:

> So basically, the way that it's delivered is classic lectures, so it is slides and going through the concepts. And it's actually delivered quite well because we use the professional codes and we also use case studies, many case studies. So, you go through different scenarios with the groups. But often, very often they might be a little bit less engaged in the content, and it can switch to humour and joking as well.

Case studies, focusing on apparent examples of engineering malpractice, or poor decision-making, are commonly used as a means of considering ethical dilemmas within engineering education. PT02 reflected on the benefits of using such case studies as a potential platform for students to discuss ethical issues. However, he did note the limitations of such an approach, in suggesting that it focuses on individual decision making whilst not accounting for the complexity of engineering practice:

> You know, most of the focus in engineering education internationally is on training engineers how to solve moral dilemmas right. Which is fine as far as it goes, the one good thing that I think it does; it sort of teaches people to argue and think about…well on what basis do you consider

whether something is good or bad? So at least it does that. It's not enough and, it's really inadequate in my view because it's very individualistic and it's a bit… it doesn't take into account the complexity of engineering practice.

In providing a similar insight to PT02, PT03 pointed to how case studies were considered in their 'Engineer in Society' module,

> Ah yeah, I mean I wouldn't know it off the top of my head but, I know that we have covered case studies things in that *Engineer in Society* module with [lecturer's name omitted]. You know we talked about people, major projects going, on road projects going on and people not being happy about the projects and going further, going to courts, Supreme Courts. I suppose it goes back to the fact that people are always affected by this, people will not always roll over either like when it comes to their land there might be family values or whatever they're going on. I suppose we have covered stuff like that in this course.

In further considering the delivery model that he was exposed to in his recent education, PT01 described how ethics was addressed in a relatively narrowly framed professional context:

> Yeah well, I suppose we cover that in a module called *The Engineer in Society*. We also covered 'Environmental Engineering' and subjects like that. We also covered 'Highway Engineering' and the EIA and EIS [processes]. Also protecting the environment and the landscape so yeah it was covered, and also in relation to ethics and how engineers carry themselves professionally and keep everything above board.

In providing a contrasting perspective on the treatment of ethics in their engineering programme in North America, PT08 described how only some disciplines had it and in a very limited way:

> The academy; ethics just doesn't show up. There are not ethics requirements for engineers at [name redacted], only some disciplines have it. Those courses are well known for being just a joke; everyone gets an 'A', you show up you talk about...and for example, there's no ethics course in environmental engineering, they have a day where they talk about professional ethics in one of their senior classes. The topic they talked about two years ago; one of my students came like just…her head was exploding. They talked about gossip in the workplace and the ethical implications of that. And I was like oh wow like we are really raising the bar here you know! So, I feel like in the academy, there is no

> serious engagement with ethics. But the academy is little insulated from the real world here in the way that they structure it.

Also focusing on ethics content in undergraduate engineering education in North America, and in aligning with the treatment of the subject in Ireland, PT07 described how the approach was based around seminars and case studies. It primarily focused on safety-related issues as opposed to what she foresaw as being necessary, which involved a more holistic approach towards ethical engineering engagement with society:

> …some ethics seminar series that we had to go through. Specifically, talking about a lot of…so nuclear there's this huge emphasis on safety, especially you know with the different accidents that have happened. So, we talked about a lot of the impacts to the public of engineering work and how to keep the public safe. And even somehow trying to get people involved in trying to communicate what nuclear engineering is so that you kind of dissolve the stereotype and fear around nuclear technology. But it wasn't really talking about how to work with everyone else in your environment. You know it didn't talk about not having...being really cocky and being really overconfident. It didn't talk about trying to be humble and learning from everyone around you to build the best design and to design everything well.

PT07 further highlighted, a narrowly framed approach to ethics within her engineering education:

> And school didn't provide any training for you know so…and there really wasn't that much social or how to work with people. There wasn't anything like that; it was only if you wanted to take it on as an elective. Which I did, some psychology courses like in leadership, but they didn't really help me; it talked about the different learning styles of people and stuff. So, it was like more if I wanted to teach maybe but not…

In also reflecting on the narrowly framed ethical treatment of case studies, PT07 observed that this treatment did not prepare students for the 'shades of grey' type ethical dilemmas that may occur in practice:

> Challenger was kind of the same thing; pressure from management so that they could launch on a certain day even though this engineer is like hey we haven't tested these O-rings at this temperature, I'm not

> comfortable with it. But he got overruled and eventually like stepped down and was okay with it because all of his bosses were in the same room with him and, you know, disagreeing with him saying we have to have a unanimous decision here to launch. … And it kind of makes you go like oh this is a once in a lifetime thing for a rare person and, it's never going to happen to me.

Taking a historical perspective and, in reflecting on my engineering education in an IoT in Ireland in the 1980s, I recall that there was a lack of emphasis on ethics as it applied to the practice of engineering. Similarly, PT10, who, it will be recalled is a highly experienced engineer and entrepreneur, reflected on his engineering educational experience in an Irish Institute of Technology in the 1980s:

> I never remember anything coming into the course…being taught ethics. The one area I remember…once, one guy coming in and giving a talk and he was talking about how important it was for the equipment that you specify and all the rest of that, that it has an implication for 20 to 25 years. So actually, getting that right is really important. Would you believe it, that's the one thing that I took from the whole ethical part of my own education.

Also, in referring to his engineering education in an Irish university in the 1980s, PT06 referred to only one module that addressed the topic to some degree:

> Well I mean like, yeah we had a module called *The Engineer in Society,* and that was given by the head of the department whose name I can't remember now, and it was to do with kind of the bigger picture of being an engineer, and I suppose that was the thing that would've most covered ethics.

It appears that in the intervening time, based on participant contributions, the treatment of ethics within the curriculum remains limited, individualistic and focused on narrowly framed ethical dilemmas.

5.4.2 Focus group considerations: barriers and benefits to curriculum change

Within the focus group, in considering a more broadly framed treatment of ethics in the curriculum, PT12 observed that there is a requirement to consider the broader ethical and philosophical questions to incorporate ethics appropriately within engineering education:

> But I think to encompass ethics properly which is talked about in engineering, and it's talked about in the kind of organisations governing engineering. To encompass ethics properly, you need to be asking the larger ethical questions, the philosophical questions and I don't think that that's addressed at any level of engineering yet.

In considering this point, however, PT13 saw the teaching of ethics as a broader societal and educational issue and not necessarily unique to engineering:

> It's like teaching morality; there is nothing different to teaching engineers morality to any other profession; it is just the application. Like what you describe is a situation that you could easily find yourself in. So, it's…they are broader educational issues

In considering any curriculum change, PT15 pointed to the potential difficulty of adding any additional programme content:

> To do that, you can't just dump an extra ten credits in the programme. You have to decide; okay, this is more important than something else. And we have to drop something and, that's the difficulty. We all think that everything that we teach is really, really important.

As a counter to this suggestion, PT16 noted the fact that with the increased use of learning technology, in the modern classroom, more time can be devoted to the discussion and class interaction activities than might traditionally have been the case:

> Someone was saying, 'what's happened over the years? We used to spend hours in lectures, taking down notes. And a lot of our time was spent taking down notes'. Now students get electronic notes; they're not spending a lot of time taking down notes. So, are we covering more material now then we were before? We have extra time in class, and can we locate some of that extra time to more sociology or philosophy you know…We must have wasted an awful lot of time just writing. I remember spending hours writing.

In summary, the discussion noted the current relatively narrow treatment of ethics and, apparently, in line with professional body accreditation requirements. Some participants expressed the view that the curriculum currently lacked consideration of the broader ethical dimension of engineering practice. The contrasting view was also expressed, however, that to meet all of the current programme learning outcomes, there was insufficient space in the curriculum to add more content and so existing content might need to be dropped to prioritise the treatment of ethics.

5.5 Ethical Considerations in Engineering Practice

In reflecting on the framing of codes of ethics, PT02 remarked on how the requirement within the professional body codes of ethics to meet the welfare of the public is narrowly framed predominantly around safety issues:

> …all of the discussion is about the safety dimension, the health dimension, and there is very little discussion about what the welfare thing actually means. And that takes you into the domain of what you are interested in in terms of social justice and so on. How do you define or how do you determine whether engineers are actually meeting the welfare of the public? Because it is usually seen mainly in terms of the safety issue. So okay, the discussion is about whose problem is being solved, what criteria we are using to solve engineering problems and who benefits from engineering. I think that they are the three, from a social justice point of view they seem to be the key issue as to who benefits.

Describing how the code of ethics informs engineering practice, PT05, who fulfils a role within a professional body in the United Kingdom/Ireland region, describes how the fear of litigation is a primary motivator in ensuring that engineers consult with the professional body in seeking guidance compliance with the code of ethics:

> Okay, well in terms of…at the discipline level, I would see it as do no harm, very definitely. So, in terms of professional practice, in professional practice, it's more your interpersonal skills and cognitive processes rather than the technical bit obviously. And that's where you're dealing with the various stakeholders, be it the public, be it your client…And we do get calls from engineers who are being asked to sign

> off on something by their client. And they seek advice…they can't, in all honesty, sign off on it. And they will make those decisions, so you know people are aware of the responsibilities, I think more so now because there is always the threat of litigation. The carrot is one thing; the stick it usually does help if they see that there is a downside of making a poor decision.

There is a sense of authoritative and bureaucratic influences in this contribution. There is also a sense of the curbing of professional autonomy, with adherence to the professional body code of ethics being of primary concern. In reflecting similarly on the influence of codes of ethics in engineering practice, PT08, who it will be recalled is an experienced lecturer in North America, provided the following contribution:

> But in professional practice, there's a bit more focus on the codes. So that's the ontological [perspective]; here are the rules, follow them, like this is what you have to do.

PT08 further likened adherence to ethical codes of practice within engineering as being akin to 'feeding the robot'. He remarked on how, in his opinion, it becomes a 'tick-box' exercise that ignores the power dynamics associated with engineering decision-making:

> I think what they do, these (ethical) codes of practice is they feed the robot. Check the box, am I doing this and then move forward…What are the ethical implications of being in a position where I might step on someone's toes? I need to be careful where I put my foot down.

PT08 believed that there needed to be more sophisticated conversations around ethics in the context of engineering practice, as opposed to the more narrowly framed adherence to an ethical code of practice:

> I worry that the codes of ethics are arcane and don't enable us to engage in more sophisticated conversations around ethics. And they're also a way of offloading a sense of I need to do the thought work on this; onto a list of rules and requirements. So, I think that there needs to be a little more engagement with why these exist, what they mean, and how might one live this practice a little bit?

In a contrasting observation, PT03 expressed the view that engineering codes of ethics provide a guiding roadmap for good ethical practice:

> I would agree and say that they are quite effective because they offer a very definitive first port of call on where to go. We all love top ten lists, and it's usually a list of ten, and it's very inclusive. So, you can use it and identify one aspect and then you can expand on that with examples. So, throughout the codes of ethics, it touches on the relationships that the individual engineer will be faced with, so that's with colleagues, clients, co-workers.

Interestingly, PT03 viewed the code of ethics as a *guiding* roadmap. From a professional body perspective, PT05 noted how there is no legal enforcement of the code in Ireland:

> So, it does work; it does work. But I think part of the problem with the professional code is that we have no legal enforcement of it. So, it's our own code, but you know we can say that you have been a terrible engineer you know, you're kicked out. You can still work [as] we can't impose a fine, for example. So, remedies are very limited.

The contrast in contributions provided by PT08 and PT03 was quite stark, with the former envisioning a more widely framed ethical positioning whereas the latter's vision was more narrowly focused.

PT02, who it will be recalled is an experienced lecturer in the United Kingdom/Ireland region, pointed to the absence of a *paramountcy* clause in the *Engineers Ireland* Code of Ethics:

> …the Code of Ethics of *Engineers Ireland* is a bit problematic from my point of view if you compare it with international codes right, international codes always have this primacy clause, you know it says that the Engineers should hold…the paramountcy clause sorry. 'Engineers should hold paramount the health, safety and welfare of the public'. Most codes say that the *Engineers Ireland* code doesn't say that so explicitly. But all of the discussion is about the safety dimension, the health dimension, and there is very little discussion about what the welfare thing actually means. And that takes you into the domain of what you are interested in in terms of social justice and so on. How do

> you define or how do you determine whether engineers are actually meeting the welfare of the public?

The diminution of professional autonomy can also transfer into the workplace in other ways. Noting the potential challenges in negotiating power dynamics in the workplace, PT02 suggested that, while engineers may be aware of ethical issues, they may not feel empowered to address these within corporate organisational structures:

> It also assumes then that engineers have the power in their workplaces and so on to resolve these dilemmas, which I don't believe they do actually…you need to be considering the social, economic and political factors involved in resolving some of these issues and certainly around the issue of safety for example; that's a much more complex issue than telling somebody to practice safely. Much more complex in fact than the impacts of accidents.

As is evident from the contributions in this chapter concerning engineering education, such themes are not currently considered in the engineering curriculum. In also considering bureaucratic and authoritative influences in practice, PT04 remarked on how a senior manager in a multinational company in Ireland expressed the desire to focus solely on the technical aspect of their work:

> I was very interested earlier on by a senior manager in [multinational company, name redacted]. He just said, 'I want my engineers to just sit down and do their work'. But I actually think they are going to get skilled out if they don't do this. I mean, you know, we don't know to what extent robotics and artificial intelligence will be able to just input those equations and stuff that we rely on engineers to be able to do. So, I think that having a broader skillset is actually going to be the best form of survival as an engineer.

PT06, who it will be recalled is a practising engineer in Ireland, characterised a tension that can arise between good ethical practice and commercial considerations, noting that responsibilities around client representation can potentially conflict with good ethical practice. For example, this participant noted his company's policy of not working for the tobacco industry on ethical grounds:

> I think that you know, the engineer should you know have a strong ethical position and like the conflict arises, you see this is true for an awful lot of professions or areas of life, ultimately, we have a client whoever that is, for a given project. So, the client is paying us, and that's why we are working for them right because we have to make a living and you know. For example, the company I work for has a policy that we don't work for the tobacco industry right, so you can try and winnow out your clients.

On a similar theme, PT10, a highly experienced engineer and entrepreneur, described a particular ethical dilemma that he encountered. In trying to trade commercially as a supplier of industrial refrigeration equipment in Ireland, he was confronted by what he believed to be sharp ethical practice. This encounter, together with similar other events led to him deciding to walk away from this area of business, as opposed to reneging on his ethical principles. Some of his competitors did not espouse similar ethical principles however:

> I would've felt ethically maybe I would say, again, it goes back to the commercial thing. I used to sell chillers, [company name redacted] chillers, and we would be trying to sell the most efficient chiller, and some other guy would come in and undercut you. But he would be doing it; you know…chillers are an art [form], it's not just a lump of metal, but nobody was sophisticated enough to go and check what they actually did? Because there are always ways of…so there was probably a bit of ethical sharp practice there.

What PT10 was alluding to in the above comment was a form of unethical engagement in a competitive tendering process by a competing bidder. The competing bidder quoted for the supply of lower-priced equipment, thereby creating a competitive edge while knowing that the quotation was for equipment that did not meet the specified requirements. As this non-compliance was not highlighted in the submitted quotation, it represented an example of sharp ethical practice, on behalf of the competing bidder, in the view of PT10.

PT10 also pointed towards the tension between financial constraints and engineering practice as being a particular source of frustration, while still being comfortable with his career choice:

> I have to admit I really still like my work. Okay, there is…I don't know about the financial pressures that we had. But from the innovative and the creative part of the work and that and even right the way down to path laying and getting stuff ready. Yeah, if I was doing it all again, I would be…I have to admit that I wouldn't want to be anywhere different. And I mean that in a lovely way, I'm glad that I ended up in the energy sector.

Remarking on the ethical dilemmas he will likely encounter in his future career, PT11, who it will be recalled is a civil engineering student in Ireland, described what he believed to be good ethical practice in an engineering context:

> I think good ethical practice in engineering would be to make the best decision that you can because I think good ethical practice kind of forces us into this kind of black and white; this is ethically good this is ethically bad.

Remarking on the vulnerability, from an ethical perspective, of young engineers entering the working environment, PT05 considered whether they are sufficiently prepared to recognise the ethical boundaries and noted the importance of good mentoring:

> Yeah, I think though that you are specifically asking about newly qualified engineers and I think that they are probably more vulnerable because they haven't been in the workplace. Okay, workplaces do help with this. Newly qualified engineers are keener to make an impression, and really, they're probably not as aware of, you know, the boundaries of what's out there. That's something that they will learn, that's why it's part of their initial development for the C Eng[15] [qualification]. So, I think that they need good guidance from other engineers. But also, I

---

[15] Chartered members of *Engineers Ireland* are described as "Chartered Engineers" and have the right to describe themselves and, to use after their names, the abbreviation "CEng".

> think that is probably the highest risk that they're trying to balance the engineering and probably non-engineering components and they may not be aware, fully aware. They're still green behind the ears in effect, and they're still being formed really, and I think that's where the greatest risk is.

However, it is noteworthy that the mentoring that PT05 refers to will likely be provided by more senior colleagues, who are also working within the professional development guidelines established by the professional body, *Engineers Ireland*.

Finally, in describing a particularly contentious issue in terms of the maintenance of the welfare of the public, PT08 described how he was uncomfortable when confronting a colleague who designed code for drones associated with the military:

> I have butted heads with my Dean, and I tease him about it. All of his money was from defence advanced research projects. That's how he did all of his research, and so I am here talking about; I mean full disclosure, my mother is from [country name redacted], and my father is from [country name redacted], so I have like a mixed bag there, but you know [country name redacted] is like ground zero of the drone wars. And his software is in every single drone, and he is [nationality redacted] no less. And so, I tease him; I was like, 'you know your software is dropping bombs on my family'. And you know 'come on man, what do you think about this you know, let's have a conversation'. So that's an uncomfortable space for people!

This contribution again draws us back to the debate in considering narrowly versus broadly framed ethical treatments, and indeed, to a consideration of the maintenance of the welfare of society in its broadest sense. Where does society begin and end in this contentious debate, where do we draw the line?

5.5.1 Consideration of social good and potential for shutting out other ways of knowing

PT08 pointed to an epistemological problem within engineering, based on what he perceived to be a claim to authoritative knowledge and truth which he believed has had the effect of shutting down other ways of knowing:

> There's a conversation happening; it is been pushed from the outside, I don't see much of it being owned from within. And I think it's about…because it threatens people's, it threatens their claims to authoritative knowledge and truth. And that's been the big…it's an epistemological problem within engineering. I think that engineers have codified and maintained their privileged position; better salaries, more access to resources, all of that stuff. In part by being able to make claims to a certain kind of pure, authoritative, scientific knowledge. And that requires shutting out other ways of knowing you know.

On a similar theme, PT11 described what he perceived to be a potential arrogance at times concerning how engineers objectively engage with society, based on a perceived claim to authoritative knowledge:

> I think sometimes there's a kind of a big headedness to engineers… well, it's like we're doing this for your benefit. People oppose windmills and, there is kind of this idea that…oh why are you opposing windmills, it's going to be good for you in the long-term; it is good for the environment. There's a kind of almost a holier than thou aspect to it, which I don't think is helpful.

In considering the logical problem-solving capabilities of engineers, PT03 described engineers as the problem solvers 'for' society:

> Yeah, I think in the modern age we are faced with an energy crisis. So, it seems that policymakers, government, whatever other bodies…the main population kind of task engineers with that challenge to come up with solutions towards the modern energy crisis. That seems to be a driver in the mechanical engineering course here and also in civil engineering…the installation of more energy-efficient buildings, coming up with designs for renewable energy solutions. So, I made a small quotation here, it's like; 'the world is broke, fix it, engineers.

PT02 characterised a narrowly framed positioning of engineering practice as follows:

> …the big problem of engineering is that it sees itself as a technical activity, full stop. So, if you start at a different place by saying actually that engineering is a social and technical activity, you then start asking much bigger questions.

In these contributions, there is a sense of engineers being the providers of technical solutions on behalf of society but separate from society. Similarly, PT11 noted how, from his perspective, the engineer ought to be in the background taking abstract concepts and creating technical solutions for society:

> I think a few years ago a friend of mine said 'if an engineer is doing their job right, you'll never notice their work at all'. Like I think that the job of an engineer is to take those abstract concepts and translate them into practical, reliable, useful tools and equipment and everything that engineers are involved with for others in society.

Contrastingly, PT02 described the iterative nature of the design process, the subjectivities and the power relations. He believed that these factors ought to influence engineering practice; a practice which, as a result, cannot be divorced from society:

> Design is an iterative process; for example; it's not just a matter of taking something out of a lab and sticking it in the real world, that's just fallacious. It just doesn't describe what engineers do or how they work, so that's one aspect in which there is a social dimension, there are different individuals involved, different subjectivities, different levels of power and so on, and so forth and secondly, the social dimension says broadly engineering has huge impacts on society so let's consider those impacts.

Given the public dependence on the expert knowledge provided by engineering and the resulting dominant one-way communication process, it is perhaps unsurprising to note PT09's assertion that there is a lack of understanding as to what engineers do. In commenting on the interaction of engineering with society PT09 noted that while there may be a lack an appreciation of that interaction, there is also potentially a lack of public awareness as to what engineers do:

> It's an interesting one because I suppose, often I think that the public aren't even aware that there are engineers behind designing things and they just take it, not for granted, but they just assume that maybe that infrastructure is of a certain nature and that it's perfectly safe. And I suppose in that respect we're kind of designing things in not a very loud and, you know, in your face kind of way. And I suppose that the public has learnt to rely on and assume that a lot of structures that we design are kind of safe. So, I suppose that we have an obligation there to not take that for granted in that respect. I do also think that engineers, I

> guess, are relied on for forward-thinking or to kind of consider all different aspects aside from the design. Like the societal effect on people and the effect on let's say the environment as well.

On this point PT05, who it will be recalled is a professional body representative in the United Kingdom/Ireland region, also noted a potential lack of public understanding of the work of engineers and pointed again towards the primary role of engineers as being to make life better and to do no harm as a result of their practice:

> The role of the engineer in society is bound up as to what people think engineers do and there's not a huge understanding, I think in general of that. …And to use the medical term, do no harm, then I think that's a good starting point. It may not be that easy to do that all the time.

5.5.2 Focus group considerations on ethics within engineering practice theme

The focus group participants expressed a range of contrasting views when considering the themes to emerge from the first field research stage concerning how ethics and social responsibility are positioned in engineering practice. In reflecting within the focus group on the research participant contributions during stage one, PT12 posited that the social consequences of engineering decision-making could be missed given that engineers are predominantly fulfilling technological requirements:

> …it's a very technically based subject, and I think that we view ourselves as having a role towards developing technology and that kind of interaction. But I suppose there are social consequences of it; there's a point in there…that, it can be missed. That you know, even though we're at the forefront of say technologies such as wind farms and that sort of thing, people have an inherent fear of these kinds of changes. And we are not addressing that we are just…we're just fulfilling the technological requirements which is a big issue.

In this contribution, there is an acknowledgement of an understated implementation of these social responsibility principles. In questioning though if engineering is driving change in society, PT13 expressed the belief that societal and economic considerations are driving change and that engineering is only reacting to that change agenda:

> So, you say it's all being driven by engineering but is it all being driven by engineering? Because engineering… like economics drives it, social need.

In this observation, there is a sense of an abdication of social responsibility for the societal impacts of engineering decision-making. It is also perhaps worth considering the limit on professional and indeed personal scope, given the dominant societal paradigm within which engineering work is completed.

PT12 disagreed with the contribution from PT13, pointing towards engineering as driving change in areas such as technology and biotechnology and further noting that engineering is not questioning internally whether these changes are to the benefit of society:

> So, the culture of engineering is focused on looking for good technological solutions to problems that arise. And the culture of Engineering is not asking about philosophy or the background or is this a good or a bad thing. Like we are kind of obviously on the precipice of a huge change where technology and biotechnology are going to link together. There's going to be a huge impact with that. And it is engineers that are driving it forward, and engineers are coming up with all of the technology. We are not the ones kind of saying is this a good thing or is this a bad thing. And we never have been. We've never seen that as our role. We are technical people; we provide technical solutions to problems.

This debate between PT12 and PT13 continued within the focus group. In considering a dam construction project, for example, PT13 suggested that it was not the engineer's role to consider whether hydroelectricity was good or not from a societal perspective, but that the engineer is hired to deliver the project technically:

> Like, say if you're building a dam…is hydroelectricity good or not? But most of the engineers involved in that are given a specific project; we are building a dam you can then look at the ethics within that.

And in further clarifying this point, PT13 added:

> Engineering doesn't make all these decisions in isolation. Like an awful lot of what, day-to-day engineers do; say in civil [engineering] it's driven by what society decides they want to spend their money on. So, if you're into building infrastructure, you build the amount of infrastructure that is funded.

PT12 countered with an observation concerning the design of microelectronic chips:

> But that's the underlying assumption that producing the [microelectronic] chip is a morally acceptable thing to do, and then reduce the environmental impact. Nobody is asking themselves is producing the chip a good idea in engineering. We are producing the chip, and then we're trying to minimise the impact that we have from engineering.

This debate between PT12 and PT13 underlines the tension between those who favour the introduction of a more widely framed ethical perspective, concerning engineering practice, and those who more closely align with the status quo, guided by adherence to more narrowly framed professional codes of ethics.

The discussion moved on to the consideration of ethical dilemmas in engineering practice. I shared an ethical dilemma with the focus group that I was confronted with while practising as an engineer in the Middle East and which only resonated with me when I subsequently reflected on those experiences. The ethical dilemma, to which I refer in the opening chapter, related to the working conditions endured by fellow workers from the Global South while completing those projects in which I was involved. In considering this theme, PT16 suggested that, had I walked away from that project, there would have been another engineer ready and willing to take my place:

> Can you see that as…if you go in and take that project, and now you know, maybe looking back you might not take that project? But if you had not taken it on someone else would. Would it not be a case of…you know you go in and you try and improve it in some way.

PT15 added that, in his opinion, this would not necessarily be an issue for an individual engineer to confront but rather, ought to be addressed by the professional bodies:

> But you wouldn't be the first person who's worked in the Middle East to come across that dilemma. Probably at some stage, everybody who's worked over there saw something, some person working out in 48 degrees, working in the sun and saw that; and everybody has come back and has done nothing about it. In my opinion, I don't think it's an individual responsibility; I think it's something like *Engineers Ireland*, ICE or something like that; they need an ethical solution for something like that because somebody will always take your place.

PT15 also made the point that potentially economic considerations took precedence over ethical considerations at a higher level in global multinational companies:

> But I do think that if you look at the senior levels of the likes of [multinational professional services company, name redacted] and different companies like that who work on international and global infrastructure…the people who have come through are quite ethical; it's when you get up to the higher level your decisions aren't made predominantly on ethics, they are made predominantly on economics. That's, you know, how do reinforce that in such a way that somebody who is 22 years old and you know is, sees the world as a very open place and then when they become 52 years old, they see it in dollars and cents.

PT12 added that this might then discourage engineers from engaging in work in developing countries:

> And, then there's the offshoot of that, of course, is then they don't build anything in places that maybe don't have… so India… that are developing countries where they don't have the standard of welfare; they can't have it. And then we're stuck in the ethical issue of… they are not able to develop and build because we said the expertise that would know how to do these projects can't go out there.

In these contributions, there is a sense of engineering practice deferring responsibility for such considerations to others, including professional bodies.

In reflecting on some of the high-level strategic decisions that then dictate how engineers become involved in projects, the focus group debated the threshold between engineering and management. PT13 reflected on the fact that high-level decisions that, in turn, impact on engineering are taken at the management level in engineering companies and that engineers are then required to implement what is needed to deliver the strategy technically:

> …but it might not necessarily be an engineer. Like once you get to management in an engineering company, you get to become *management*. You don't necessarily do the 'nuts and bolts. Like the head of the *OPW*[16], the head of Irish Rail, they could very well be an engineer, but once you get to that level, you're making kind of broader decisions.

PT15 agreed that engineers are not trained to have an appreciation for what might be required to determine, for example, where a bridge might be located or indeed what the community impact of a bridge placement might be: We're not trained to make those decisions or to do that analysis.'

In reflecting on practice in France, PT16 pointed to the fact that the education of engineers, at the university level, focused predominantly on developing management abilities:

> A French student of mine told me that in France if you go to university to study engineering, you do very little practical work. You study management; you study finance and accountancy. All of those things as part of your engineering degree because you are trained to be a

[16] The Office of Public Works (OPW) was established in Ireland in 1831, by an Act of Parliament: An Act for the Extension and Promotion of Public Works in Ireland. The OPW supports the implementation of government policy and advises the government in the discipline areas of property and flood risk management.

> manager. You not trained…when you go to university, you are trained to be a manager in an engineering company.

Again, there is a sense of resigned acceptance that engineers must tow the managerial line in their practice.

5.6 Community engagement and societal awareness in practice

In Chapter 2, I explore how social responsibility is represented in engineering practice, framed around four ethical principles; the do no harm, the precautionary, the informed consent and the freedom of speech principles. In considering social responsibility principles, PT02 reflected on how societies are co-produced and given that, as engineers are shaping the world in which people live, it follows that engineering has a responsibility to engage with society in that co-production process:

> …societies are co-produced by… it's not just technically determined. The social dimensions of life also produce it as well. So, there is an interaction between the two: society and technology are co-determined by each other. So, therefore, engineers' responsibilities are wider than traditionally understood, for example, to make sure that something is safe. That's pretty narrow in a sense. But when you are thinking that you are shaping the world that people live in, then the responsibilities are wider, and in fact, they also have to do it with other people, they can't do it by themselves.

Pointing to what he believed to be the profound influence that engineering has had on shaping the world that people live in, PT02 asserted that the public does not understand the significance of the role of the engineer:

> You see what engineers do is construct the world that people live in. So, it's like without the engineer, the modern world, as we understand it wouldn't exist so to speak. So, all of the basic things that people do from, you know, the houses they live in, the transport system, the work systems they're located in, they're all permeated by engineering. It's just there so the engineer's role is a very significant one I think and ironically, not well understood.

On a similar theme, in considering the interaction of engineering with society, PT06 describes the primary role of the practising engineer as being to make society a better place:

> Then I think that engineers should have a, they should have a kind of overarching goal to kind of make society a better place, right and that goes for every other profession as well right.

Interestingly, PT06 further added that his company was attempting to address this objective by aligning its practices with the United Nations sustainable development goals[17]

> I think actually on something that this company is doing, starting out to do is to try and align our business with the United Nations SDGs you know the Sustainable Development Goals as a kind of a framework.

However, as PT02 alludes to below, a narrowly framed approach, although problematic, is more commonplace in engineering practice:

> To solve ethical dilemmas in the context of engineering practice and therefore not to do things unsafely and perhaps even going to blow the whistle if they find that there is something wrong. That's not satisfactory in my view, because I think given what I said earlier on about the scale of engineering and its impacts on society, that engineers need to have much more fuller sense of their responsibilities for shaping a good society if you want to see it in those terms and then how public policy, for example, has a huge impact on that you know.

PT02 further contextualised the narrowly framed ethical dimension of engineering practice as follows:

---

[17] The Sustainable Development Goals are a blueprint to achieve a sustainable future and address global challenges related to poverty, inequality, climate, environmental degradation, prosperity, and peace and justice. United Nations (2015) *Sustainable development goals - United Nations*, available: http://www.un.org/sustainabledevelopment/sustainable-development-goals/ [accessed 28 June 2017].

, United Nations (2019) *The Sustainable Development Goals*, available: https://www.un.org/sustainabledevelopment/sustainable-development-goals/ [accessed 04/01/19].

> How do you define or how do you determine whether engineers are actually meeting the welfare of the public? Because it is usually seen mainly in terms of the safety issue. So okay, the discussion is about whose problem is being solved, what criteria we are using to solve engineering problems and who benefits from engineering. I think that they are the three, from a social justice point of view they seem to be the key issue as to who benefits.

From a professional representative body perspective, PT05 noted the importance of community engagement, although, in his view, the proposed engagement fell short of full community participation:

> You know if I want to put a wind farm up at least talk to the village before you start the planning processes. And they're much more aware of those types of issues, and that type of social dimension. So, you find out what's acceptable before you start drawing anything.

In expressing a similar view, PT09, an early career practitioner working within the energy sector in Ireland, pointed towards the importance of community involvement in project decision-making in the energy sector projects that she works on:

> I suppose I touched on it already; it's becoming more and more important in my work for community engagement. And I suppose there is a kind of an ethical and moral backing to that as well. That is having respect for that engagement with the community on energy projects.

However, in further discussing the merits of keeping the public informed about project decision-making, PT09 characterised the benefits of that largely one-way communication process as follows:

> You know it is to our benefit to do that from an early stage because it means that we can advance a project much faster through, particularly the planning process as there is less opposition to those. So that's definitely one useful aspect of, kind of, using that ethical approach in our actual work. Because it expedites the project, so that's to our benefit and the community's benefit as well.

Similarly, although having referenced the United Nations SDGs previously as a motivating factor for his company in terms of the work that they choose to now engage in, PT09 then described their ethical responsibilities in relatively narrowly framed terms:

> Yeah, I'd say huge impacts on my company. In terms of licensing for the actual activities that we carry out either in the energy sector or the solid fuel sector. There are huge implications there as regards emissions and, you know, everything from an environmental point of view is very strictly monitored and also, you know, tested or investigated from time to time. So, it is quite a high environmental…I suppose ethical responsibility there.

PT08, who it will be recalled is an experienced lecturer in North America, commented on the lack of community engagement experienced by some of his graduating students when they obtain employment with multinational companies such as Google or Facebook:

> So, if they end up going to work for the Googles or the Facebooks, I think that they get very limited, if any, community interactions because they're part of a gigantic machine.

In contrast, PT08 noted that there might be more opportunities for more extensive community engagement in smaller companies, which, by their nature, are more connected to the local community:

> Environmental engineers mostly end up working for smaller consulting firms around here. They get a lot more because they have to deal with state agencies all the time and as soon as you have to enter into that space it's a different conversation, and you start thinking about public comment and stuff like that. And it's not necessarily community engagement deeply, but it's at least like they have to realise that there is a community out there that they have to serve.

PT08 characterised a key challenge for engineers as being a need to integrate their identities as members of society with their identities as practising engineers:

> If my identity as an engineer is what defines me, then I can be a technocrat and not think about the other things that are happening around me. But if I think of myself as wait, I'm a human and a member of society… if I think of myself as part of these other groupings, it's not…it's difficult because we could say well, this is the engineer part of

> me, and this is the rest of me. But I think we need these to be integrated in a way.

This consideration points to a potential need to develop an integrated approach to engineering education to embrace the social dimension, in considering all engineering decisions and choices.

PT04, a qualified Irish engineer combining creativity with science-related topics in her professional work, noted how more inclusive engineering practice would make engineers better role models in society and would widen the discipline's appeal to prospective students:

> I also think that they would be better role models. I think that attracting young students to engineering would be a no brainer because they would see the impact that it has on their community and the importance of having that kind of engineering brain. I wish…I think I am that engineer, I am an engineer with a very deep social conscience, and I think that if I had done a course that would have validated that part of my brain, I am not sure what way my career would've gone, but it certainly would have helped me to figure things out an awful lot sooner.

PT04 further pointed to several conversations that she has had with engineers where they aspire towards societal engagement in their work, with some finding real value in their humanitarian work, with bodies such as the *Niall Mellon Foundation*[18]. As a result, she identified a need for a more holistic vision within engineering and practices that might support the betterment of society:

> Because I don't think…in speaking to engineers and scientists over the last couple of years, all of them say that they are very creative, but they can't find an outlet or whatever. They get a lot of value and a sense of self-worth when they engage, particularly people that go and build houses for two weeks in South Africa with the Niall Mellon Foundation. That's what I find a lot of them do. Wouldn't it be better if we found a

[18] Niall Mellon is an Irish entrepreneur, charity Chief Executive and property developer who founded the Niall Mellon Township Trust to provide homes to impoverished communities in South Africa's townships. *Mellon Educate* was founded by Niall Mellon in 2002 and established as a charitable company in 2004.

> way of, you know, honing those sorts of desires and passions to doing the same thing here and on a more regular basis?

In highlighting a potentially contentious example of the consideration of societal welfare, PT07 described a hypothetical bridge project linking two previously unconnected communities:

> …let's say…there's a wide river and before there hadn't been a bridge there. And yes, community on side 'A' would love to sell their produce to the community on side 'B', but they haven't done it before, so these engineers come in and build this beautiful bridge for people and now 'A' can sell in 'B'. But now 'B's prices are going down because, before they didn't have this competition and maybe people go bankrupt, go out of business and can't feed their own families. So, I think that everything that engineers do can have negative impacts, whether it's to a very small minority community. And I think that there are ways to try and mitigate it and try and find out socially beforehand to see what they can do about it. And see what different parties' interests are and what they really want out of these programmes.

I discussed the hypothetical bridge project alluded to by PT07 above with PT08, who it will be recalled is an experienced lecturer in an in North America. In considering this example, PT08 pointed to the need for co-ownership in those kinds of decisions, although this would not be common engineering practice:

> Yeah, that bridge example is a good one, I like that. And I might poach something like that because it makes me think about how you can imagine the diversity of experience. It might mean that someone now has access to going to a better school. It may mean that some families are now unemployed, it may mean like all of these different positive, negative, confusing…And a lot of what I tried to push is, who should own that decision? Why not let those that are going to be affected be the ones who own how it happens, if it happens, when it happens, that sort of thing.

This depth of appreciation and awareness of the societal impact of engineering decision-making was not apparent in general in my discussions with research participants. PT07 further reflected on becoming more engaged within her education, following a switch from nuclear engineering to civil engineering. She perceived that this increased interest was inspired by the fact that her learning became more applied, and she particularly valued the increased community engagement:

> And then I guess what may have been more appropriate; so, I started in Nuclear Engineering, but then I switched over to Civil Engineering…and so, my reason for that was that I was in an organization called *Engineers Without Borders*[19] in my undergrad. And I got to work with communities giving them like potable water and things. And first of all, it was an amazing hands-on experience with these people. It was so much fun, and I got to actually practise engineering before I even graduated. And I learned way more in that than I ever did in my undergrad and I just thought that it was amazing.

In further reflecting on the awakening of her societal awareness, concerning engineering practice, PT07 described a recent experience while completing voluntary work in the Global South:

> So, like something that I've been dealing with recently is that any kind of infrastructure and any engineering project needs mined materials. So, what if you're mining from these beautiful areas and you're taking away these things that we'll never as humans get to see again. These beautiful nature reserves; what are you really taking away from society when you really do that?

On a similar note, in reflecting on the impact of engineering decision-making concerning a bridge project in North America, PT07 remarked on how the poor community was impacted by the construction of the new bridge but did not gain any benefit from its installation:

> And you know I remember a project in Kansas City, Missouri, it was a big bridge project. And they were building this highway bridge over impoverished areas of Kansas City. And the impoverished people didn't have any say in it. And now there's all this noise, and their property value goes down even further. They hated this bridge, but it did help some people to get to work a lot faster. And it reduces a lot of traffic congestion and all that stuff. But the engineers didn't think about it

---

[19] Engineers Without Borders (EWB) is a non-governmental organisation (NGO) and registered Charity dedicated to bridging the gap between academia, industry and NGOs. EWB-Ireland provides opportunities for Irish engineers and scientists to learn about and contribute to sustainable development globally.

> before and what they were doing and maybe they did hear something but chose to ignore it.

In this instance, there is a call for a nuanced and balanced treatment of the precautionary and informed consent principles. This might have acted as an ethical counterbalance to the formally rational support of development in such instances in considering all parties impacted by such projects.

In considering community work in the context of humanitarian relief work, PT08 remarked on how this kind of work, although worthy, can act as an 'ethical back door', as real community engagement is not required and often bypassed in such work:

> …working in disaster areas and part of it is; it's twofold, it's out of a sense of a little bit like wow, this is like a real uphill battle here. Bring this stuff to bear, and part of it is working in disaster relief is like an ethical back door because I feel like it's like cheating. I feel like I don't have to engage with the community in the same way.

In this contribution, PT07 is pointing to a need for community engagement practices informed by empathy. As a result, there should be a focus on the social and cultural capacities of the community as opposed to what the community might lack. In further considering the burden of responsibility placed on engineers in practice, PT07 noted the first responsibility of the engineer is to consider who is being impacted by their decision-making:

> Well, I think good ethical practice means not necessarily listening to your bosses but listening to society and the people that you're serving more, over your bosses. And considering every kind of project that you're doing, everything your boss tells you; but thinking about who it impacts, what are the impacts, what should I do as an engineer. What do I need to check before I'm okay with doing this? And making sure that you as an individual, as an engineer are okay with what you are being ordered to do and standing up against it if you have to or just trying to put in some change.

Writing from a professional body perspective, PT05 noted the heightened social responsibility challenges, given the now globalised nature of engineering practice:

> …particularly in ethical and social responsibility is it is geographically dependent. So, if a graduate engineer goes off and works in Saudi Arabia whereas you know you work in up to thirty-five degrees centigrade or whatever before they start shutting down the sites or before larger breaks [occur]. So, there are all those types of local and social contexts that they won't get exposed to in college.

In further considering this theme, PT03, a relatively new entrant to academia in Ireland, called for an expansion of the ethical dimension of engineering practice. In effect, PT03 is calling for engineers, to not only maintain high personal ethical standards but also to call their colleagues to account if ethical practices are not being maintained:

> So just acknowledging, kind of, wellbeing around them so that when they're working in a company or whatever, that they should question the actions of people around them and is that ethical or if they are being harassed in a sense. If females…if they are not being given equal opportunities based on their backgrounds, their culture, nationality of origin that they should acknowledge and identify that that's not appropriate and it's an ethical issue that should be, you know, resolved.

In further explaining the lack of public understanding of the role of the engineer in society, PT03 points to engineers as being the technicians of society who, he also notes, work quietly in the background:

> So, the people that make it function and what are the basic needs of society? So, at a very basic level, it is clean water, sustainable food sources, light, heat and shelter. So, engineers provide all of that in a modern, civilized society. So, they're the kind of technicians in the background and probably the majority of the population or the communities, they all have a knowledge or an appreciation of how their own homes work at a basic level in terms of electricity and technology; it just happens, the engineers are the technicians in the background.

5.6.1 Focus group reflections on community engagement

The focus group engaged in vigorous debate, offering contrasting viewpoints in considering the contributions from individual research participants in the area of community engagement and societal awareness in engineering practice. Focus group participants first pointed towards poor communication as being a key factor when considering how engineers engage with the community. In alluding to the difficulties experienced by *Irish Water*[20], when attempting to establish an independent water utility company in Ireland, PT12 pointed towards a failure of engineering to communicate clearly with the public as to why there was a requirement to pay for their supply of water:

> Like *Irish Water* is basically hamstrung with a lack of funding now even though it's so necessarily required and funding in infrastructure is so limited. And engineers are facing a real challenge of actually articulating that to people in a way that they can actually digest and be willing to pay for what's required. So, we actually have to be able to communicate these issues to people, so we can't just actually offload it onto somebody else.

In this contribution from PT12, there is a sense of the expert voice coming to the fore, a one-way communication process that might be paraphrased as "we need to explain to the public what we think they need to know". PT13 identified this as an issue which might be dealt with by bringing in communication expertise, as opposed to something that might be addressed within engineering and further pointing to the opportunity to collaborate with other disciplines as a result:

> It is bringing in outside expertise as well. It is the same with issues like wind farms; there are professionals who are just much better at communicating. That's what they're for. So, if you have to have public engagement, it is good to have the engineers contributing to it but not

---

[20] Irish Water is the national water utility in Ireland with responsibility for the delivery of water and wastewater services to homes and businesses in the country.

> necessarily leading it because you're never going to get to a point where you are going to have the same skill set or understanding of that…if you take the Irish Water communications if that's the arrangement that you're dealing with. Or then you're bringing in professionals who are able to communicate what you want them to communicate on your behalf. In a way that gets you collaborating with different disciplines. Collaborating with people who are good at that side of things. For communications like you want to get people who can promote it.

PT12 countered with her view that engineers are hiding some of these issues from society, by failing to communicate clearly:

> But it's engineers that are hiding the problem for society because the problems are there. The water is draining into the ground, and we are coming out every time there's a burst water main and replacing it quickly enough that people don't get that bothered by it or that woken up to the issue. So, we are able to kind of keep the show on the road.

In considering sustainability and environmental themes, I reflected on the fact that President Trump had reversed the overall environmental policy when he was elected. This resulted from his actions to withdraw North America from the *Paris Climate Accord*[21]. I questioned why there had been no obvious, coordinated reaction from the engineering profession against this drastic and negative environmental policy shift. Focus group participants expressed a diverse range of views on this theme. PT14 noted that there had been some reaction to President Trump's actions:

> But, wasn't there a lot of companies that came out in revolt against it…The Paris Accord, he basically pulled America out of it. There were a lot of companies that said that they are going to continue actually agreeing to all the targets and to all the requirements anyway.

[21] In December 2015, in Paris, parties to the United Nations Framework Convention on Climate Change (UNFCCC) reached an agreement, The Paris Climate Accord, to combat climate change and to accelerate the actions and investments necessary to sustain a low carbon future.

In adopting a contrasting position, however, PT15 expressed the view that economic considerations applied for individual engineers, as bills still needed to be paid so professional work needed to continue:

> So, I suppose the choice is, do you work on that or do you lose your mortgage? Or do your family go hungry?

In considering this point, and in perhaps adopting an expert-led approach, PT12 pointed towards engineering remaining focused on the technical and rational issues and thereby avoiding getting involved in any apparent emotional issues:

> Well, Trump is the opposite of an engineer. Just on the Trump one like, he is appealing to people's emotions at every level. Engineers, we look at the technical, rational side. He appeals to the emotions, and he hits all the right spots for people who vote for him.

In further expanding the discussion about community engagement, I introduced the thoughts of PT07, when describing the potential impact of a bridge project on communities that were previously not linked. In considering this point, PT14 suggested that looking at immediate negative impacts on either community, in the short-term might, be misleading given that, in his opinion, the increased trade over time would potentially benefit both communities in the long-term:

> The thing that strikes me about it is the timeframes aren't mentioned. So, if you look at it generally, if you increase trade in the longer term everybody benefits, everything moves up, and so in the longer term, this will probably be beneficial for both communities. Or at least both will recover to where they were. But in the short-term, you see that there is an impact.

PT13 believed that more context was needed to evaluate this scenario fully:

> These kinds of examples…like in any major infrastructure project. It's like the planning process that you get objections. The *Bus Connects*[22] in Dublin; they have to buy out peoples' gardens…windfarms, people don't want any infrastructure projects. Compulsory purchase orders, these are all decisions that have to be made on any project. That's a good example, but you need the context.

In considering the potential detrimental engineering impact on communities, PT15 believed that the example of the bridge passing over a poor neighbourhood in Kansas City was a better example, given the obvious negative impact of the bridge on the community and the apparent lack of involvement of the community, in agreeing to the locating and building of the bridge:

> The one below it, about the bridge going through the poor area. That's, you know poor people don't make decisions.

However, in describing a bridge project in which he was involved, again perhaps adopting a formally rational perspective, PT15 pointed to the fact that engineers are generally not involved in decisions such as where a bridge is to be located:

> But, usually with…the bridge down in [county name redacted], we looked at the least environmental impact. There was a freshwater mussel, and there were otters living in the river. And how could you develop the bridge and not disturb the habitats? We were never asked the question, is it a good idea to put the bridge here in the first place?

PT16 expressed the view that more community interaction within engineering education would help with the development of communications skills:

> You know what I think would be really helpful if engineers from the get-go are involved in community projects. So that they get used to communicating what's in the technical field to people who are not technical.

---

[22] *BusConnects Dublin* is a major investment programme to improve public transport in Dublin. It aims to overhaul the current bus system in Dublin through a multi-year programme of multiple integrated actions to deliver a more efficient and reliable bus service, with increased capacity, for Dublin.

PT16 noted the lack of community involvement in general. In considering the philosophical and sociological aspects of the debate, it is interesting to note that research participants observed that such philosophical discussions do not occur within engineering education currently. The debate within the focus group, considering the themes to emerge from the participant interviews, concerning societal engagement, again point to diverging perspectives together with indications of the dominance of expert voices and formally rational thinking, as perhaps compared with the less prominent and perhaps more reasoned positions informed by substantive rationality.

5.7 Considering Possibilities for Change within Engineering Education

In Chapter 4, I explore a range of alternative engineering curricula aimed at fostering greater student awareness of the broader ethical dimension of engineering practice. This section focuses on contributions from research participants, in considering a change to engineering education to embrace a broader ethical dimension of engineering as opposed to retaining the status quo represented by more narrowly framed ethical perspectives. Concerning this theme, in Chapter 2, I consider the social responsibility principles that might inform ethically-sound engineering practice. The informed consent and precautionary principles are two propositions, in particular, that may be usefully addressed within engineering education, by means of enhancing links with the community within engineering programmes. PT08, who it will be recalled is an experienced lecturer in an in North America, described an initiative that he has promoted to enhance engagement between community partners and students:

> …specifically, we work with like six to seven community partners where they do get out into the field, but that's a novel experience for them.

PT08 introduced this initiative to counter what he believed to be a lack of focus on the social paradigm in engineering education in North America. PT08 described a 'side door' that he used to address this deficiency partially:

> And so, there is that momentum as well, but the way that myself and with the support of people around me have been able to bring social sciences into engineering has been a lot of side doors. We have a requirement at [institute name redacted] called the [programme initiative name redacted] requirement. It came out of the resistance to apartheid and Third World Liberation Front…Like you can't understand America if you don't understand how race works here…and what does it mean to be an environmental engineer in a country where, you know, people of colour and poor people are the ones who get all the trash dumped by their houses and air pollution and stuff like that?

PT08 described what he perceived to be a beneficial impact on the students as follows:

> I think it's really generative; they learn a lot. They learn a lot about what's important and what's not important. Things from knowing how to communicate with people to like how to take in other people's concerns that may be very contrary to yours. All of these things that you have to deal with in the quote "real world". I think that forces it on them.

In discussing how engineering might be viewed as a caring profession, PT08 remarked on how valuable that might be as an aspiration for the profession:

> And you know, I think that that word is really valuable. To bring the word care in. It's hard to fight against that word, you know. And like as a pedagogical tool I've done that a lot, talking about the ethics of care and what would that look like? What would it mean to say I care about this person or this community and then, I'm going to do work around this?

PT04, who it will be recalled is a qualified Irish engineer combining creativity with science-related topics in her professional work, pointed to a potential benefit for engineering students in having a module that enabled them to engage with the community:

> Like there should be at least one module where they have to do a project with the community, you know what I mean...So, I think that if they had one module out in society or in the community, they would begin to see how engineers can fix very simple things. And it might give them a greater sense of pride and a greater sense of understanding of the value that they have in their wider community and then maybe will reach out more to it after they graduate.

In considering how to foster a sense of social responsibility, PT05 also pointed to the benefit of project work with a community focus although again the consideration is somewhat narrowly focused:

> But on social responsibility, I think, where we see a lot of that coming through is particularly in project work. So, you know, you might have a project to work on a cycle lane or to make a building for a sports team. And I think that the students are much more aware …the other thing where I think they're probably more aware now is with public consultations. I think that there's been enough of that in the media through various delays of planning, I think.

In considering the need to broaden the engineering curriculum, PT04 suggested a need to integrate the social sciences, as she believed that this would help to raise the societal awareness of engineering students:

> …there has to be some elements of social science I think or philosophy or even just like a nod to architecture and something that makes them see that there's a design element behind everything and an intention and even if you are not somebody with a very strong social conscience that you actually care about, that this is going to be something physical that is going to relate to people in some shape or form and the end-user needs to be part of that conversation. So, the earlier that they understand how to interact with people and how to communicate with people and understand their place in society and how valued they can be they might actually…that actually would be, I think very, very, important.

PT02 pointed to the potential benefits of teaching the history of technology to engineering students, to develop an appreciation of the impact of technology on society:

> And I think probably engineers could learn more about the social responses by studying the history of technology, for example, and the history of engineering rather than just teaching engineering ethics. So,

> what happens when they end up in the history of engineering? Well, you see that things go wrong sometimes. Different interests shape what engineers do. Over time there have been movements for social change in engineering, why weren't they successful? These are the kinds of questions that studying the history of engineering would perhaps present to the students.

PT02 further elaborated on such an approach as opposed to, for example, 'just sticking students in an ethics class':

> What I'm arguing for is a much more developed change to the curriculum so that it includes…it says something like studying that the history of technology has a value. And it's not just a question of sticking them into an ethics class or a communications class, which is the other thing that happens in engineering programs and saying that that is adequate. So, students get a sense of where the technologies have come from and how they were shaped and whose interests are represented, you know.

PT02 also reflected on how he perceived engineering education to be too heavily focused on the scientific and business aspects of engineering. He referred to the potential benefits of an alternative integrated approach to engineering education:

> My big part of the discussion is if you're going to deal with these issues, engineering education needs to be rethought which is why…what they've tried to do is to distil out what are the main paradigms in engineering education. And I think that this is really where this is at, this is the nub of the issue for me, right.

PT02 further introduced the concept of what he viewed as the three basic paradigms within engineering education:

> So, they say that there are three basic paradigms, the Scientific Paradigm, the Enterprise and Business Paradigm, and there is the Social Paradigm or what they call the Integrative Paradigm. And until you get to the third one, I think you're not going to satisfactorily deal with some of the issues that we're talking about here. Because engineering education has traditionally been too scientific. It is now dominated by concerns of employers which is seen as an alternative, but in turn in fact, in some ways, it undermines some of the rigour in engineering because I think that engineers sometimes are way too apologetic about what they know …I think that sometimes you get this reductionist position in this sort of business paradigm, which says you know that they should only learn things, which allow them to get a job sort of

> thing. And I think that that's a very bad training for anyone because I think that you need to know the things that, maybe are abstract and force you to think and encourage you to look at deeper structures in terms of what is causing what in society.

On a similar theme, PT08 remarked on how he aspired towards building an alternative integrated engineering curriculum. He also discussed how he was attracted to a programme integrating the humanities with engineering, in a manner than he believed would foster more awareness of the societal impact of engineering within students:

> …in my head, you know engineers love this blank slate design approach. If I could do that, we would build it up from the bottom, and it would be integrated into every single class. Like ethics, morals, these sort of considerations, would be constant pressure inside every class. Now there's an interesting programme that may be worth looking at in *James Madison University*…they have an engineering major that is in their *Arts and Letters School* or whatever. It's a proper social sciences degree, but you major in engineering. So there, these humanistic ethics-oriented questions are always coming up, and I think that it should be baked into every course and I think it just takes a little creativity.

Further expanding on the point that societies are co-produced, and in invoking the informed consent principle, PT02 pointed to the need for a different approach within the engineering curriculum to enhance the capability of engineers to engage with the public and to involve them in engineering decision-making:

> So, the issue then arises of how you engage with the public and involve them in engineering decision-making and so on. I think to do that you need a much more…a different approach to the curriculum.

5.8 Focus Group Considerations: contesting the need for change

A wide range of views were expressed within the focus group when considering a potential agenda for change in engineering education.

The debate on this theme commenced with the consideration of interdisciplinary engagement. PT13 noted that such an initiative might foster a deeper learner appreciation for and understanding of other disciplines:

> I know it came up at the teaching and learning thing. Like engineers going to other disciplines and explaining what it is that we do. Because there is definitely a fear that way. Like professionally I found that some of the professions that I deal with don't like maths and they don't trust it. They don't understand this; they don't trust it. They don't know whether or not you're telling them the truth; it could be anything. Whereas in engineering you tend to have a decent grasp of the fundamentals of what you're dealing with…or bring in external speakers, or even from other departments that have….it is a very efficient way of doing it. Because if you get engineers trying to teach things that they are not necessarily that great at themselves, it's not going to be.

Concerning this theme and to promote communication skills and collaborative practices, PT15 recommended student involvement in projects with external parties:

> But I think you can introduce projects. That they can work with groups from the outside and say, 'yes, we're involved in a project. And we're communicating with say [organisation name redacted]'. There's no reason why if [name redacted] is writing a letter with regard to some study that is going on. That he can get the students to write the same letter. So that they can get used to presenting information. And then you could say well, here's the letter that I wrote, and you can see you know, these are the things that you missed. And you can then move a project on like that.

PT13 agreed on this point and suggested that students may also gain an appreciation for contentious issues on projects through exposure to such issues:

> …and exposing them to conflict as well. Because a lot of those examples, it would be for the greater good and quite clear that you have to listen to them. But you are going to be on their side, and they're going to be on your side. But it's exposing them to contentious projects. Like wind farms, if you make a policy decision…that is where we're going to go. You might say well I agree with this ethically, but the local community might be against it.

PT16 also alluded to the importance for students in developing their listening skills in such a scenario:

> But then you get to listen to you know why they are against. You can actually address some of their fears, maybe have a chance to.

Again, perhaps revealing the expert engineering voice, PT12 pointed to the need for engineers to be able to communicate their messages to non-technical people clearly:

> There has to be some ability of engineers to kind of communicate those engineering messages across to non-technical people…Well, it's probably something that definitely, across the board in engineering, there's a struggle with this.

PT13 agreed, and alluded to the fact that there are often contentious issues associated with engineering projects, that require well-developed communication skills:

> Kind of a follow on from that example…like say in engineering that often you're going to have to communicate things, and the other party is never going to agree with you. The assumption is that there is a solution to that, that everybody is happy. That doesn't really happen on any major project.

PT13 further considered if there should be a focus on the development of these capabilities at the undergraduate level, or perhaps as a continuing professional development (CPD) opportunity for early-career engineers:

> It's at what point do you bring in some of that education as well. Do you build them up to a point where they are technically proficient and then if they want to go further…like with CPD, you're constantly being educated professionally...If you go into a technical role, you get more specialised in the technical area, and if you go into a management role; you do an MSc in project management or whatever; how much do you prefer having them technically proficient at the start and then teach them with a certain amount of broader ethics and morality or whatnot.

PT15 indicated that he had hoped that *Engineers Ireland* would look towards a focus on the development of these abilities when setting accreditation criteria for the transition between levels 8 & 9 awards:

> That's what I had hoped when *Engineers Ireland* introduced this level 8 & level 9. I hoped that that's what they were going to do. That we were going to get a combination of the soft skills with the hard skills. But all they seem to have done is…it hasn't happened.

In aligning with the viewpoints expressed by research participants during the first field research stage, PT12 noted her belief that philosophical debates do not arise within engineering education. She expressed the view that this resulted from the prioritisation of scientific knowledge within engineering. She believed that this was due to the focus on providing technical solutions, as opposed to engaging in a philosophical debate about the merits of such solutions. PT12 further pointed to the potential benefit of exposing all second-level students to sociology and the humanities, as she believed that this would be to the benefit of society in general, and not just the discipline of engineering:

> To me, accepting what you said about science, I do think that at secondary school level we have to cover it across the board. Because it doesn't just affect engineers, it affects doctors, and it affects everyone else…that they would do some form of bigger vision about what goes on in the world and start asking themselves questions about what is going on in the world. So that would mean that they would all have it and not just engineers.

PT16 agreed and emphasised the point that the second-level education system does not operate like this currently in Ireland:

> …but that is not how the education system operates, the education until now, it was very much don't be asking questions, you do what you are told.

PT16 also noted the benefit in introducing engineering students to philosophy and added the consideration that there may now be some space to do so with the increased use of learning technology potentially freeing up some class time.

5.8.1 A consideration of barriers to change

In considering the need to focus on the engineering students fostering communications capabilities within postgraduate programmes, PT12 noted that, while this might have been envisaged, it is not happening in practice:

> What happened though is you need any old level 9 to do it. That would be an ideal place for it. Because you're right, you do need to come out of it a technically proficient engineer when you walk out the door. You have to be technically proficient above all else.

As a means of potentially explaining why this may not have occurred, PT13 pointed to how, unusually, Ireland has only one professional body representing all engineering disciplines in Ireland and, as a result, it potentially dilutes its influence within individual disciplines:

> It is such a disparate discipline, though. Say we're all in *Engineers Ireland*. But you have nothing in common with a large proportion of the membership. So, it kind of dilutes everything. So, a lot of professions have very strong professional bodies; it's because they all basically do the same thing to a greater or lesser extent. Whereas with *Engineers Ireland*, it is everything from civil to environmental, electronic or mechanical. It is so disparate.

PT13 alluded to the structure of college programmes in North America which permit students to select from a wider range of elective modules, covering a diverse range of subject areas:

> In some US third-level courses, well, you only have to get so many credits. And an awful lot of your credits can be got for things like...say, philosophy and political science; it doesn't really matter what it is, you just have to get the credits. Well, would we rather have a system where after 3, 4 or 5 years, they are technically proficient and have a certain amount of background in those, and then they develop those other areas

in their careers? Or would you say you would like a more rounded (experience) in these aspects, but then you're going have to learn the technical stuff later.

5.9 Conclusion

This chapter presents findings to emerge from the first and second field research stages. The objective was to explore the positioning of engineering education and practice from the ethical and social responsibility perspectives.

The first field research stage involved completing a series of interviews with a range of participants involved in a variety of roles in engineering education and engineering practice. The second field research stage then involved a consideration of the themes to have emerged from the first stage, within a focus group setting.

The themes considered within the field research included: (a) exploring ethical arrangements in engineering education (b) consideration of ethics within engineering practice (c) community engagement and societal awareness in practice (d) consideration of alternative educational approaches. In this chapter, the positioning of ethics and social responsibility in engineering is explored within each of the above thematic domains.

What became apparent when coding the field research findings, was that there were highly contrasting perspectives presented within the initial series of interviews as compared to the views to emerge from the subsequent focus group. Within the individual interviews, some participants identified a wider social responsibility associated with engineering practice and, as a result, believed that this justified a prioritising and broadening of the treatment of ethics within engineering education. However, within the focus group, there was a broad characterisation of the engineer's work as being predominantly technically focused. An emphasis on technical problem solving became apparent within the group, with broader societal concerns then being presented as issues to be reflected on and dealt with by other interest groups outside of engineering. The tension that emerged within these debates then assumed real importance as the research evolved, in considering the challenges and opportunities associated with adopting a social responsibility approach to engineering education and practice.

Chapter 6: Analysis – engineering and social responsibility within the sustainability domain

6.1 Introduction

In this chapter, I consider the broad implications and significance of the findings from the empirical research data. As I alluded to in Chapter 1, the theoretical framing of this study emphasises the importance of the role of rationality and power in shaping contemporary engineering and how this then impacts on societal engagement within engineering education, when viewed under the guise of sustainability.

The themes considered in this analysis are: (a) the implications for engineering education and practice, resulting from the influences of instrumental/technocratic rationality in modernity which are evident within the research (b) the significant shaping effect on engineering education, resulting from professional body influences which, in turn, are shaped by a dominant market-driven societal paradigm (c) the resulting implications for the treatment of sustainability within engineering education and (d) as a follow-on from the three previous thematic considerations, an exploration of the implications of moving from an educational model, informed by neoliberal/modernity perspectives, towards a model based on sustainability.

As will become apparent in the analysis, each of these thematic considerations is interlinked and intertwined and provides a lens through which to view how these influences shape the treatment of sustainability within engineering education.

6.2 Dominance of Instrumentally/Technocratically Rational Thinking

What has become evident in this study is the impact of dominant instrumentally/technocratically rational thinking within contemporary engineering education and practice. The importance of this consideration is that this positioning helps to frame an understanding of how engineers envision their role within society. In terms of education, instrumental/technocratic rationality also influences the type of knowledge prioritised in engineering education. This is particularly important in both developing an understanding of the current ethical positioning of engineering education and engineering practice and, as will become evident later in the chapter, in considering the positioning of engineering education within the sustainability domain.

There was a contrast in viewpoints expressed within the individual research interviews and the focus group contributions. Substantive/reasoned perspectives, more openly recognising the social dimension of engineering, were more apparent in individual participant contributions whereas, technocratically/instrumentally rational positions were predominantly evident within the focus group. For example, such opposing rational positions were evident in the contrasting contributions relating to a project involving the construction of a bridge, which traversed a disadvantaged community in Kansas City. In considering the impact on the impoverished community, PT07 noted, that they (the members of the community) had no say in choosing a location for the bridge; she further added that the community 'hated this bridge, but it did help some people to get to work a lot faster'. Within the focus group, however, the consensus was that decisions, such as identifying locations for new infrastructure, are not for engineers to make. This viewpoint was represented, for example, by PT15 who noted that engineers were not generally involved in decisions such as, where a bridge is to be located but, importantly, did not find this positioning to be problematic. The contention here is that such positioning, informed by market-oriented values and instrumentally/technocratically rational thinking, is more evident in contemporary engineering. By contrast, PT07 adopted a more reasoned/substantive position when directing her concern towards the disadvantaged community impacted by the project while wryly observing the beneficial means-end outcome to the project in enabling people using the new bridge to get to work faster.

The assertion here, as was evident in Chapters 2 & 3, is that instrumental rationality and technocracy are currently dominant and instrumentally/technocratically rational thinking then informs how engineers engage with society. Instrumental/technocratic rational positioning was also evident in the professional body publications critiqued in Chapter 2. For example, such means-end thinking is evident in the following contribution from *Engineers Ireland* documentation, '[i]t is only by working together in collaboration with the engineering profession and industry partners that we will be able to achieve our ambition to improve society and encourage and educate future generations of engineers' (Engineers Ireland, 2016, p. 4). What is apparent here is that the professional body frames the ambition to *improve* society in collaboration with the engineering profession and industry. This positioning aligns, for example, with Bucciarelli's (2008) contention that engineering education is similarly framed by instrumental rationality, noting how it represents a profession that is apparently 'value-neutral [and] that we are all but *guns for hire*' (Bucciarelli, 2008, p. 13). There is congruence here too with the dominant market-driven societal paradigm, as alluded to in Chapter 3.

In their education, engineers predominantly learn to think analytically, with a dominant technical focus, leading to problems being deconstructed into parts to form solutions (Heywood, 2017). As was evident, for example, in the review of programme content in Chapters 2 & 3, the predominant instrumentally rational and technocratic focus within engineering programmes prioritises such narrowly framed approaches. There is a strong focus placed on *problem-solving*, with a lack of attention paid to *problem-framing* (Riley, 2012). This technocratic approach leads towards an engagement with social problems, in a manner that attempts to address such problems similarly to technical problems (Gunckel and Tolbert, 2018). Problems are dealt with by breaking them down into constituent parts and then integrating technology *solutions* as a means of controlling those parts. Such an approach is inappropriate in considering the 'wicked' problems often arising within the sustainability domain, which as I allude to in Chapter 3, potentially require approaches informed by systems thinking and broader social awareness. In aligning with this theme, a reductionist perspective was evident, for example, in a contribution of PT13, when considering how engineers focus their micro-ethical lens on technical problem-solving. Using a dam project, by way of example, PT13 conveyed a micro-ethical perspective in the following contribution '…if you're building a dam…is hydroelectricity good or not? …engineers involved in that are given a specific project…you can then look at the ethics within that'. In this comment, the focus of the practitioner's lens is directed towards the technical challenges of designing and constructing the dam; there is no perceived need to be involved in problem-framing. The lack of a focus on problem framing is a recurring theme to emerge from the review of engineering educational approaches in Chapter 2; there is little or no attention paid within engineering education to the underlying structures that define and shape their work (Riley, 2012). Any potential societal implications, including ecological concerns, are for *others* to consider. This reductionist technical focus was more commonplace in contributions within the focus group. For example, in considering how the location of a fictitious bridge, linking two previously unconnected communities, might be contentious from a societal standpoint, PT15 remarked that '…engineers are not trained to have an appreciation for what might be required to determine, for example, where a bridge might be located or indeed what the community impact of a bridge placement might be…we're not trained to make those decisions or to do that analysis…'.

This statement might be true in the context of current engineering education; however, what was apparent was the sense that it would be for *others* to consider the appropriateness of the bridge location. In the contribution from PT15, there is a sense of engineers being charged with responsibility for exclusively solving the technical aspects of the project, informed by instrumentally rational approaches. In problematizing such technocratic approaches in referring to a hydroelectric dam project, Gunckel and Tolbert (2018) note that, in solving the energy problem, the consequential ecological and societal impacts can potentially be missed in the initial cost-benefit analyses. Such narrow problem-framing aligns with the default technocratic positioning operationalised, in adopting instrumentally rational engineering approaches, as alluded to in Chapter 2.

Together with the consideration of ignored or unintended consequences of engineering actions, the other problematic aspect of such technocratic approaches is that by reducing problems to technical issues that can be managed and solved, the underlying causes of problems may never be identified and addressed (Gunckel and Tolbert, 2018). In this regard, in considering the logical problem-solving capabilities of engineers, PT03 described engineers as the problem-solvers *for* society, noting how '…the main population kind of tasks engineers with that challenge to come up with solutions towards the modern energy crisis…the world is broke, fix it, engineers'. Again, there is a sense of a decision-making approach, informed by technocracy, with a universally applied technological framework utilised for *solving* unsustainability problems.

6.2.1 Technocratic engagement with key discourses of modernity

So, what might the implications be for engineering practice, given the preferential default towards instrumentally/technocratically rational approaches, in terms of engagement with society? In Chapter 3, I explore key discourses of modernity including globalization, neoliberalism (Ritzer, 2003; Held and McGrew, 2007; Ritzer and Dean, 2015) and the subsequent reflexive modernity discourse (Beck, 1992; Giddens, 1999). I also explore the positioning of engineering in uncritically supporting globalization and neoliberal agendas (Riley, 2007; Vallero and Vesilind, 2007; Bowen, 2008). The contention here is that such positioning results from an ideological alignment between these key discourses of modernity, founded on instrumental rationality, and the dominant ideological positioning of contemporary engineering.

In Chapter 2, I note how engineers have been essential supporters of a paradigm of infinite growth (Karwat *et al.*, 2014); I also describe how engineering is a key and uncritical supporter of globalisation. In Chapter 2, for example, I refer to Riley's (2007) assertion that engineers are increasingly exposed to a range of sociological factors that create and perpetuate the globalization phenomenon. This uncritical support of development leads, for example, to large-scale engineering projects proving contentious in terms of their societal impacts in developing countries (Riley 2007; Robbins 2007; Baillie 2009; Nieusma and Riley 2010). Such thinking is particularly evident in the contributions from research participants in the focus group. PT14, for example, asserts that with increased trade, everybody benefits from the self-evidently beneficial progress.

Engineering is at the forefront of modernisation, a process of innovation that has become autonomous (Beck, 1996) and self-evidently necessary. In Chapter 2, in writing about the rapid global growth of the microelectronics industry, Smith *et al.* (2006) reflect on how our world is being transformed with little consideration of the downsides of this revolution. The downsides to which Smith *et al.* (2006) refer, include the environmental degradation and occupational health hazards associated with the high-tech manufacturing industry (Smith *et al.*, 2006). Such uncritical support for development gets to the core of reflexive modernity theory and, in particular, the risk society concept (Beck, 1992; 1996), as described in Chapter 3. There is a lack of consideration for potential unintended risks and consequences. In its place, there is an instrumentally rational and uncritical sense that there is an unquestionable benefit to society associated with development. Such thinking is also evident in the uncritical acceptance by *Engineers Ireland* of the benefits of the transformative growth described in Chapter 2. Such positioning reveals a lack of consideration as to whether or not such development is sustainable.

In a further observation on this theme within the focus group, PT13 noted how he believed that economic and social needs drive engineering and that engineering then implements what is required technologically. Engineering facilitates change, but '…investment decisions come from the outside'. PT13 further added, concerning building infrastructure, that '…the amount of infrastructure built is only what is sanctioned for funding, with decisions made concerning funding coming from outside'. In further expanding on this idea, and by way of example in referring to a hypothetical dam project, PT13 suggested that engineers get involved in designing and building such projects, but that they are not engaged at the philosophical level of whether or not hydroelectricity is good. He further added that '…most of the engineers involved in that are given a specific project…we are building a dam; you can then look at the ethics within that'. In reflecting on the underlying tension concerning this engagement process within engineering, PT12 questioned why engineers were not involved in the conversation before that. She questioned why engineering was not involved at that philosophical level, with those kinds of questions and, in the debate over whether 'something is good or bad for society'. In summary, PT12, noted from an instrumentally rational perspective, that engineers deliver solutions and that this tends to be the limit to the focus of the engineering role. In other words, she noted that 'engineers focus on making something happen technically; they are not involved in the political conversations.'

6.2.2 A potential tipping point: the emergence of substantive/reasoned perspectives

Importantly though, the evidence presented in this research points towards signs of emerging approaches that more fully embrace the social dimension that Nicolaou *et al*. (2017) identify as predominantly underrepresented currently in engineering education. This was evident in some of the educational approaches proposed in Chapter 2. As will be recalled, for example, the *Engineering and Society* course provided by Clarkson University, New York, allows students to explore how non-technical factors influence the development and integration of technology with society (DeWaters *et al.*, 2015). Similarly, an *Engineering, The Environment, and Society* course, provided at University of California, Berkeley, challenges students to look beyond the technical elements of their work and to recognize the deeply social and political nature of engineering questions (University of California, 2018).

There is a sense of a holistic sustainability philosophy influencing the thinking of PT07, in considering the tension between ecological concerns and project imperatives, when considering her mining project, '[s]o, like something that I've been dealing with recently, is that any kind of infrastructure and any engineering project needs mined materials…[s]o, what if you're mining from these beautiful areas and you're taking away these things that we'll never as humans get to see again'. The tension between ecological devastation and project imperatives, requiring the mining of materials to propel development raises a series of nuanced and interwoven considerations. A further example of approaches, informed by such thinking, was evident in the contributions of both PT07 and PT08 when considering the fictitious bridge project, linking two previously separated communities. In recognising the 'wickedness' of such problems, PT08 observed that there was a requirement to consider the multi-layered implications of the project, such as; '…it may mean like all of these different positive, negative, confusing [outcomes]… what I tried to push is, who should own that decision… [w]hy not let those that are going to be affected be the ones who own how it happens'. The perspectives adopted by both PT07 and PT08 contrasted sharply with the reductionist and instrumentally rational approach adopted by PT15, in considering this same scenario and as noted earlier in this chapter.

A further contribution, informed by a more nuanced understanding of the interplay between environmental transformations and social relations, was provided by PT02, who it will be recalled has a background in sociology. In considering the theme of social responsibility within engineering, PT02 alluded to micro-ethical approaches being both problematic and commonplace in engineering practice, noting the need for engineers '…to have a much fuller sense of their responsibilities for shaping a good society…'. PT02's argument here is that there is a justification for such repositioning, given the scale of the impact of engineering on society.

This study does not set out to uncover what might inform these varying and sometimes competing rationalities within engineering, but rather to acknowledge that they exist and that there is an inherent tension between them. The argument being that it is important to reveal and further explore these tensions when considering the future direction of engineering education. For PT07, who it will be recalled is a PhD student, currently based in the Global South, a key influencing factor in raising her social awareness of engineering endeavours was her postgraduate research on societal risk on infrastructure projects in the Global South. It was apparent, in this participant's engagement in the study, that macro-ethical perspectives were clearly evident in informing her contributions. PT07 readily acknowledged, however, that these were perspectives and dilemmas to which she had not been exposed in her undergraduate education, when noting that '…there really wasn't that much social or how to work with people…I did, some psychology courses like in leadership but they didn't really help me …'. She freely acknowledged that her awareness of the societal impact of engineering decision-making became much more apparent to her in her postgraduate studies and associated fieldwork.

In the context of this research, the importance of these emergent perspectives, recognising the social dimension of engineering, is that they offer a critique of the currently dominant reductionist and instrumentally rational educational approaches, informed by the dominant market-driven societal paradigm. The importance of these emerging perspectives, each of which runs counter to the dominant instrumentally rational educational approaches, will become apparent later in this chapter in the analysis of the benefits and challenges in adopting a sustainability approach within engineering education.

While there were emergent signs of more holistic sustainability perspectives, as evidenced by research participant contributions, little evidence has been uncovered pointing towards the adoption of such perspectives within engineering education or indeed, engineering practice. Unusually, in this regard, PT06, who it will be recalled is a practising engineer, provided an alternative perspective to the unquestioning acceptance of the merits of development and economic progress within engineering. In developing this theme, PT06 pointed towards some of the recent positive work being undertaken by his company, in aligning their business strategy to the *United Nation's Sustainable Development Goals* (United Nations, 2015). Although the approach is framed within the 'sustainable development' discourse which was critiqued in Chapter 3 owing to its problem-oriented sustainability rhetoric, the measure goes some way towards countering the instrumentally/technocratically rational approaches that currently dominate within contemporary engineering practice.

6.3 Power Dynamics and Expertise: maintaining the educational status quo

While the dominant instrumentally/technocratically rational means and methods evident in engineering are apparently 'value neutral', the research finds that the instrumental/technocratic rationalisation of engineering is not neutral, as it is imbued with the values of powerful interest groups (Brubaker, 1984). In this regard, the study has explored the powerful overarching influence that *Engineers Ireland*, as the professional representative body for engineers in Ireland, holds in shaping both engineering education and practice. It is evident too that the professional body is, in turn, shaped by the dominant market-driven societal paradigm, reflected in the critique of key discourses of modernity in Chapter 3.

The professional body reach spans across engineering education, engineering practice and also extends to providing engineering-related submissions and representations to government and official bodies, thereby helping to shape national policy. In Chapter 2, in critiquing professional body positioning, I explore how *Engineers Ireland* holds a dominant influence in shaping the engineering profession, both within engineering education and practice. In this regard, it was highly significant that no dissenting voices emerged from the research to contradict this characterisation of the professional body. This is apparent in the critical review of professional body publications included in Chapter 2. In critiquing that profound influence on engineering education and practice in Ireland, PT02 described it as follows: '…*Engineers Ireland* is like a God…I find this really remarkable as an outsider.' What PT02 is alluding to here is the sheer scale and breadth of the influence that *Engineers Ireland* maintains within engineering, across both education and professional practice. As it will be recalled from Chapter 2, in their role as the accrediting body for engineering programmes in Ireland, *Engineers Ireland* prescribes the programme learning outcomes to be achieved by accredited programmes. In so doing, there is a validation of the form of knowledge that is prioritised within engineering education. The learning outcomes are framed predominantly around instrumentally/technocratically rational perspectives. Effectively, the professional body prescribes the type of knowledge, and formative learning experiences deemed necessary to attain the title of *Chartered Engineer*. The validated educational formation is then followed by a period of professional development, which then creates the basis for attaining the title, a title which reveals instrumentally rational motivations:

> The Chartered Engineer is a practitioner of high ethical standards who is responsible for non-routine intellectual work: applying his/her engineering knowledge to provide solutions to complex problems. (Engineers Ireland, 2014b, p. 6)

A key argument here is that the privileging of certain kinds of knowledge is informed by the dominant engineering ideology, which, it will be recalled from Chapter 3, is informed by authoritative expertise. Furthermore, the privileging of micro-ethical perspectives views engineering as fulfilling a narrowly framed technocratic role in society. In so doing, there is a perpetuation of the currently dominant engineering ideology in the educational formation of future generations of engineers.

Additionally, as was evident also in the critique in Chapter 2, the professional body validates developmental learning via its continuing professional development (CPD) policy (Engineers Ireland, 2017a). In that regard, the definition of what the professional body recognises as CPD is instructive in considering what kind of knowledge is privileged:

> The systematic maintenance, enhancement and development of knowledge and skill, and the development of personal qualities necessary for the execution of professional and technical duties throughout the practising engineering professional's career. (Engineers Ireland, 2017a, p. 3)

Instrumentally/technocratically rational thinking is again apparent in the definition. Again, there is congruence here with the dominant engineering ideological conception developed in Chapter 3. As it will be recalled, this dominant engineering ideology is objective, instrumentally/technocratically rational, founded on expert-based knowledge, which is then manifested within bureaucratic settings.

It is important to recognise that professional body influences are particularly dominant in Ireland, given the overarching role upheld by *Engineers Ireland*, as the sole representative body for engineers in Ireland.

The contention here is that there is a profound bureaucratic influence maintained by *Engineers Ireland* in shaping the professional development of engineers, from their undergraduate education through to their attainment of the *Chartered Engineer* title and on to tracking their career professional development. As a result, the argument here is that *Engineers Ireland* deploys knowledge and training to 'advance their instrumentally rational steering capacities' (Maley, 2004, p. 83).

So how might this directional influence take hold? As I outline in Chapter 2, *Engineers Ireland* prescribes the accreditation criteria for engineering programmes in Ireland. Higher Education Institutions then interpret those requirements in the development of engineering programmes. Accreditation panels appointed by *Engineers Ireland* are then charged with responsibility for accrediting programmes. Interestingly, in the context of this research, and as noted in Chapter 2, programme outcome 'E' within the accreditation criteria, which focuses on ethics and social responsibility, is vaguely phrased. It cannot be described as being prescriptive and, as a result, it is open to wide interpretation. In considering this point, PT02 aptly questions how seriously *they* (the engineering schools) grapple with the interpretation of this learning outcome, in noting that the schools understand the need to address the ethical learning outcome, but that they are not sure how to do it. In vaguely framing this programme learning outcome, there is no clear vision provided by *Engineers Ireland*, concerning the positioning of engineering from an ethics and social responsibility perspective. The argument, in this study, however, is that an overall instrumentally rational directional tone is established by *Engineers Ireland* in their range of publications as critiqued in Chapter 2. The authoritative voice is evident, with any inferences to community interaction and engagement being, at best, muted. This is acknowledged in the following quotation referred to in Chapter 2, '[w]ithin Ireland, *Engineers Ireland* is the authoritative voice of the engineering profession on relevant national issues.' (Engineers Ireland, 2014b, p. 3).

There are also several examples of expertise, in terms of positioning, being evident in the publications, for example, the following quotation is but one example, '[a] community of creative professionals delivering solutions for society'. (Engineers Ireland, 2017b, p. 1). As I alluded to in Chapter 2, there is a sense of a one-way, expert-based communication process in this quotation. The argument here is that similar recurring statements and contributions from the professional body illustrates how the professional body then shapes engineering in Ireland. As was evident in Chapter 3, there is an ideological alignment between professional body and engineering practice positioning and the (instrumentally) rational and expert-based defending position of neoliberal perspectives, as alluded to by Hay (2004). There is too an alignment here with the dominant market-driven societal paradigm.

Instrumentally/technocratically rational perspectives, at the institutional level, and bureaucratic influences, evident in professional body publications, then influence how educators interpret the vaguely/openly phrased programme outcome 'E' in Engineers Ireland's accreditation criteria for professional titles (Engineers Ireland, 2014a). As evidenced by the consideration of programme content in Chapter 2, and in the various participant contributions, this leads to micro-ethical (Herkert, 2001) treatments being apparent in the engineering curriculum. It is also the case, based on the critique in Chapter 2 that the somewhat vague phrasing of the ethical and social responsibility programme outcome in the professional body accreditation criteria represents a minimal treatment of this aspect of the curriculum. As was apparent in the critique of curricula content, also included in Chapter 2, the response from higher education institutions is to then afford minimal curriculum coverage to these important themes. By way of example, this was represented by PT01's description of the treatment of ethics in his recently completed civil engineering honours degree programme, as being a consideration of 'how engineers carry themselves professionally and keep everything above board'.

Similarly, as I also note in Chapter 5, in considering her undergraduate civil engineering education in North America, PT07 describes how the educational approach was based around seminars and case studies. Furthermore, the subject treatment focused primarily on safety-related issues, as opposed to, what might have been a more holistic approach toward ethical engagement with society. As I allude to in Chapter 2, much has been written about the need to reconsider the treatment of ethics in engineering education, by reframing that treatment based on the adoption of dual micro and macro-ethical perspectives (Herkert, 2001; Conlon, 2013; Zandvoort *et al.*, 2013; Jamison *et al.*, 2014). The research suggests that the importance of this aspect of this study warrants further and ongoing consideration and will require active professional body engagement in the process, given the power and extent of their overarching influence.

Professional body reach also extends into engineering practice. As I also refer to in Chapter 2, the *Engineers Ireland* CPD Accredited Employer Standard (Engineers Ireland, 2012) and their Continuing Professional Development Policy (Engineers Ireland, 2017a) provide signposts as to what the professional body notes as important in shaping the development of graduate engineers. As I note in the chapter, there is a strong focus on the development of skills to fulfil professional and technical duties.

6.4 Sustainability and Engineering Education: held captive by a triality of constraints

There is linkage between the previously discussed discourse of globalisation and the discourse of sustainability, given that many of the global environmental problems, and in particular global climate change, are traceable to modernisation and economic development (Ritzer and Dean, 2015). However, ideologically, it is apparent that particular sustainability discourses are informed by totally different sets of principles and values (Bakari, 2013). As became evident in the analysis earlier in this chapter, globalisation is founded on instrumental rationality. As was also apparent in Chapter 3, there is congruence here with the ideological underpinnings of the 'sustainable development' culture. Ideologically, variants of sustainability philosophy, such as the sustainability-as-flourishing conception are founded on a different set of values and principles, based around a belief system that prioritises the flourishing of human and other life forms, with a focus on 'being' as opposed to 'having' (Fromm, 1976; Ehrenfeld, 2000).

As is evident in Chapter 2, however, educational approaches that have been adopted within the sustainability domain have predominantly placed a technocratic focus on solving known unsustainable/environmental problems. This is evident, for example, in the contribution from Nicolaou *et al*. (2017) in Chapter 2, pointing towards the 'reinforcing mechanisms facilitating the provision of disciplinary education aimed at producing technically proficient, employable graduates in which the social dimension is marginalized' (Nicolaou *et al.*, 2017, p. 13).

What has become apparent in this research, is that there is a preference for positivistic and objective epistemological approaches, informed by technocratic perspectives which focus on the solving of specific *problems* of sustainable development in a piecemeal manner, within existing political structures and using expert-based approaches (Gough and Scott, 2006). This point was emphasised in the contribution from PT02 in Chapter 5 when he noted structural restraints within the system '…our system is so structured in a sense, and there is a sort of problem with the way engineers see what engineering students need to cover'. This links to earlier research findings, both in the literature review and field research, which point towards the prominence of reductionist and instrumentally/technocratically rational perspectives seeking scientific/technological solutions for individual sustainability-related challenges. There is also a link here to the ethical positioning within the sustainability domain. As was evident in Chapter 2, there is a favouring of micro-ethical approaches (Herkert, 2001) and the adoption of individualistic, object world perspectives (Bucciarelli, 2008; Byrne, 2012). As was also evident in the chapter, such micro-ethical approaches within the curriculum are often framed around ethical case studies. As was noted in the chapter, selected case studies generally focus on the (micro) ethical dilemma faced by an individual engineer (Conlon, 2013). What is missed, however, is the broader (macro-ethical) context of the social, organisational and even political complexities of engineering practice (Bucciarelli, 2008). The argument here is that the ethical treatment of sustainability within contemporary engineering education is constrained by a triality of ideological, epistemological and power-related influences, as represented in Figure 6-1 below:

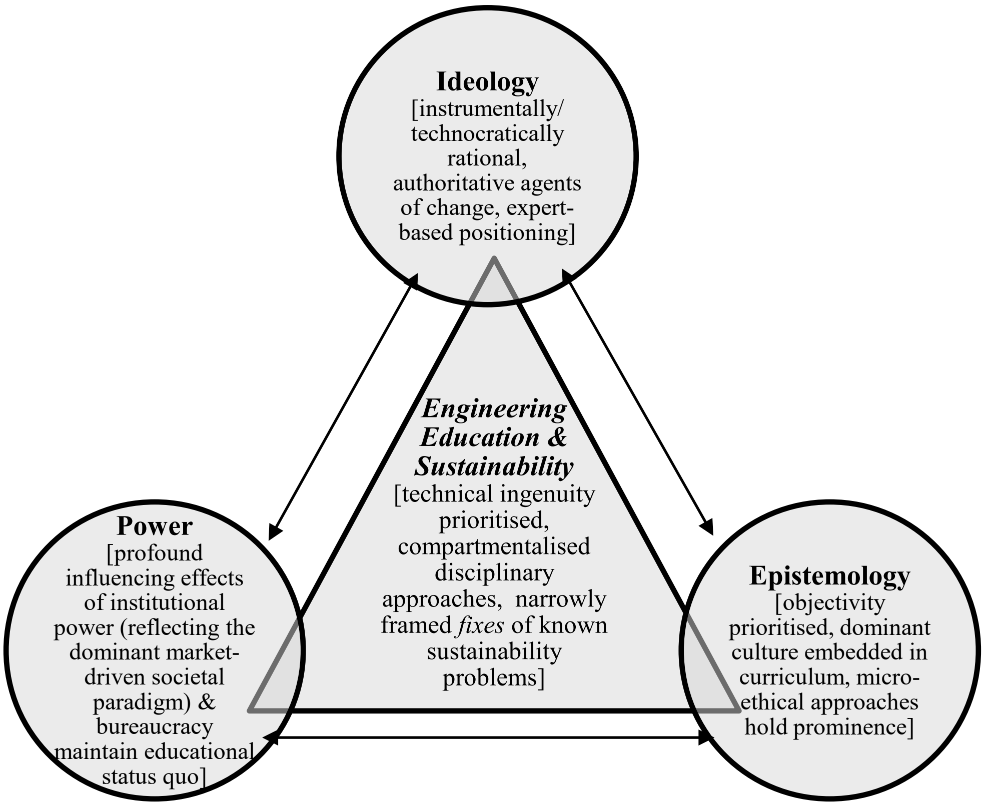


Figure 6-1: Engineering education & sustainability: captured within a triality of constraints

(Author's own figure)

So, what are we problematizing here? The assertion here is that the engineering curriculum is not value-free, as the ideological values and interests of dominant groups within engineering legitimise the type of knowledge included in the curriculum. In this regard, Giroux (1983) asserts that the dominant culture is not simply embedded in the form and content of knowledge, the hidden curriculum influenced by underlying norms, values and attitudes are transmitted tacitly within teaching modes. As was evident in the critique of professional body positioning, and indeed in the critique of the dominant societal paradigm explored in Chapter 3, there is a complex link between the curriculum and principles that structure similar modes of knowledge and social relations within larger society (Giroux, 1983). There is also the consideration of the influences of individual educators, with their epistemological preferences (Graham, 2012), which are, in turn, informed by ideological belief systems within engineering.

It is important too to note professional body influences and, to recognise the overarching position of power, authority and control that shapes engineering education. Here, it is important to acknowledge the societal influences which, in turn shape professional body policy perspectives. This is evident in the congruence in professional body policy perspectives with national and international policy positions in earlier chapters, each set firmly within the dominant market-driven societal paradigm. These constraining influences, in turn, impact upon potential curriculum development initiatives, with any changes to be negotiated within the triality of constraints depicted in Figure 6-1 above.

When viewed through a sustainability lens, dominant reductionist and technocratic perspectives seeking scientific/technological solutions for individual sustainability-related challenges are totally inadequate as a response to the scale, nature and interconnected complexity of those challenges. As was evident in Chapter 3, current dominant approaches, informed by a ‘sustainable development’ narrative fall well short of a transformative ‘paradigm shift’ that would be required to inform a truly sustainable educational philosophy (Sterling, 2001; Blewitt, 2012).

As Ryan and Murphy (2018) note, sustainability challenges such as climate change and global poverty and, indeed, other ‘wicked’ problems, are not just difficult to resolve but also to *define* and therefore new ways of perceiving those challenges are required. The dominant engineering approach, reliant on the adoption of narrowly framed objective perspectives, is misaligned with this call for more open and holistic ways of considering problem-framing and problem-solving within the sustainability domain. In this regard, in considering the ethical challenges confronted by young engineers called to work in the Global South, PT05, who it will be recalled is a professional body representative in the United Kingdom/Ireland region, acknowledged that ‘…there are all those types of local and social contexts that they won’t get exposed to in college’. Instrumentally/technocratically rational approaches are increasingly being questioned by the public, as is evident in the emergence of anti-globalisation movements (Riley, 2007; Vallero and Vesilind, 2007; Schlosberg and Coles, 2016) and the risk societal exploration contained in Chapter 3. While *reflexive modernization* (Beck, 1996; Giddens, 1999) results in modernity turning on and critiquing itself in response to phenomena such as climate change (Schlosberg and Coles, 2016), there is a call for reflexive responses from within engineering in considering the consequences, unintended or otherwise, of engineering decision-making within a sustainability context. In this regard, the sustainability-as flourishing philosophy, as advocated by Ehrenfeld (2008a) represents one such response, a response that would indeed represent a potentially transformative influence on sustainable education.

6.4.1 The emergence of green shoots: recognition of the sustainability exceptions

Earlier in this chapter, I allude to an evident tension between the contrasting rational positions uncovered within this study. While instrumentally/technocratically rational perspectives dominate, it was also apparent that substantive/reasoned approaches informed the contributions of some research participants. Whilst instrumentally/technocratically rational perspectives remain evident in the *Science, Technology and Society* (STS) studies and the *Education for Sustainable Development* (ESD) modules critiqued in Chapter 2, a somewhat limited emergence of macro-ethical approaches (Herkert, 2001) was also evident within the STS and ESD modules considered. For example, Byrne (2012) noted the responsibility towards future generations in requiring an 'enhanced level of commitment to social and ecological domains' (Byrne, 2012, p. 235), in the problem-based learning approach that he integrated in his teaching within the ESD subject area.

It was also evident, however, that where sustainability is addressed in engineering programmes, it is often siloed within a single module. In further evidence of the demotion of sustainability in terms of thematic importance, it was apparent in Chapter 2 that the module within which ESD themes are considered is often treated as optional or elective. The argument here is that this further neglect of sustainability within the engineering curriculum runs counter to its societal importance, especially given the increasing level of urgency associated with sustainability-related societal challenges.

6.5 Reimagining the Treatment of Sustainability within Engineering Education

In reimagining the treatment of sustainability within engineering education in what would amount to a transformative agenda, what is proposed here is that a paradigm shift in the thinking of, and approach to, engineering education is required. What I am pointing towards is a need to release engineering education from its current captivity under the triality of systemic, ideological and epistemological constraints alluded to earlier in this chapter. It is evident that current sustainability discourses are located predominantly within an economic/development mindset, with a focus on reducing unsustainability as opposed to truly embracing a holistic vision of sustainability.

This proposal for a transformative approach can only be tentatively offered here, given that such a change agenda has not received universal endorsement within this study. However, based on the evidence presented here, the argument is that a cogent and compelling case can be made for continuing the debate in considering the adoption of such a radical and transformative approach.

The call for developing this discussion is also justified, given the evidence presented, pointing to an urgent need to consider the failure of instrumentally/technocratically rational approaches as a means of solving the complex and interrelated sustainability challenges, with environmental degradation being but one of these pressing societal dilemmas. As became apparent in Chapter 3, there is also the emergence of complex and multi-dimensional risks, apparently manufactured through the industrial application of science and technology, together with the growing concern about the effects of globalisation, as evidenced by anti-globalisation responses that feature in Chapter 3. Each of these phenomena points towards a justifiable need for a fundamental change in engineering approaches. It is clearly unsustainable to engage with these challenges by adopting instrumentally/technocratically rational and non-reflexive expertise. It is totally unacceptable for us, as engineers, to look away and to maintain an apparently 'value-free' and instrumentally rational status quo. The argument being that the perspective adopted for example, by PT15, in sidestepping an ethical dilemma by concluding that '…the choice is, do you work on that or do you lose your mortgage...[o]r do your family go hungry?', is simply unacceptable and unsustainable. In response, there is a call for substantive and reasoned perspectives as a counter to engineers being seen as 'the hired gun doing the bidding of clients and employers' (Vesilind, 2010, p. 13). However, most engineers continue to uncritically believe in the power of technology to transform society while holding on to an errant assumption that technology is developed independently from society or political/cultural influences. PT02 described it succinctly, in noting such interconnectivity, by asserting that 'the big problem of engineering is that it sees itself as a technical activity, full stop. So, if you start at a different place by actually saying that engineering is a social and technical activity, you then start asking much bigger questions'. As I allude to previously, the societal challenges associated with sustainability require inter-sector, interdisciplinary and transboundary responses (Ryan and Murphy, 2018).

So, what might such a reimagined engineering education look like? It is not within the remit of this study to consider in detail the means to arrive at any reimagined engineering pedagogy. In broad terms, any proposed approach should acknowledge and challenge the constraining influences alluded to previously in this chapter whilst also offering a more holistic engagement with the education-for-sustainability discourse. In order to do so however, and in considering constraining influences, there is a requirement to develop teacher and learner understand of how power works through the production, distribution, and consumption of knowledge in order to constitute learners as informed subjects and social agents (Giroux, 2010). This creates a justification for a critical pedagogical approach (Giroux, 1983; Freire, 1996). There is a requirement to move away from the reductionist addressing of unsustainable practices, focused on technological 'fixes', and move towards the embracing of an ideal-state sustainability philosophy such as the sustainable-as-flourishing conception alluded to in Chapter 3. Given the underlying social constraints however this is not to underestimate the daunting challenge that this will represent. There is a call for critical thinking, reflection and reflexive approaches. On that note, in Chapter 4, I allude to the importance, in my research, of a praxis-based approach, involving reflection and reflexive action (Freire, 1996), when considering a transformation in the treatment of ethics in education. A recurring theme in the analysis in this chapter and elsewhere in this study, is the lack of critical thinking and reflexive practice amongst engineers, with a privileging of micro-ethical perspectives over macro-ethical approaches (Herkert, 2001). Critical thinking for Freire was not an object lesson in test-taking, but a tool for self-determination and civic engagement (Giroux, 2010). Given the triality of constraints conceptualised earlier in this chapter, there is a requirement to *go deep* to identify the underlying sociocultural barriers preventing a holistic integration of sustainability within engineering education (Nicolaou *et al.*, 2017). Critical pedagogy attempts to understand how power works through the production, distribution, and consumption of knowledge within particular institutional contexts and seeks to constitute students as informed subjects and social agents. Sustainability challenges, such as the ecological crisis our planet is currently facing, requires a reflective and reflexive focus on critical analysis and ethical positioning. The argument here is that this presents a compelling case for the adoption of ecological perspectives that oppose the globalisation of neoliberalism, thereby realising culturally relevant forms of knowledge within the sustainability domain (Kahn, 2010).

In an educational context, critical thinking about engineering brings meaning into the classroom, by drawing together practices of reflection and reflexivity within engineering (Claris and Riley, 2013). It provides a motivational context, creating a relationship between learners and engineering, unifying the personal, the technical, and the social. The contention here is that such a praxis-based approach would empower engineering students to develop a more holistic and comprehensive understanding of problems, beyond the deployment of technology *fixes* into more socially just and ecologically sensitive interventions (Karwat *et al.*, 2014). This approach would align more closely with what PT02 speculated might be required to more holistically meet the *welfare of society* ethical obligation, when asserting that '…the discussion is about whose problem is being solved, what criteria we are using to solve engineering problems and who benefits from engineering. I think that they are the three, from a social justice point of view they seem to be the key issue as to who benefits'? PT08 also noted the need for a more sophisticated praxis-based approach in considering ethics in engineering education and practice, noting that '…the codes of ethics are arcane and don't enable us to engage in more sophisticated conversations around ethics…[s]o, I think that there needs to be a little more engagement with why these exist, what they mean and how might one live this practice a little bit'.

This discussion illuminates the fundamental misalignment between the currently dominant ideological positioning within engineering, founded on instrumental/technocratic rationality, and positioning that will be required to fully embrace education for sustainability. There is a clear call here for transformative approaches informed by critical pedagogy and embracing substantive/reasoned perspectives. The argument here is that the engineering educational status quo is no longer remotely acceptable when considered from a sustainability standpoint. However, that is not to underestimate the significant challenge that will be involved in negotiating the triality of ideological, epistemological and power-related constraints if sustainable learning within engineering is to be transformed.

6.6 Conclusion

This study set out to consider the challenges and opportunities associated with adopting a social responsibility approach to engineering education and practice. In addressing this question, what has emerged from the research is a means of framing an understanding of power discourses and their influences on engineering education. The research also provides a lens through which to view how these influences subsequently shape contemporary engineering positioning within the sustainability domain.

What has become apparent, in analysing the empirical data to emerge from this research, is the profound shaping influence of instrumental/technocratic rationality on engineering education and practice. Furthermore, there is a powerful professional body shaping effect on engineering education, with influences of institutional power and bureaucracy maintaining control of the kind of knowledge privileged in engineering education. It is important too, to emphasise here that professional body positioning is shaped by the underlying sociocultural perspectives that hold prominence in modernity, based on market-driven capitalist values. Epistemologically, contemporary education prioritises technical rationality in solving well-defined problems, adopting means and methods informed by positivist thinking. The contention here is that engineering is held captive by this triality of constraints which, in turn, constrains curriculum change. As a result, and as will be recalled from Chapters 2 & 3, approaches to the treatment of sustainability within engineering education have, at best, been piecemeal (Gough and Scott, 2006). The approaches tend to be peripheral, with a predominant focus on the development of technical proficiency, with a further understated focus on the environmental dimension of sustainability (Nicolaou *et al.*, 2017). This contrasts with the more comprehensive approaches considered in Chapter 3, that frame education for sustainable development as needed to address the cognitive, social/emotional and behavioural interrelated dimensions of learning.

It is in the reimagining of how such a holistic approach towards sustainable education within engineering might be adopted, that the framing for understanding the constraining influences of power, ideology and epistemology becomes an important reference source. Such framing provides us with a lens through which to view how these influences ethically shape contemporary engineering positioning within the sustainability domain. It also points to the significant challenges associated with changing the status quo within engineering education, given the strength and power of these constraints. This creates the call for transformative and critical pedagogical approaches to interrogate and challenge these oppositional forces.

Chapter 7: Conclusion

7.1 Introduction

In completing this thesis, I have added to what has been very limited qualitative research conducted in Ireland to date, in focusing on the treatment of ethics in engineering education and practice. In the opening chapter, I note and recognise some particularly noteworthy exceptions, including research conducted by Conlon (2010; 2013; 2015), Byrne (2010; 2012) and Heywood (2008; 2016; 2017). Nonetheless, to date, the treatment of ethics and social responsibility within engineering remains an under-researched aspect of engineering education and practice in Ireland (Conlon, 2013; Heywood, 2017). As a result, this contribution is timely in considering the contemporary sustainability challenges, with resulting ethical implications for engineering, both in education and practice terms.

Sustainability underpins this study thematically, with the resulting requirement for engineering interventions that transcend boundaries and require joint responses from a range of stakeholders (Ryan and Murphy, 2018). This study points to this being a particular ethical challenge for both engineering education and engineering practice, given the present positioning of both, together with current professional body influences, set firmly within a dominant capitalist societal paradigm. It is also evident that this is an increasingly important consideration for engineering as contemporary societal risks, in areas such as environmentalism and sustainability, become increasingly impactful (Nieusma and Riley, 2010; Pelling *et al.*, 2015).

This chapter concludes the study by firstly providing a summary response to the research question. I follow this with a consideration of the overall contribution of this research. Finally, I provide some reflections that might guide future research in this area.

7.2 Addressing the Research Questions

In undertaking this research, I set out to address the following question:

> *What are the challenges and opportunities associated with adopting a social responsibility approach to engineering education and practice?*

In seeking to respond to this research question, the study has explored the extent to which social responsibility is addressed within engineering education and engineering practice, under a sustainability guise. In that exploration, the study has found that influences of power, epistemological preferences and ideological philosophies profoundly shape engineering education and how engineers engage with society, within the sustainability domain.

The research has also explored a potential call for approaches to professional engineering ethics within engineering education that recognise sustainability impacts beyond current disciplinary boundaries. In this regard, the level of support for such a call within the research is, at best, mixed. The research finds that instrumental/technocratic rationality are currently dominant, creating a block towards the more transformative practices necessary within the sustainability domain. This dominant ideology, underpinned by instrumentally/technocratically rational thinking, is upheld by authoritative bureaucratic structures and is manifested in objective, expert-based decision-making processes. The contention here is that this positionality leads to a problematic engagement of engineering within the sustainability domain, which has created the thematic backdrop for the study.

The research also finds that the powerful bureaucratic influence of *Engineers Ireland*, is highly significant in shaping education and engineering practice, was also evident in the study. The professional body upholds a powerful reach across engineering, from their programme outcomes control of the engineering curriculum (Engineers Ireland, 2014a), through to establishing the criteria to attain the professional title of *chartered engineer* (Engineers Ireland, 2014b). Professional body control then extends onwards to shaping the professional development of engineers throughout their careers, via their CPD policies (Engineers Ireland, 2017a) and in guiding ethical positioning in practice, via their code of ethics (Engineers Ireland, 2018a). Given this powerful position of influence, it is instructive then to consider what emerges, in terms of professional body positioning from the critique of *Engineers Ireland* publications. Again, we return to the prevalence of authoritative perspectives, emergent expertise and a distinct lack of consideration of seeing the public as co-owners of technology development and engineering decision-making. This mirrors the positional underpinnings of the currently dominant ideology within contemporary engineering, which in turn is set firmly within the dominant capitalist societal paradigm. The contention here is that, given this powerful professional body positioning, this represents a potentially significant barrier to any possible change that might be envisioned in response to this research. Alternatively, the professional body represents a potentially powerful source of support for repositioning subject to, what would amount to, a significant shift in professional body thinking and alignment.

The research also reveals the need for transformative and critical pedagogical approaches in considering the ‘wicked’ problems often manifest within the sustainability domain. What is clear, based on the critique of current engineering education, is that learners are currently not exposed to such transformative practices within their engineering education. This was also evident in the contributions of those who might more fully recognise the macro-ethical dimension to engineering practice and, indeed, to those whose positioning appeared to be aligned with exclusively micro-ethical thinking. This leads to a consideration of whether or not the study substantiates a call for approaches to professional engineering ethics, which recognise impacts beyond current disciplinary boundaries, in addressing sustainability concerns. The evidence of support for such a call emerging is, at best, mixed. However, in recognition of the contributions favouring such a response, I tentatively propose an ideological repositioning of engineering, as a counter to the dominant engineering ideological conception, developed in Chapter 3. It is proposed that such a repositioning would provide a basis for further explorative debate and discussion in further considering the repositioning of engineering within the sustainability domain. My intention in proposing such repositioning is to create a more holistic, critical and multidimensional engagement of engineering with society. I do so to support interdisciplinary approaches in solving complex global sustainability problems (Ryan and Murphy, 2018). Figure 7-1 illustrates the components of a proposed reflexive engineering ideology (Robbins, 2007; Ehrenfeld, 2008a; Riley, 2012; Conlon, 2015):

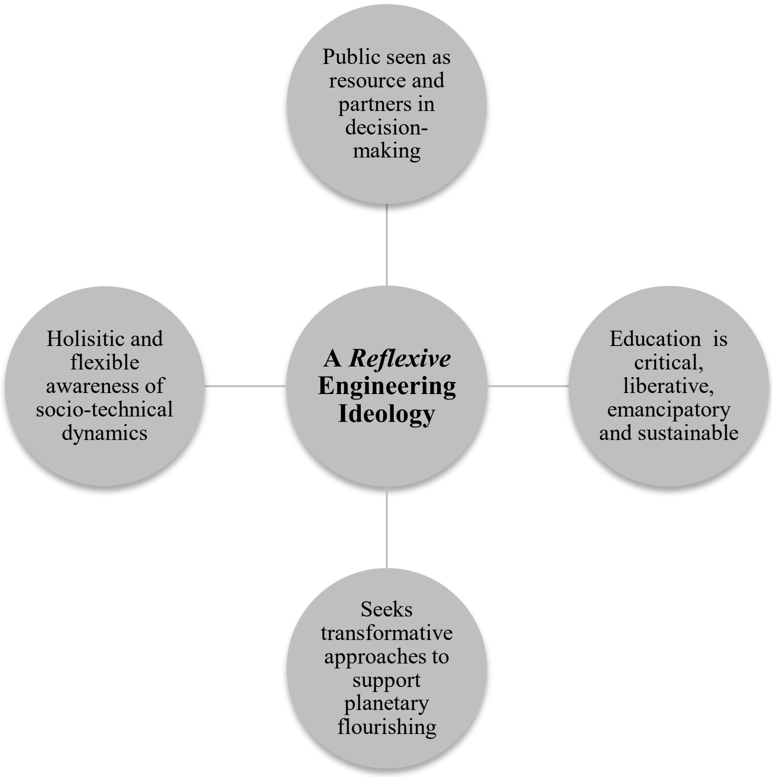


Figure 7-1: A Reflexive Engineering Ideology
(Author's own figure)

This explorative study validates aspects of this ideological reframing. There was, for example, broad agreement on the view that educational approaches should be adopted to introduce more participatory community engagement in engineering education. In contrast, I note in Chapter 3 that the dominant engineering ideology is objective, instrumentally/technocratically rational and founded on expert-based knowledge, manifested within bureaucratic thinking and thereby creating a block to professional autonomy.

In the context of my research, my teaching practice and my previous work in engineering practice, I described in earlier chapters how I am drawn towards praxis-based (Freire, 1996) approaches. On a similar theme, Giroux (2004) asserts that teaching in classrooms, or in any other public sphere, should both honour the experiences students bring to such sites and connect their experiences to 'specific problems that emanate from the material contexts of their everyday life' (Giroux, 2004, p. 84). The argument here is that it is this form of reflective practice or *praxis,* which would, if embraced within engineering education, be of significant value in reimagining the ethical positioning of engineering in society. I propose, subject to further debate, that such repositioning would focus on participatory practices, together with the more reasoned consideration of the interrelationship of technology and society. The contention here is that this would reposition engineering to more appropriately engage within risk society debates (Beck, 1992), given that the dominance of technoscience is nowhere more apparent than in the concept of the risk society (Loon, 2002). Given the societal importance of these contemporary issues, the contention here is that engineering needs to be at the centre and leading these debates.

The study also finds that the engineering curriculum is not 'value-free', as the ideological values and interests of dominant groups, within engineering and wider society, legitimise the type of knowledge included in the curriculum. As a response to this finding, the study calls for a consideration of critical pedagogical approaches to challenge dominating and constraining influences while supporting the fostering of social responsibility and civic engagement (Giroux, 2010). There is also a call for transformative approaches that recognise the need to transcend boundaries within the sustainability domain (Ryan and Murphy, 2018).

The contention here is that, in broad terms, any proposed approach should be informed by a reflexive engineering ideology. Proposed approaches should address the three interwoven and the three overlapping dimensions of holistic learning, including the cognitive, the social and emotional and the behavioural, within the sustainability domain (UNESCO, 2019). This is not to understate the challenges of integrating such an approach, given the requirement to negotiate such curriculum change within the triality of constraints of instrumentally rational/technocratic ideological influences, profound shaping effects of power and bureaucracy and epistemological preferences for reductionist objectivity.

7.3 Research Contribution

In setting out to complete this research, I had anticipated that it would be a relatively straightforward dialogic engagement within the engineering community, in considering a reframing of the ethical positioning of engineering education and engineering practice. I then encountered challenges and barriers that I now recognise, in hindsight, are symbolic of the current positioning of ethics within engineering education. As a result, the key contribution to have emerged from this research is that it creates a framing for understanding power discourses and their influences on engineering education. As a response to the critique of a currently dominant engineering ideology, the research reveals a contrasting reflexive engineering ideology more appropriately framed for active participation within the sustainability domain. In considering such an ideological repositioning, the possibilities associated with adopting a social responsibility approach to engineering education and practice begin to emerge.

The theoretical framing of the study emphasises the importance of rationality and power in shaping engineering education and how this then impacts on societal engagement within engineering, when viewed under the guise of sustainability. It also provides a lens through which to view how these influences subsequently shape contemporary engineering positioning within the sustainability domain. What has been evident in the research is that these shaping effects significantly constrain curriculum change within engineering education.

This research is also timely in its execution when considering the increasingly important contemporary debates within the sustainability domain and, particularly so, in the context of the urgency of climate change concerns as evidenced, for example, by the recent rise of the Extinction Rebellion[23] movement.

7.4 Considerations for Future Research

It is my hope, for those considering the treatment of ethics within engineering education and engineering practice, that findings and recommendations to emerge from this study might be used as a reference source in exploring change initiatives. In acknowledging the formative nature of this research, I propose the following as potentially valuable and rewarding areas of future research and discussion:

- ❖ Given the importance of this debate within engineering, and noting the societal dilemmas previously referred to, there is an urgent need to continue and develop the discussion from this explorative stage. With that in mind and by way of example of one such initiative, I recently secured funding from the *National Forum for the Enhancement of Teaching and Learning in Higher Education* to host a seminar in 2021 entitled: *Engineering an Ethical Reboot: Embracing the Social Dimension of Engineering*. The target audience will be staff and students in higher education from a range of disciplines and backgrounds, including STEM (in particular those in engineering), social sciences, humanities, design,

[23] Extinction Rebellion was formed in early 2018 by people determined to reverse societal and political inaction on climate change. That year saw temperatures in the north of Norway top 30°C, and the UN released a scientific report warning that warming beyond 1.5°C will cause drought, crop failure, mass starvation, and societal collapse. Fraser, S. (2019) 'Extinction Rebellion: Who is The BMJ calling radical environmentalists?', *BMJ*, 365, l2256.

practising engineers and community-based decision-makers. The themes to be explored align with those to have emerged from this study.

- There is a requirement to research pedagogical approaches that might foster critical awareness amongst teachers and learners with a view towards challenging the constraining power/ideological/epistemological influences alluded to in this thesis. There is also a critical need to consider educational approaches towards fostering a reflexive engineering ideology. In this regard some further research themes have emerged from this study including: 1) identifying ways of fostering enhanced community and inter-disciplinary engagement, perhaps by means of multi-disciplinary community engagement projects, 2) considering the means to expose learners to 'wicked' sustainability dilemmas, perhaps again by the introduction of systems thinking and flourishing philosophies and, from a risk societal standpoint in and introducing a historical consideration of the implications of technology adoption within society, 3) exploring the means towards embracing a critical theoretical perspective within the curriculum, thereby enhancing learner reflective and reflexive capabilities whilst challenging institutional and societal norms.
- I note the powerful and influential role fulfilled by *Engineers Ireland* in shaping engineering education via its accreditation process. I also note how the bureaucratic reach of the professional body stretches across engineering education and practice, informed by instrumentally/technocratically rational perspectives. Further exploratory research, with the active participation of *Engineers Ireland*, focusing on considering how the professional body's Accreditation Criteria (Engineers

Ireland, 2014a) and Code of Ethics (Engineers Ireland, 2018a) might be reframed, in response to this explorative research, would be beneficial in informing further debate. Such research should also consider further influences of the dominant market-driven societal paradigm on professional body positioning.

- ❖ In considering the means towards fostering a reflexive engineering ideology, there is a requirement to explore professional development approaches for early-career engineers. There is also a requirement to research education and development approaches that might foster and develop such a philosophy.

7.5 And to Conclude…

This research captures a key historical moment within engineering education. What has been uncovered in the research is a depth and breadth of highly influential structural and agency imbued forces that perpetuate the status quo in engineering education, while also presenting potentially significant, oppositional barriers to change.

There are signs, evident within the research, of emergent educational practices, each of which is addressing, to varying degrees, some of the underlying deficiencies revealed in the research. The research partially validates the integration of more transformative and reflexive approaches within engineering education with the intention to embrace a more holistic and flourishing conception of sustainability. However, this is not to underestimate the challenges associated with introducing such approaches, given the powerful and overarching influences that maintain and perpetuate the currently dominant societal paradigm, informed by unsustainable market-driven/capitalist principles. As is evident in this study, the currently dominant engineering ideology, founded on instrumentally rational thinking, fits seamlessly and uncritically within this dominant societal paradigm, which the research finds is highly problematic from a sustainability perspective.

This represents an early stage in this important debate; indeed, we may be on the cusp of a paradigm shift in thinking and approaches, given how sustainability-related challenges are taking on increasing levels of urgency and societal importance. The perpetuation of current engineering educational practices and, the privileging of apparently (but mistakenly) value-neutral knowledge, focusing on instrumentally rational means and methods, is, I argue, no longer remotely fit for purpose when considered within the sustainability domain.

.

References

Abbott, A. (1988) *The System of Professions: An Essay on the Division of Labor*, University of Chicago Press.

Accreditation Board for Engineering and Technology (2019) *Criteria for Accrediting Engineering Programs, 2019-2020*, available: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2019-2020/ [accessed 30 July 2019].

Alcott, B. (2005) 'Jevons' paradox', *Ecological Economics*, 54(1), 9-21.

Amadei, B. (2014) *Engineering for Sustainable Human Development : A Guide to Successful Small-Scale Community Projects*, Reston, United States: ASCE.

American Educational Research Association (2011) *Code of Ethics*, available: http://www.aera.net/Portals/38/docs/About_AERA/CodeOfEthics(1).pdf [accessed 19 September 2018].

Apple, M.W. (2004) *Ideology and curriculum*, 3rd ed., New York: Routledge Falmer.

Bacon, C.M., Mulvaney, D., Ball, T.B., Melanie DuPuis, E., Gliessman, S.R., Lipschutz, R.D. and Shakouri, A. (2011) 'The creation of an integrated sustainability curriculum and student praxis projects', *International Journal of Sustainability in Higher Education*, 12(2), 193-208, available: http://dx.doi.org/10.1108/14676371111118237.

Baillie, C. (2009) 'Engineering and society: Working towards social justice, part I: Engineering and society' in Baillie, C., ed., *Synthesis lectures on engineers, technology and society*, San Rafael, CA: Morgan and Claypool.

Baillie, C. and Levine, M. (2013) 'Engineering Ethics from a Justice Perspective: A Critical Repositioning of What It Means To Be an Engineer', *International Journal of Engineering*, 2(1), 10-20.

Bakari, M.E.-K. (2013) 'Globalization and Sustainable Development: False Twins?', *New Global Studies*, 7(3), 23-56.

Beck, U. (1992) *Risk society: Towards a new modernity*, Sage Publications.

Beck, U. (1996) 'Risk Society and the Provident State' in Lash, S., Szerszynski, B. and Wynne, B., eds., *Risk, Environment and Modernity: Towards a New Ecology*, London;Thousand Oaks, California: Sage Publications.

Beck, U. (1997) 'Global Risk Politics', *Political Quarterly*, 68(B), 18-33, available: http://dx.doi.org/10.1111/j.1467-923X.1997.tb02851.x.

Beck, U. (2010) 'Climate for change, or how to create a green modernity?', *Theory, Culture & Society*, 27(2-3), 254-266.

Beever, J. and Brightman, A.O. (2016) 'A principlist approach for thinking about the social impacts of engineering', in *ASEE Annual Conference & Exposition*, New Orleans, Louisiana.

Blewitt, J. (2012) 'Radicalizing education for sustainability', *Schumacher Institute Challenge Paper*, available: https://research.aston.ac.uk/en/publications/radicalizing-education-for-sustainability [accessed 12 June 2020].

Borne, D.G. (2010) 'Sustainable Development: Representing a Reflexive Modernity Inside the United Nations', *Journal of Global Analysis*, 1(1), 27-50.

Bowen, W.R. (2008) *Engineering ethics: Outline of an aspirational approach*, Springer Science & Business Media.

Brante, T. (2011) 'Professions as Science-Based Occupations', *Professions and Professionalism*, 1(1), 4, available: http://dx.doi.org/10.7577/pp.v1i1.147.

Braun, V. and Clarke, V. (2006) 'Using thematic analysis in psychology', *Qualitative Research in Psychology*, 3(2), 77-101, available: http://dx.doi.org/10.1191/1478088706qp063oa.

Brint, S. (2015) 'Professional Responsibility in an Age of Experts and Large Organizations' in *Professional Responsibility* Springer, 89-107.

Brookfield, S. (2005) *The power of critical theory for adult learning and teaching*, Maidenhead, Berkshire, England; New York: Open University Press.

Brubaker, R. (1984) *The limits of rationality: an essay on the social and moral thought of Max Weber*, London; Boston: Allen & Unwin.

Brundtland, G.H. (1987) *Report of the World Commission on environment and development: our common future*, Oslo: United Nations.

Brunel University (2019) *Programme Specification Leading to: BEng/MEng (Hons) Civil Engineering*, available: https://www.brunel.ac.uk/about/quality-assurance/documents/programme-specifications/BEng-Civil-Engineering.pdf [accessed 29 July 2019].

Bucciarelli, L.L. (2008) 'Ethics and engineering education', *European Journal of Engineering Education*, 33(2), 141-149, available: http://dx.doi.org/10.1080/03043790801979856.

Burns, H.L. (2015) 'Transformative sustainability pedagogy: Learning from ecological systems and indigenous wisdom', *Journal of Transformative Education*, 13(3), 259-276.

Byrne, E., Mullally, G. and Sage, C. (2016) *Transdisciplinary perspectives on transitions to sustainability*, Routledge.

Byrne, E.P. (2010) 'Teaching engineering ethics and sustainability', in *Engineering Education for Sustainable Development 2010 Conference (EESD'10). Gothenburg, Sweden, 19-22 September 2010.*, Engineering Education in Sustainable Development.

Byrne, E.P. (2012) 'Teaching engineering ethics with sustainability as context', *International Journal of Sustainability in Higher Education*, 13(3), 232-248, available: http://dx.doi.org/10.1108/14676371211242553.

Byrne, E.P. and Fitzpatrick, J.J. (2009) 'Chemical engineering in an unsustainable world: Obligations and opportunities', *Education for Chemical Engineers*, 4(4), 51-67.

Canney, N. and Bielefeldt, A. (2015) 'A framework for the development of social responsibility in engineers', *International Journal of Engineering Education*, 31(1B), 414-424.

Cech, E.A. (2013) 'The (mis) framing of social justice: Why ideologies of depoliticization and meritocracy hinder engineers' ability to think about social injustices' in *Engineering Education for Social Justice* Springer, 67-84.

City University London (2019) *Bachelor of Engineering in Civil Engineering: course content and assessment*, available: https://www.city.ac.uk/__data/assets/pdf_file/0003/474960/USCIVB-USCIVE-BEng-Hons-Civil-Engineering-incl-with-placement.pdf [accessed 30 July 2019].

Claris, L. and Riley, D. (2013) 'Situation Critical: Critical Theory and Critical Thinking in Engineering Education [Career Advisor]', 7(Generic), 32-36.

Cohen, L., Manion, L. and Morrison, K. (2000) *Research methods in education*, New York; London: RoutledgeFalmer.

Colby, A. and Sullivan, W.M. (2008) 'Ethics teaching in undergraduate engineering education', *Journal of Engineering Education*, 97(3), 327-338, available: http://dx.doi.org/10.1002/j.2168-9830.2008.tb00982.x.

Conlon, E. (2010) 'Towards an Integrated Approach to Engineering Ethics', in *International Symposium for Engineering Education*, Cork, Ireland.

Conlon, E. (2013) 'Broadening Engineering Education: Bringing the Community In: Commentary on "Social Responsibility in French Engineering Education: A Historical and Sociological Analysis"', *Science and Engineering Ethics*, 19(4), 1589-1594, available: http://dx.doi.org/10.1007/s11948-013-9476-x.

Conlon, E. (2015) 'A critical realist approach to engineering ethics', in 2015;2016;, IEEE, 1-6, available: http://dx.doi.org/10.1109/ISTAS.2015.7439443.

Conlon, E. and Zandvoort, H. (2011) 'Broadening ethics teaching in engineering: Beyond the individualistic approach', *Science and Engineering Ethics*, 17(2), 217-232.

Consiglio, A. (2014) 'Construction Workers' Lives Hang in the Balance', *The Cambodia Daily*, 20 Nov 2014, available: https://www.cambodiadaily.com/news/construction-workers-lives-hang-in-the-balance-72679/ [accessed 19 July 2018].

Creswell, J.W. and Miller, D.L. (2000) 'Determining validity in qualitative inquiry', *Theory into practice*, 39(3), 124-130.

Crotty, M. (1998) *The foundations of social research: meaning and perspective in the research process*, Thousand Oaks, California; London: Sage Publications.

Cumming-Potvin, W., Baillie, C. and Bowden, J.A. (2013) 'Engineering for social and environmental justice: Scaffolding knowledge during collaborative writing journeys', *International Journal for Infonomics (IJI)*, 1(1), 811-817.

Denzin, N.K. and Lincoln, Y.S. (2011) *The Sage handbook of qualitative research*, Thousand Oaks, California: Sage.

Department of Education and Skills (2014) *'Education for Sustainability' The National Strategy on Education for Sustainable Development in Ireland, 2014-2020*, available: https://www.education.ie/en/Publications/Education-Reports/National-Strategy-on-Education-for-Sustainable-Development-in-Ireland-2014-2020.pdf [accessed 15 May 2020].

DeWaters, J., Halfacre, J., Moosbrugger, J., Chapman, E. and Wultsch, E. (2015) 'Enhancing the experience of first-year engineering students with an entry-level STS course: Science-technology-society', in 2015, IEEE, 1-8, available: http://dx.doi.org/10.1109/FIE.2015.7344285.

Dirlik, A. (2007) 'Global South: Predicament and Promise', *The Global South*, 1(1), 12-23, available: http://dx.doi.org/10.2979/GSO.2007.1.1.12.

Donnelly, R. and Boyle, C. (2006) 'The Catch-22 of engineering sustainable development', *Journal of Environmental Engineering*, 132(2), 149-155.

Durkin, R.J. (2016) 'Experiential Learning in Engineering Technology: A Case Study on Problem Solving in Project-Based Learning at the Undergraduate Level', *Journal of Engineering Technology*, 33(1), 22.

Ehrenfeld, J.R. (2000) 'Colorless Green Ideas Sleep Furiously: Is the Emergence of" Sustainable" Practices Meaningful?', 1(4), 34-47.

Ehrenfeld, J.R. (2008a) *Sustainability by Design: A Subversive Strategy for Transforming Our Consumer Culture*, New Haven, Connecticut: Yale University Press.

Ehrenfeld, J.R. (2008b) 'Sustainability needs to be attained, not managed', *Sustainability: Science, Practice and Policy*, 4(2), 1-3, available: http://dx.doi.org/10.1080/15487733.2008.11908016.

Engineering Council (2014) 'The UK Standard for Professional Engineering Competence: Third edition'.

Engineers Australia (2019) *Code of Ethics and Guidelines on Professional Conduct*, available: https://www.engineersaustralia.org.au/ethics [accessed 22 June 2020].

Engineers Ireland (2012) *Engineers Ireland - CPD Accredited Employer standard*, available: http://www.engineersireland.ie/CPD-Training/CPD-Accredited-Employer-Scheme.aspx [accessed 12 February 2017].

Engineers Ireland (2014a) 'Accreditation Criteria for Professional Titles', available: http://www.engineersireland.ie/EngineersIreland/media/SiteMedia/services/accreditation/EngineersIrelandAccreditationCriteria2014.pdf [accessed 2 March 2018].

Engineers Ireland (2014b) *Regulations for the Registration of Professional Title*, Dublin, Ireland: Engineers Ireland.

Engineers Ireland (2016) *Engineers ireland - Strategy 2017-2020*, available: http://www.engineersireland.ie/EngineersIreland/media/SiteMedia/communications/publications/Engineers-Ireland-Strategy/Engineers-Ireland-Strategy-2017-2020.pdf [accessed 16 July 2018].

Engineers Ireland (2017a) *Continuing Professional Development Policy*, available: http://www.engineersireland.ie/EngineersIreland/media/SiteMedia/cpd/engineers-ireland-cpd-policy-document.pdf [accessed 16 July 2018].

Engineers Ireland (2017b) *CPD Accredited Employer Standard Quick Guide*, Dublin, Ireland: Engineers Ireland, available: http://engineersireland.ie/EngineersIreland/media/SiteMedia/cpd/employer-standard/CPD-Quick-Guide.pdf [accessed 13 October 2018].

Engineers Ireland (2018a) *Code of Ethics*, available: http://www.engineersireland.ie/EngineersIreland/media/SiteMedia/about/CodeOfEthics2018.pdf [accessed 13 July 2018].

Engineers Ireland (2018b) *Engineering 2018: A barometer of the profession in Ireland*, available: https://www.engineersireland.ie/EngineersIreland/media/SiteMedia/communications/publications/Engineering-2018-Report.pdf [accessed 22 December 2018].

Evetts, J. (2013) 'Professionalism: Value and ideology', *Current Sociology*, 61(5-6), 778-796, available: http://dx.doi.org/10.1177/0011392113479316.

Feenberg, A. (2017) 'Critical theory of technology and STS', *Thesis Eleven*, 138(1), 3-12, available: http://dx.doi.org/10.1177/0725513616689388.

Flick, U. (2009) *An introduction to qualitative research fourth edition*, London; Thousand Oaks, California: Sage.

Fraser, S. (2019) 'Extinction Rebellion: Who is The BMJ calling radical environmentalists?', *BMJ*, 365, l2256.

Freire, P. (1996) *Pedagogy of the oppressed*, New York; London: Penguin Books.

Fromm, E. (1976) *To have or to be?* , New York: Harper and Row.

Gergen, K.J. (1985) 'The Social Constructionist Movement in Modern Psychology', *American Psychologist*, 40(3), 266-275, available: http://dx.doi.org/10.1037/0003-066X.40.3.266.

Gergen, K.J. and Gergen, M. (2004) 'Social construction: Entering the dialogue'.

Giddens, A. (1971) 'Max Weber: Protestantism and capitalism' in Giddens, A., ed., *Capitalism and Modern Social Theory: An Analysis of the Writings of Marx, Durkheim and Max Weber*, Cambridge: Cambridge University Press, 119-132.

Giddens, A. (1999) 'Risk and responsibility', *The modern law review*, 62(1), 1-10.

Giroux, H.A. (1983) *Theory and resistance in education: a pedagogy for the opposition*, Exeter, New Hampshire: Heinemann Educational Books.

Giroux, H.A. (2004) 'Cultural Studies and the Politics of Public Pedagogy: Making the Political More Pedagogical', *Parallax*, 10(2), 73-89, available: http://dx.doi.org/10.1080/1353464042000208530.

Giroux, H.A. (2006) *America on the edge: Henry Giroux on politics, culture, and education*, 1st ed., New York: Palgrave Macmillan.

Giroux, H.A. (2010) 'Rethinking education as the practice of freedom: Paulo Freire and the promise of critical pedagogy', *Policy Futures in Education*, 8(6), 715-721.

Gough, S. and Scott, W. (2006) 'Education and sustainable development: a political analysis', *Educational Review*, 58(3), 273-290, available: http://dx.doi.org/10.1080/00131910600748026.

Graham, R.H. (2012) *Achieving excellence in engineering education: the ingredients of successful change*, Royal Academy of Engineering London.

Grant, G.B. (2012) 'Transforming sustainability', *Journal of corporate citizenship*, (46), 123-137.

Grasso, D. and Martinelli, D. (2007) 'Holistic Engineering', *Chronicle of Higher Education*, 53(28), B.8.

Guba, E.G. and Lincoln, Y.S. (1994) 'Competing paradigms in qualitative research' in *Handbook of qualitative research*, Thousand Oaks, California: Sage.

Guentzel, R.P. (2012) 'Modernity socialism vs orthodox Marxism: Ideological strife in the Party of Democratic Socialism (PDS), 1993-1999', *Historian*, 74(4), 705-724, available: http://dx.doi.org/10.1111/j.1540-6563.2012.00330.x.

Gunckel, K.L. and Tolbert, S. (2018) 'The imperative to move toward a dimension of care in engineering education', *Journal of Research in Science Teaching*, 55(7), 938-961, available: http://dx.doi.org/10.1002/tea.21458.

Gunderson, R., Petersen, B. and Stuart, D. (2018) 'A critical examination of geoengineering: economic and technological rationality in social context', *Sustainability*, 10(1), 269.

Gunderson, R., Stuart, D. and Petersen, B.J.N.P.E. (2019) 'The political economy of geoengineering as plan B: Technological rationality, moral hazard, and new technology', 24(5), 696-715.

Harvey, D. (2005) *A brief history of neoliberalism*, New York;Oxford;: Oxford University Press.

Harvey, D. (2007) 'Neoliberalism as Creative Destruction', *The Annals of the American Academy of Political and Social Science*, 610(1), 22-44, available: http://dx.doi.org/10.1177/0002716206296780.

Hay, C. (2004) 'The normalizing role of rationalist assumptions in the institutional embedding of neoliberalism', *Economy and Society*, 33(4), 500-527, available: http://dx.doi.org/10.1080/0308514042000285260.

Hayward, R.D. and Kemmelmeier, M. (2011) 'Weber Revisited: A Cross-National Analysis of Religiosity, Religious Culture, and Economic Attitudes', *Journal of Cross-Cultural Psychology*, 42(8), 1406-1420, available: http://dx.doi.org/10.1177/0022022111412527.

Held, D. (1990) *Introduction to critical theory: Horkheimer to Habermas*, 1 ed., Cambridge, United Kingdom: Polity Press.

Held, D. and McGrew, A.G. (2007) *Globalization/anti-globalization: beyond the great divide*, 2nd ed., Cambridge: Polity Press.

Hendricks, C. (2010) 'Inclusive Governance for Sustainability' in Browne, V. A., Harris, J. A. and Russell, J., eds., *Tackling wicked problems through the transdisciplinary imagination*, London, New York: Earthscan, 148-61.

Herkert, J.R. (2001) 'Future directions in engineering ethics research: Microethics, macroethics and the role of professional societies', *Science and Engineering Ethics*, 7(3), 403-414, available: http://dx.doi.org/10.1007/s11948-001-0062-2.

Herkert, J.R. (2005) 'Ways of thinking about and teaching ethical problem solving: Microethics and macroethics in engineering', *Science and Engineering*

Ethics, 11(3), 373-385, available: http://dx.doi.org/10.1007/s11948-005-0006-3.

Hess, D.J. (2007) *Alternative pathways in science and industry: activism, innovation, and the environment in an era of globalization*, Cambridge, Massachusetts: MIT Press.

Heywood, J. (2008) 'Philosophy and engineering education. A review of certain developments in the field', in 2008, IEEE, S4H-7-S4H-12, available: http://dx.doi.org/10.1109/FIE.2008.4720559.

Heywood, J. (2016) *The Assessment of Learning in Engineering Education*, Hoboken, New Jersey: John Wiley and Sons, Inc.

Heywood, J. (2017) 'The Human Side of Engineering', *Synthesis Lectures on Engineering*, 11(1), 1-166.

hooks, b. (1994) *Teaching to transgress: education as the practice of freedom*, New York: Routledge.

Horst, W.J.R. and Webber, M.M. (1973) 'Dilemmas in a General Theory of Planning', *Policy sciences*, 4(2), 155-169, available: http://dx.doi.org/10.1007/BF01405730.

Human Rights Watch (2015) *World Report 2015*, available: https://www.hrw.org/world-report/2015 [accessed 2018-03-19].

Institute of Mechanical Engineers (2016) *Big Ideas: the future of engineering in schools*: Institute of Mechanical Engineers, available: https://www.raeng.org.uk/publications/reports/imeche-big-ideas-report [accessed 3 March 2018].

Institute of Technology Carlow (2019) *Bachelor of Engineering (Honours) in Civil Engineering Course Outline*, available: https://www.itcarlow.ie/courses/type/undergraduate-cao-courses/built-environment-extended-campus-courses/cw478.htm [accessed 29 July 2019].

Institute of Technology Sligo (2019) *Bachelor of Engineering (Hons) in Civil Engineering: course outline*, available:

https://www.itsligo.ie/courses/beng-in-civil-engineering/ [accessed 30 July 2019].

International Labour Organisation (2012) *Decent Work Country Programme for Cambodia 2011-2015*, available: http://www.ilo.org/asia/countries/cambodia/WCMS_446090/lang--en/index.htm [accessed 13 April 2019].

Jamison, A. (2009) 'The historiography of engineering contexts', *Engineering in context*, 49-60.

Jamison, A. (2012) 'Turning engineering green: Sustainable development and engineering education' in *Engineering, Development and Philosophy* Springer, 7-21.

Jamison, A. (2013) 'The making of green engineers: Sustainable development and the hybrid imagination', *Synthesis Lectures on Engineering*, 8(1), 1-153.

Jamison, A., Kolmos, A. and Holgaard, J.E. (2014) 'Hybrid Learning: An Integrative Approach to Engineering Education', *Journal of Engineering Education*, 103(2), 253-273, available: http://dx.doi.org/10.1002/jee.20041.

John, A. (1986) 'Garraty, The Great Depression', *An inquiry into the causes, course, and consequence of the worldwide depression of the nineteen-thirties, as seen by contemporaries and in the light of history (San Diego/New York/London 1986)*.

Johnston, S.F. (2001) 'Towards culturally inclusive global engineering?', *European Journal of Engineering Education*, 26(1), 77-89, available: http://dx.doi.org/10.1080/03043790010008771.

Kahn, R.V. (2010) *Critical pedagogy, ecoliteracy, & planetary crisis: The ecopedagogy movement*, New York: Peter Lang.

Kalberg, S. (1980) 'Max Weber's Types of Rationality: Cornerstones for the Analysis of Rationalization Processes in History', *American Journal of Sociology*, 85(5), 1145-1179, available: http://dx.doi.org/10.1086/227128.

Karwat, D.M.A., Eagle, W.E., Wooldridge, M.S. and Princen, T.E. (2014) 'Activist Engineering: Changing Engineering Practice By Deploying

Praxis', *Science and Engineering Ethics*, 21(1), 227-239, available: http://dx.doi.org/10.1007/s11948-014-9525-0.

Kavanagh, D. (1990) *Thatcherism and British politics: the end of consensus?* , Oxford: Oxford University Press.

Kiely, R. (2005) *Empire in the age of globalisation: US hegemony and neoliberal disorder*, London; Ann Arbor, Michigan: Pluto.

Klein, N. (2007) *The shock doctrine: the rise of disaster capitalism*, London: Allen Lane.

Kline, R.R. (2001) 'Using history and sociology to teach engineering ethics', *IEEE Technology and Society Magazine*, 20(4), 13-20, available: http://dx.doi.org/10.1109/44.974503.

Kolb, D. (1984) *Experiential learning: Experience as the source of learning and development*, Englewood Cliffs, New Jersey: Prentice-Hall.

Kolmos, A., Hadgraft, R.G. and Holgaard, J.E. (2016) 'Response strategies for curriculum change in engineering', *International Journal of Technology and Design Education*, 26(3), 391-411, available: http://dx.doi.org/10.1007/s10798-015-9319-y.

Larson, M.S. (1979) *The rise of professionalism: A sociological analysis*, Berkeley, California: University of California Press.

Lash, S., Szerszynski, B. and Wynne, B. (1996) *Risk, Environment and Modernity:Towards a New Ecology*, London;Thousand Oaks, Calif;: Sage Publications.

Layton, E.T. (1986) *The revolt of the engineers: social responsibility and the American engineering profession*, Baltimore, Md: Johns Hopkins University Press.

Leydens, J.A., Lucena, J.C. and Schneider, J. (2012) 'Are Engineering and Social Justice (In)commensurable? A Theoretical Exploration of Macro-Sociological Frameworks', *International Journal of Engineering*, 1(1), 63-82.

Lock, A. and Strong, T. (2010) *Social constructionism: sources and stirrings in theory and practice*, Cambridge, UK; New York: Cambridge University Press.

Loon, J.V. (2002) *Risk and technological culture: towards a sociology of virulence*, London; New York: Routledge.

Lucena, J., Schneider, J. and Leydens, J.A. (2010) *Engineering and sustainable community development*, Morgan & Claypool.

Lynch, W.T. and Kline, R. (2000) 'Engineering Practice and Engineering Ethics', *Science, Technology, & Human Values*, 25(2), 195-225, available: http://dx.doi.org/10.1177/016224390002500203.

Maley, T. (2004) 'Max Weber and the Iron Cage of Technology', *Bulletin of Science, Technology & Society*, 24(1), 69-86, available: http://dx.doi.org/10.1177/0270467604263181.

Marcuse, H. (1989) 'From Ontology to Technology: Fundamental Tendencies of Industrial Society' in *S.E. Bronner and D. Kellner (eds) Critical Theory and Society: A Reader*, London: Routledge, 119-127.

Marcuse, H. (2013) *One-dimensional man: Studies in the ideology of advanced industrial society*, London: Routledge.

Mason, J. (2002) *Qualitative researching*, 2nd ed., Thousand Oaks, California; London: Sage Publications.

McGhee, P. and Grant, P. (2019) 'Sustainability-as-flourishing: teaching for a sustainable future', *Social responsibility journal*, ahead-of-print(ahead-of-print), available: http://dx.doi.org/10.1108/SRJ-03-2019-0095.

Michelfelder, D., Michelfelder, D., Jones, S.A. and Jones, S.A. (2013) 'Sustaining Engineering Codes of Ethics for the Twenty-First Century', *Science and Engineering Ethics*, 19(1), 237-258, available: http://dx.doi.org/10.1007/s11948-011-9310-2.

Mol, A.P.J. and Spaargaren, G. (2000) 'Ecological modernisation theory in debate: A review', *Environmental Politics: Ecological Modernisation Around the World Perspectives and Critical Debates*, 9(1), 17-49, available: http://dx.doi.org/10.1080/09644010008414511.

Murphy, M. (2009) 'Bureaucracy and its limits: accountability and rationality in higher education', *British Journal of Sociology of Education*, 30(6), 683-695, available: http://dx.doi.org/10.1080/01425690903235169.

National Society of Professional Engineers (2019) *NSPE Code of Ethics for Engineers*, available: https://www.nspe.org/resources/ethics/code-ethics [accessed 22 June 2020].

Newberry, B. (2004) 'Engineering globalization: oxymoron or opportunity?', in 2004, IEEE, 29-35, available: http://dx.doi.org/10.1109/ISTAS.2004.1314322.

Newberry, B. (2007) 'Are engineers instrumentalists?', *Technology in Society*, 29(1), 107-119.

Nicolaou, I., Conlon, E. and Bowe, B. (2017) 'Into the Deep: The Role of Paradigms in Understanding Engineering Education for Sustainable Development', *Irish Journal of Social, Economic and Environmental Sustainability*, 1(2), available: http://dx.doi.org/doi.org/10.21427/jcxh-gb46.

Nieusma, D. (2015) 'Conducting the instrumentalists: a framework for engineering liberal education', *Engineering Studies,*, 7(2-3), 159-163.

Nieusma, D. and Riley, D. (2010) 'Designs on development:Engineering, globalization, and social justice', *Engineering Studies,*, 2(1), 29-59, available: http://dx.doi.org/10.1080/19378621003604748.

Nussbaum, M. (2003) 'Capabilities as Fundamental Entitlements: Sen and Social Justice', *Feminist Economics*, 9(2-3), 33-59, available: http://dx.doi.org/10.1080/1354570022000077926.

O'Sullivan, E., Morrell, A., O'Connor, M.A. and MyiLibrary (2002) *Expanding the boundaries of transformative learning: essays on theory and praxis*, New York: Palgrave.

Ormrod, J.S. (2013) 'Beyond World Risk Society? A Critique of Ulrich Beck's World Risk Society Thesis as a Framework for Understanding Risk Associated with Human Activity in Outer Space', *Environment and Planning D: Society and Space*, 31(4), 727-744, available: http://dx.doi.org/10.1068/d16511.

Ozaktas, H.M. (2013) 'Teaching Science, Technology, and Society to Engineering Students: A Sixteen Year Journey', *Science and Engineering Ethics*, 19(4), 1439-1450, available: http://dx.doi.org/10.1007/s11948-011-9329-4.

Pelling, M., O'Brien, K. and Matyas, D. (2015) 'Adaptation and transformation', *Climatic Change*, 133(1), 113-127.

Pellow, D.N. and Brulle, R.J. (2005) 'Power, justice, and the environment: toward critical environmental justice studies', *Power, justice, and the environment: A critical appraisal of the environmental justice movement*, 1-19.

Polimeni, J.M., Mayumi, K., Giampietro, M. and Alcott, B. (2012) *The jevons paradox and the myth of resource efficiency improvements*, London: Earthscan.

Ponomarev, S. (2014) 'Migrant workers, in their tiny apartment in Abu Dhabi', *The New York Times*, 2014-05-18, available: https://www.nytimes.com/2014/05/19/nyregion/workers-at-nyus-abu-dhabi-site-face-harsh-conditions.html [accessed 27 March 2018].

Preston, C.J. (2013) 'Ethics and geoengineering: reviewing the moral issues raised by solar radiation management and carbon dioxide removal', *Wiley Interdisciplinary Reviews: Climate Change*, 4(1), 23-37, available: http://dx.doi.org/10.1002/wcc.198.

Qureshi, A.S. and Nawab, A. (2013) 'The Role of Engineers in Sustainable Development', in *Proceedings of the Symposium on Role of Engineers in Economic Development and Policy Formulation, Lahore, Pakistan*, 105-114.

Rae, J. and Volti, R. (2001) *The engineer in history*, New York: Peter Lang.

Ray, L., Reed, M., Ray, L. and Reed, M. (1994) *Organizing Modernity : New Weberian Perspectives on Work, Organization and Society*, London: Taylor & Francis Group.

Redman, E.J. (2013) 'Advancing Educational Pedagogy for Sustainability: Developing and Implementing Programs to Transform Behaviors', *International Journal of Environmental & Science Education*, 8(1), 1-34.

Riley, D. (2007) 'Resisting neoliberalism in global development engineering', in *114th Annual ASEE Conference and Exposition, 2007, June 24, 2007-June 27, 2007*.

Riley, D. (2008) 'Engineering and social justice', *Synthesis Lectures on Engineers, Technology, and Society*, 3(1), 1-152.

Riley, D. (2012) 'We've Been Framed! Ends, Means, and the Ethics of the Grand(iose) Challenges', *International Journal of Engineering*, 1(2).

Riley, D. and Lambrinidou, Y. (2015) 'Canons against cannons? Social justice and the engineering ethics imaginary', in *ASEE Conferences*.

Ritchie, J., Lewis, J., Nicholls, C.M. and Ormston, R. (2013) *Qualitative research practice: A guide for social science students and researchers*, London: Sage.

Ritzer, G. (1975) 'Professionalization, Bureaucratization and Rationalization: The Views of Max Weber', *Social Forces*, 53(4), 627-634, available: http://dx.doi.org/10.1093/sf/53.4.627.

Ritzer, G. (2001) *Explorations in Social Theory : From Metatheorizing to Rationalization*, London; Thousand Oaks, California: Sage.

Ritzer, G. (2003) 'Rethinking Globalization: Glocalization/Grobalization and Something/Nothing', *Sociological Theory*, 21(3), 193-209, available: http://dx.doi.org/10.1111/1467-9558.00185.

Ritzer, G. (2011) *Sociological theory*, 8th ed., New York: McGraw-Hill.

Ritzer, G. and Dean, P. (2015) *Globalization: a basic text*, Second ed., Malden, Massachusetts; Chichester, West Sussex: John Wiley & Sons, Inc.

Robbins, P.T. (2007) 'The reflexive engineer: perceptions of integrated development', *Journal of International Development*, 19(1), 99-110, available: http://dx.doi.org/10.1002/jid.1351.

Ryan, A. and Murphy, C. (2018) 'Reflexivity Practice and Transformative Learning' in Ryan, A. and Walsh, T., eds., *Reflexivity and Critical Pedagogy*, Leiden; Boston: Brill Sense, 67-87.

Ryan, A. and Walsh, T. (2018) *Reflexivity and Critical Pedagogy*, Leiden; Boston: Brill Sense.

Ryan, A.B. (2015) 'Methodology: Collecting Data' in Walsh, T. and Ryan, A., eds., *Writing your thesis: a guide for postgraduate students*, Maynooth: MACE Press, 117-137.

Saks, M. (2012) 'Defining a Profession: The Role of Knowledge and Expertise', *Professions and Professionalism*, 2(1), available: http://dx.doi.org/10.7577/pp.v2i1.151.

Santos, B.d.S. (2016) 'Epistemologies of the South and the Future', *From the European South: a transdisciplinary journal of postcolonial humanities*, (1), 17-29.

Schafer, K.J. (2018) 'A brief history of rationality: reason, reasonableness, rationality, and reasons', 41(4), 501-529.

Schlosberg, D. and Coles, R. (2016) 'The new environmentalism of everyday life: Sustainability, material flows and movements', *Contemporary Political Theory*, 15(2), 160-181, available: http://dx.doi.org/10.1057/cpt.2015.34.

Scott, A. (2013) 'Capitalism as culture and statecraft: Weber– Simmel–Hirschman', *Journal of Classical Sociology*, 13(1), 30-46, available: http://dx.doi.org/10.1177/1468795X12461411.

Scott, J. (1990) *A Matter of Record: Documentary Sources in Social Research*, Cambridge, UK: Polity Press.

Scott, J. (2005) *Social Theory : Central Issues in Sociology*, London: Sage Publications.

Sen, A. (1985) *Commodities and capabilities (Lectures in Economics: Theory, Institutions, Policy)*, Oxford: Oxford University Press.

Sen, A. (2004) 'Capabilities, Lists, and Public Reason: Continuing the Conversation', *Feminist Economics*, 10(3), 77-80, available: http://dx.doi.org/10.1080/1354570042000315163.

Shepherd, J.G. (2009) *Geoengineering the climate: science, governance and uncertainty*, London: The Royal Society Publishing.

Smith, T., Sonnenfeld, D.A. and Pellow, D.N. (2006) *Challenging the chip: labor rights and environmental justice in the global electronics industry*, Philadelphia: Temple University Press.

Spaargaren, G. (1997) 'The ecological modernization of production and consumption: essays in environmental sociology'.

Spitzer, H. (2013) 'Introduction of Interdisciplinary Teaching: Two Case Studies', *Science and Engineering Ethics*, 19(4), 1451-1454.

Stephens, J.C., Hernandez, M.E., Román, M., Graham, A.C. and Scholz, R.W. (2008) 'Higher education as a change agent for sustainability in different cultures and contexts', *International Journal of Sustainability in Higher Education*, 9(3), 317-338.

Sterling, S. (2001) *Sustainable Education: Re-Visioning Learning and Change. Schumacher Briefings*, Bristol: Schumacher Briefings.

Sterling, S. (2004a) 'An Analysis of the Development of Sustainability Education Internationally: Evolution, Interpretation and Transformative Potential' in Cullingford, C. and Blewitt, J., eds., *The Sustainability Curriculum: The Challenge for Higher Education*, London: Earthscan.

Sterling, S. (2004b) 'Higher education, sustainability, and the role of systemic learning' in *Higher education and the challenge of sustainability* Springer, 49-70.

Stern, N. (2007) *The Economics of Climate Change: The Stern Review*, Cambridge: Cambridge University Press.

Technological University Dublin (2019) *Bachelor of Engineering (Honours) Civil Engineering DT027: overview*, available: http://www.dit.ie/catalogue/Programmes/Details/DT027?tab=Overview [accessed 30 July 2019].

Toulouse, C. (1991) 'Thatcherism, Class Politics, and Urban Development in London', *Critical Sociology*, 18(1), 55-76, available: http://dx.doi.org/10.1177/089692059101800104.

UC Berkeley (2019) *Humanity and Social Studies Course Requirements*, available: https://engineering.berkeley.edu/academics/undergraduate-guide/degree-requirements/humanities-and-social-sciences [accessed 30 July 2019].

UNECE (2009) *Learning from each other: The UNECE Strategy for Education for Sustainable Development*, Geneva: UNECE.

UNESCO (2010) *Education for sustainable development lens: a policy and practice review tool*, available: https://unesdoc.unesco.org/ark:/48223/pf0000190898 [accessed 7 January 2020].

UNESCO (2012) *Shaping the education of tomorrow: 2012 report on the UN Decade of Education for Sustainable Development, abridged*, available: https://unesdoc.unesco.org/ark:/48223/pf0000216606 [accessed 7 January 2020].

UNESCO (2019) *Educational Content Closeup: examining the learning dimensions of Education for Sustainable Development*, UNESCO, available: https://unesdoc.unesco.org/ark:/48223/pf0000372327 [accessed 12 June 2020].

UNESCO (2020) *Sustainable Development Goals*, available: https://www.un.org/sustainabledevelopment/sustainable-development-goals/ [accessed 12 February 2020].

United Nations (2000) *The Millennium Development Goals*, available: http://www.unfoundation.org/what-we-do/issues/mdgs.html [accessed 28/05/2017].

United Nations (2015) *Sustainable development goals - United Nations*, available: http://www.un.org/sustainabledevelopment/sustainable-development-goals/ [accessed 28 June 2017].

United Nations (2019) *The Sustainable Development Goals*, available: https://www.un.org/sustainabledevelopment/sustainable-development-goals/ [accessed 04/01/19].

University College Cork (2019) *Civil, Structural and Environmental Engineering: course outline*, available: https://www.ucc.ie/en/ck600/civil/#course-outline [accessed 30 July 2019].

University of California, B. (2018) *Course Spotlight: Engineering, the Environment and Society*, available: https://americancultures.berkeley.edu/students/courses/spotlight-ac-courses/course-spotlight-engineering-environment-and-society [accessed 31 August, 2018].

University of Limerick (2019) *Bachelor of Engineering in Civil Engineering UL Undergraduate Courses*, available: https://www.ul.ie/courses/bachelor-engineering-civil-engineering [accessed 30 July 2019].

Vallero, D.A. and Vesilind, P.A. (2007) *Socially responsible engineering: Justice in risk management*, Wiley Online Library.

Vare, P. and Scott, W. (2008) 'Education for sustainable development: Two sides and an edge', *DEA Thinkpiece*.

Vaughan, D. (1996) *The Challenger launch decision: risky technology, culture, and deviance at NASA*, Chicago: University of Chicago Press.

Vesilind, P.A. (2002) 'Vestal Virgins and Engineering Ethics', *Ethics and the Environment*, 7(1), 92-101, available: http://dx.doi.org/10.1353/een.2002.0011.

Vesilind, P.A. (2010) *Engineering Peace and Justice: The Responsibility of Engineers to Society*, London: Springer.

Walker, M. (2005) *Higher education pedagogies*, United Kingdom: McGraw-Hill Education.

Walker, M. (2010) 'Critical Capability Pedagogies and University Education', *Educational Philosophy and Theory*, 42(8), 898-917, available: http://dx.doi.org/10.1111/j.1469-5812.2007.00379.x.

Walker, M. and McLean, M. (2015) 'Professionals and Public Good Capabilities', *Critical Studies in Teaching and Learning*, 3(2), 60-82.

Weber, M. (1968) *Economy and society (g. roth & c. wittich, eds.)*, New York: Bedminster Press.

Weber, M. (1978) *Economy and society: An outline of interpretive sociology*, Los Angeles: University of California Press.

Wilensky, H.L. (1964) 'The Professionalization of Everyone?', *American Journal of Sociology*, 70(2), 137-158, available: http://dx.doi.org/10.1086/223790.

Wilson, D. (2019) 'Exploring the Intersection between Engineering and Sustainability Education', *Sustainability*, 11(11), 3134, available: http://dx.doi.org/10.3390/su11113134.

Wolff, S. (2004) 'Analysis of documents and records' in Jenner, B., Flick, U., von Kardoff, E. and Steinke, I., eds., *A companion to qualitative research*, London: Sage.

Wrenn, M.V. (2015) 'Agency and neoliberalism', *Cambridge Journal of Economics*, 39(5), 1231-1243, available: http://dx.doi.org/10.1093/cje/beu047.

Zandvoort, H., Børsen, T., Deneke, M. and Bird, S.J. (2013) 'Editors' Overview Perspectives on Teaching Social Responsibility to Students in Science and Engineering', *Science & Engineering Ethics*, 19(4), 1413-1438, available: http://dx.doi.org/10.1007/s11948-013-9495-7.

Appendices

Appendix 1: Field Research Planning

ID	Representative Group	Invitation Date	Interview Date	Transcript Issued	Transcript Approved
PT04	Practitioner (Ireland)	14.04.18	04.07.18	31.07.18	05.08.18
PT06	Practitioner (Ireland)	14.04.18	24.07.18	29.07.18	31.08.18
PT10	Practitioner (Ireland)	12.07.18	24.08.18	25.08.18	17.09.18
PT09	Practitioner (Ireland)	07.08.18	13.08.18	22.08.18	28.08.18
PT03	Academic (Ireland)	14.06.18	21.06.18	09.08.18	10.08.18
PT02	Academic (United Kingdom/Ireland region)	16.04.18	18.06.18	08.08.18	09.08.18
PT08	Academic (US)	14.04.18	31.07.18	20.08.18	20.08.18
PT05	Institutional Body (United Kingdom/Ireland region)	14.04.18	12.07.18	13.08.18	17.08.18
PT11	Student (Ireland)	2.10.18	09.10.18	22.10.18	24.10.18
PT01	Student (Ireland)	18.05.18	21.05.18	20.06.18	02.07.18
PT07	Postgrad Student (US)	18.05.18	31.07.18	17.08.18	06.09.18
PT12	Academic (Focus Group)	27.11.18	10.12.18	07.01.19	14.01.19
PT13	Academic (Focus Group)	27.11.18	10.12.18	07.01.19	14.01.19
PT14	Academic (Focus Group)	27.11.18	10.12.18	07.01.19	14.01.19
PT15	Academic (Focus Group)	27.11.18	10.12.18	07.01.19	14.01.19
PT16	Academic (Focus Group)	27.11.18	10.12.18	07.01.19	14.01.19

Appendix 2: Research Interview Questions

Questions for Engineering Undergraduate Student:

1. How did you end up studying engineering?
    a. Are you happy with your choice and if not why not?

2. What do you see as the role of the engineer in society?

3. What responsibility do you think an engineer has to others in society?

4. As part of your programme have you considered if engineering impacts upon society?
    a. What is your view of this part of the programme?
    b. Is it effective?
    c. Is it viewed as maybe less important than other parts of the programme?
    d. Why/ why not?

5. In considering engineering practice, do you think that there are winners and losers (who gains and who loses out)?

6. What do you consider to be good ethical practice?

7. Where do you learn good ethical practice?

8. As part of your programme, have you had to consider dilemmas where the needs of community/society might be in conflict with those of your employer or client?

9. Is there anything else that you would like to add to this discussion?

Research Questions: Engineering Practitioner

1. How did you become an engineer? What is it about engineering that grabbed you?

2. What do you see as the positive aspects of practising as an engineer and are the sides to engineering practice that are less positive/welcome?

3. What was your engineering educational experience like?

4. How do you feel that ethics was covered in your engineering education?

5. Does knowledge of ethical practice in engineering originate from any other sources?
6. What do you see as the role of the engineer in society?
7. Is too much being asked of engineers in terms of social responsibility?
8. How do ethical codes impact on your practice in useful and perhaps not so useful ways?
9. In practising as an engineer have you been confronted with ethical dilemmas and if so, how have you dealt with such dilemmas? How did this make you feel?
10. Is there anything else that you would like to add to this discussion?

Research Questions: Academic Engaged in Engineering Education

1. Can you provide some background as to why you ended up in the field of engineering? What was it about engineering that grabbed you?
2. What do you see as the role of the engineer in society? Is too much being asked of engineers in terms of social responsibility?
3. Where do you see social responsibility occurring at the discipline level within engineering and in terms of professional practice?
4. What are your views on how professional imperatives are weighted against ethical concerns for newly qualified/practising engineers?
5. Are the themes of socially responsible engineering and the potential engineering impacts upon society covered in the curriculum currently and if so to what extent are these themes covered?
    - If your view is that these themes are not adequately covered, how do you think that social responsibility might be taught more effectively to engineering students [perhaps a mandatory standalone module or some other method?]?

6. Do you believe that engineering students gain an understanding of the nature of their interactions with the community/society in engineering practice?

7. Are professional codes of practice an effective tool in terms of promoting ethical and socially responsible engineering?

8. Is there anything else that you would like to add to this discussion?

Appendix 3: Stage 1 Field Research Coding Output – Open Coding

Name	Description	Files	References
Awareness within engineering of societal impacts	Commentary on how engineering should be viewed as a social and a technical activity leading to bigger questions being asked of the profession.	8	18
Benefits of informal education	Learning for learning sake; the perceived benefit of supplementary education outside of an assessment context.	1	4
Bridging communities	Interesting insights on how projects might be viewed more holistically in terms of societal impacts	3	3
Claims to authoritative knowledge	Commentary from one participant in relation to how engineers maintain their privileged position in society on the basis of their claim to perceived authoritative knowledge and truth.	1	1
Conflicting employer and societal demands		1	4
Constructors of the world	Commentary on the importance of the role of engineering in creating and developing the modern world	2	2
Critical thinking deficit	Commentary from one participant on a perceived critical thinking deficit within engineering education in the US.	1	1
Engaging in and with the community	Participant input in relation to community engagement within engineering pedagogy and in engineering practice.	5	11
Engineering programme accreditation demands	Commentary on engineering programme accreditation issues and constraints	2	5
Engineering viewed as an applied science	Development of problem solving capability is perceived to be a positive aspect of engineering training and practice during which the ability honed to take the complex and abstract and create something usable in society.	5	5

Name	Description	Files	References
Engineers and emotional intelligence	Contributors who pointed towards engineers generally lacking in emotional intelligence and that perhaps their education is not addressing this deficiency.	4	7
Environmental awareness	Motivation to support green agenda/improve the environment	6	10
Ethical awareness developed from other source(s)	Participant contributions on how ethical awareness of engineering students is also derived from other sources outside of their engineering programmes.	4	6
Ethical back door	One participant questioned the ethical merit of engagement in disaster relief, describing it as an 'ethical back door' as the urgent nature of the relief work negated the need for appropriate community engagement.	1	1
Feeding the robot	Comment from one participant on how ethical codes of practice can become a box ticking exercise thereby 'feeding the robot' and not requiring critical thinking or reflexivity.	1	1
Financial constraints	Project outcomes are often curtailed by financial constraints	2	3
Getting into the field	Contributions pointing towards the benefits of work placements within engineering programmes.	1	1
Guardians of technological progress	Commentary on the perceived powerful position maintained by engineers in shaping the world from a technological perspective.	2	6
Importance of teamwork	Participants viewed engineering as a social practice that requires extensive teamwork.	2	4
Inclusivity and engineering education	How inclusive is engineering education? Suggested strategies to increase inclusivity etc.	1	8
Integrating societal and engineering identities	If it is accepted that engineering has a social dimension does it not makes sense to try to integrate an engineer's societal and engineering identities?	4	12
Interdisciplinarity and engineering education	Commentary from participants who pointed towards the need to broaden engineering education to include interaction with other disciplines.	3	12
Is too much being asked of engineers	Insights from participants who were responding to a question relating to whether too much is being asked of engineers in terms of societal interaction.	3	4
Learner experiences within engineering education	Insights from learners concerning their experiences within engineering education.	3	7
Linking engineering pedagogy with sociology	Commentary from participants who perceived merits in broadening engineering pedagogy to include aspects of sociology	3	15

Name	Description	Files	References
Logical deduction privileged	Participant contributions on the theme of how engineering is framed from a positivist standpoint with fact-based and business oriented decision making dominates over an appreciation of the societal context	3	6
Making society a better place	Commentary from participants relating to motivations to study and practice and in the context of helping and improving society.	4	10
Morality and engineering	Commentary on situations where tensions may arise between business objectives and individual moral principles in practising engineering.	2	6
Narrowly framed community references	References to community in the Engineers Ireland publications research	2	14
Negative aspects of engineering	Summary of various negative aspects of engineering design and project execution	6	9
Part of the machine	Interesting insights on how engineering graduates might be shielded from societal engagement if employed in large corporations such as Google etc.	2	3
Perceived benefits of internships	Potential benefits of internships within an engineering education.	2	7
Perceived deficiency in learner input	Participant contributions on the extent (if any) that learners can influence their education in terms of module selection etc.	2	6
Personal and professional identities separated	Participants who perceived that the segregation between the professional and personal identities of engineers was unhelpful.	3	4
Public view of engineering	How does the public view the role of engineers and engineering in general?	2	3
References to the public within EI publications	References to the public in Engineers Ireland publications selected for review	5	42
Reflections on engineering programme content	Engineering education has been observed to be very focused on theory, there is also a perceived rigidity in terms of programme content	8	29
Regulatory compliance drivers	To what extent is the green agenda driven by regulatory requirements as opposed to aspirational motivations to improve the environment.	3	3
Reimagining engineering as caring profession	Consideration of the ethics of care and whether it fits within engineering	4	7
Responsiblity of engineers to shape a good society	What responsibility does the engineering profession have in terms of shaping a good society?	2	3

Name	Description	Files	References
Societal references within EI publications	References to interfaces of engineering with society drawn from Engineers Ireland publications	6	29
Society and technology co-determined	Research participant input in relation to the need for participatory deign and engineering practice when developing new technology.	4	8
Solvers of the energy crisis	Are engineers tasked with solving the energy crisis, do engineers take on this mantle based on the previously referenced claim to authoritative knowledge?	1	1
Study and career path influences	Participant commentary on influences when choosing engineering, factors when choosing a career in engineering	10	34
Studying history of engineering may be benficial.	Commentary from one participant concerning the potential benefits of studying the history of engineering in terms of gaining an appreciation of the historical social responses within engineering practice.	2	6
Tension between teaching and research commitments	Commentary from one research participant on pressures to privilege research output over teaching on commercial grounds.	1	5
The positioning of ethics in engineering education	How do participants perceive that ethics was covered within their engineering education?	9	44
The social dimension is silent	Commentary on a culture within engineering, which shapes how disciplines act and how the people within those disciplines are educated with the focus heavily placed on technology, mathematics and the sciences.	3	7
The social dimension of engineering	How does society perceive engineering? What is the potentially beneficial impact of E engineering on society.	10	77
The three paradigms in engineering education	One research participant proposed three paradigms within engineering; the scientific paradigm, the enterprise and business paradigm and the social paradigm.	1	3
Winners and losers	Participant input as to whether there are societal winners and losers as a result of engineering practice.	3	5

Appendix 4: Stage 1 Field Research Coding Output – Developing Themes

Name	Description	Files	References
Engineering educational insights	**Participant insights in relation to engineering pedagogy.**	10	97
Benefits of informal education	Learning for learning sake; the perceived benefit of supplementary education outside of an assessment context.	1	4
Engineering programme accreditation demands	Commentary on engineering programme accreditation issues and constraints	2	5
Inclusivity and engineering education	How inclusive is engineering education? Suggested strategies to increase inclusivity etc.	1	8
Interdisciplinarity and engineering education	Commentary from participants who pointed towards the need to broaden engineering education to include interaction with other disciplines.	3	12
Learner experiences within engineering education	Insights from learners concerning their experiences within engineering education.	3	7
Linking engineering pedagogy with sociology	Commentary from participants who perceived merit in broadening engineering pedagogy to include aspects of sociology	3	15
Perceived benefits of internships	Potential benefits of internships within an engineering education.	2	7
Perceived deficiency in learner input	Participant contributions on the extent to which learners can influence their education in terms of module selection etc.	2	6
Reflections on engineering programme content	Engineering education has been observed to have a predominant focus on theory, there is also a perceived rigidity in terms of programme content.	8	29
Studying history of engineering may be beneficial	Commentary from one participant concerning the potential benefits of studying the history of engineering in terms of gaining an appreciation of the historical social responses within engineering practice.	2	6
Tension between teaching and research commitments	Commentary from one research participant on pressures to prioritise research output over teaching on commercial grounds.	1	5
The positioning of ethics in engineering education	How do participants perceive that ethics was covered within their engineering education?	9	44
Three paradigms in engineering education	One research participant proposed that there were three paradigms within engineering education; the scientific paradigm, the enterprise and business paradigm and the social paradigm.	1	3
Engineering ideology & professional identities	**Engineering attributes and perspectives of research participants in this regard.**	10	31
Claims to authoritative knowledge	Commentary on how one participant perceived that engineers maintain their privileged position in society on the basis of their claim to perceived authoritative knowledge and truth.	1	1
Engineering viewed as an applied science	Development of problem solving capability is perceived to be a positive aspect of engineering training and practice during which the ability is honed to take the complex and abstract and create something usable in society.	5	5
Engineers and emotional intelligence	Contributors who pointed towards engineers perhaps lacking in emotional intelligence and that perhaps their education is not addressing this deficiency.	4	7
Guardians of technological progress	Commentary on the perceived powerful position maintained by engineers in shaping the world from a technological perspective.	2	6
Importance of teamwork	Participants viewed engineering as a social practice that requires extensive teamwork.	2	4
Logical deduction privileged	Participant contributions on the theme of how engineering is framed from a positivist standpoint with fact-based and business oriented decision making dominates over an appreciation of the societal context	3	6
Personal and professional identities separated	Participants who perceived that the segregation between the professional and personal identities of engineers was unhelpful.	3	4
Possible critical thinking deficit	Commentary from one participant on a perceived critical thinking deficit within engineering education in the United States.	1	1
The social dimension is silent	Commentary on a culture within engineering, which shapes how disciplines act and how the people within those disciplines are educated with the focus heavily placed on technology, mathematics and the sciences.	3	7

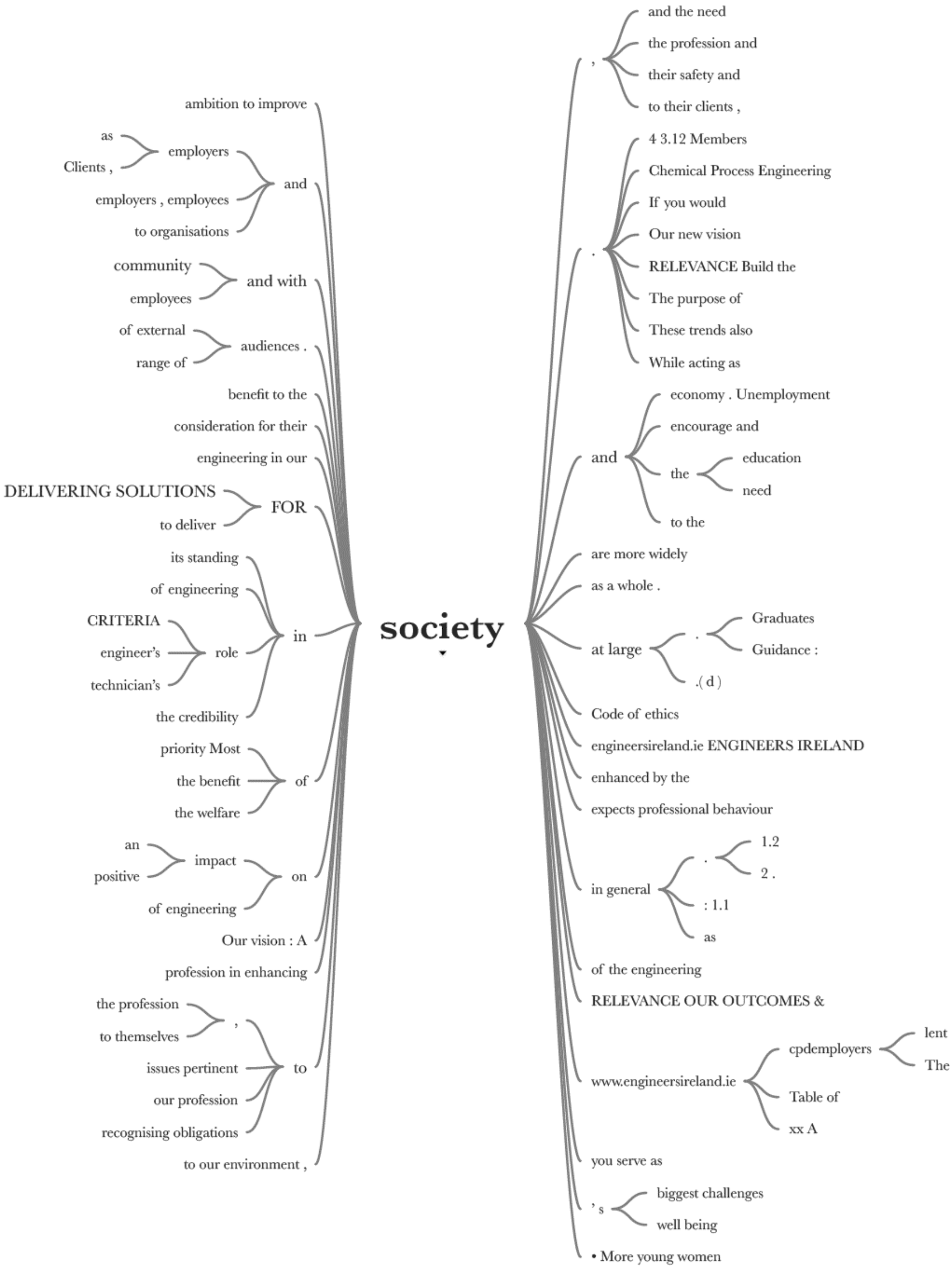
Name	Description	Files	References
Ethics within engineering practice	**Commentary on how ethical considerations may inform engineering practice.**	10	51
Ethical awareness developed from other source(s)	Participant contributions on how ethical awareness of engineers is also developed from other sources outside of their engineering practice.	4	6
Ethical back door	One participant questioned the ethical merit of engagement in disaster relief work, describing it as an 'ethical back door' as the urgent nature of the relief work negated the need for appropriate community engagement.	1	1
Ethical dilemmas in practice	Demands placed on engineering that create competing pressures and potentially ethical dilemmas/conflicting societal demands	5	16
Conflicting employer and societal demands		1	4
Financial constraints	Project outcomes are often curtailed by financial constraints	2	3
Negative aspects of engineering	Summary of various negative aspects of engineering design and project execution	6	9
Feeding the robot	Comment from one participant on how ethical codes of practice can become a box ticking exercise thereby 'feeding the robot' and not requiring critical thinking or reflexivity.	1	1
Morality and engineering	Commentary on situations where tensions may arise between business objectives and individual moral principles in practising engineering.	2	6
Participatory engineering bringing in the community	**To what extent does engineering engage with the community within engineering practice or engineering education?**	8	27
Bridging communities	Insights on how projects might be viewed more holistically in terms of societal impacts	3	3
Constructors of the world	Commentary on the perceived importance of the role of engineering in creating and developing the modern world	2	2
Engaging in and with the community	Participant input in relation to community engagement within engineering pedagogy and in engineering practice.	5	11
Getting into the field	Contributions pointing towards the benefits of work placements within engineering programmes.	1	1
Part of the machine	Interesting insights on how engineering graduates might be shielded from societal engagement if employed in large corporations such as Google etc.	2	3
Public view of engineering	How does the public view the role of engineers and engineering in general?	2	3
Reimagining engineering as caring profession	Consideration of the ethics of care and whether it fits within engineering	4	7
Winners and losers	Participant input as to whether there are societal winners and losers as a result of engineering practice.	3	5
Study and career path influences	**participant commentary on influences when choosing engineering, factors when choosing a career in engineering**	10	34
The Engineer in a society	**participants perceptions on engineering in relation to its ethical positioning in society**	11	103
Awareness within engineering of societal impacts	Commentary on how engineering might be viewed as a social and a technical activity leading to bigger questions being asked of the profession.	8	18
Integrating societal and engineering identities	If it is accepted that engineering has a social dimension does it not makes sense to try to integrate an engineer's societal and engineering identities?	4	12
Is too much being asked of engineers	Insights from participants who were responding to a question relating to whether too much is being asked of engineers in terms of societal interaction.	3	4
Making society a better place	Commentary from participants relating to motivations to study and practice and in the context of helping and improving society.	4	10
Society and technology co-determined	Research participant input in relation to the need for participatory design and engineering practice when developing new technology.	4	8
The social dimension of engineering	How does society perceive engineering? What is the potentially beneficial impact of engineering on society?	10	77
What responsibility do engineers hold to shape a good society	What responsibility does the engineering profession have in terms of shaping a good society?	2	3

Appendix 5: Stage 2 Field Research Coding Output – Focus Group Consideration of Emerging Themes

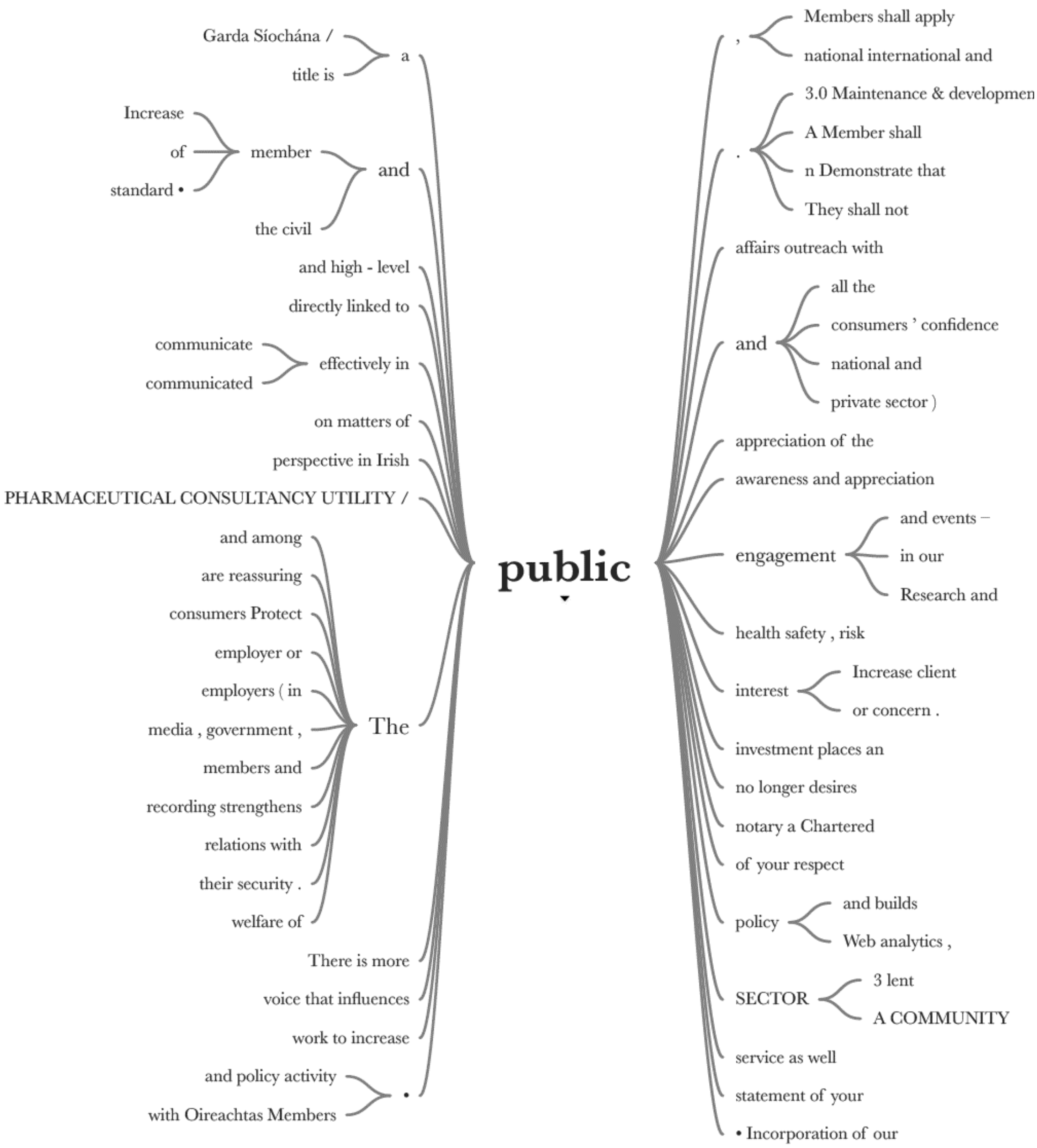
Name	Description	Files	References
01_Engineering ideology & professional identities	Engineering attributes and perspectives of research participants in this regard.	1	28
02_The Engineer in a society	Participant perceptions on engineering in relation to its ethical positioning in society.	1	16
03_Participatory engineering: bringing in the community	To what extent does engineering engage with the community within engineering practice or engineering education?	1	24
04_Consideration of an agenda for change	Participant proposals on potential changes to engineering pedagogy	1	27

Appendix 6: References to 'community' in EI Publications

Appendix 7: References to 'society' in EI Publications



Appendix 8: References to the 'public' in EI Publications



Appendix 9: Research Participant Information Sheet and Consent Form

Maynooth University Tier 2-3 Application form for Ethical Review

For office use only – Application reference number:

PARTICIPANT INFORMATION SHEET

Maynooth University
National University of Ireland Maynooth

Research Project Title

How might the ethical underpinning of an engineering education promote social justice?

Purpose of the Study

The overall aim of the proposed research is to explore the ethical positioning of the engineering profession and to assess to what extent it might currently promote socially just engineering solutions.

Why have you been invited to participate?

You have been invited to participate as you are currently a [practicing engineer] [academic responsible for engineering programme delivery] [representative of an engineering institutional body] [recent engineering programme graduate] [engineering programme undergraduate].

What will the study involve?

The study will involve participation in an interview. It is envisaged that the interview will take approximately 1 hour. During the interview you will be invited to reflect on your experiences in engagement with engineering as a [practicing engineer] [academic responsible for engineering programme delivery] [representative of an engineering institutional body] [recent engineering programme graduate] [engineering programme undergraduate]. You will be invited to talk openly about your experience. You may also be invited to participate voluntarily in a follow on focus group or focus groups. Interviews and focus groups will be audio-recorded and will take place at venues agreed with you in advance.

Do you have to take part?

You do not have to participate in this study. Participation is entirely voluntary. As a participant you will receive this Information Sheet and a Consent Form prior to the study commencing. You should read all the information carefully and may ask the researcher any questions which you have relating to the study. Having read all the information, if you are happy to partake in the study, you should sign and date two copies of the Consent Form. You will retain one copy of the form and the researcher will store the other copy securely.

You have the option of withdrawing before the study commences (even after having signed the Consent Form) and you may withdraw at any time during the study. Should you wish to withdraw at any stage, any data which you have shared to that point will be destroyed.

Note: Electronic Information sheets and consent forms will be encrypted and stored on a PC or secure server at Maynooth University whilst hard copy Information sheets and consent forms will be held securely in locked cabinets, locked rooms or rooms with limited access on campus.

Will the data be confidential?

A commitment to confidentiality will be upheld as it is a necessary part of the research process.

This right to confidentiality is an important, but not absolute, principle that the University strives to uphold in all its research activities.

Will the data you provide be anonymous?

Anonymity will be ensured at all times throughout the study. No clues as to your identity will appear in the thesis as names will be changed. Any extracts from what you have said in the interviews will be entirely anonymous, should they appear as quotes in the thesis.

Note: It must be recognized that, in some circumstances, confidentiality of research data and records may be overridden by courts in the event of litigation or in the course of investigation by lawful authority. In such circumstances the University will take all reasonable steps within law to ensure that confidentiality is maintained to the greatest possible extent.

What will happen to the information which you give?

The information you provide will be transcribed and you will be have an opportunity to review the transcription to see if it is an accurate reflection of what you said during the interview. You will be allowed change any aspect or redact any information with which you are not happy. In addition, you may ask questions about the study at any time following the interview sessions and may request at any time to have your transcript withdrawn as data from the study.

The information which you provide will be kept confidential for the duration of the study and will only be available to the researcher and the research supervisor. It will be securely stored. Electronic data collected will be encrypted and stored on a PC or secure server at Maynooth University whilst hard copy data collected will be held securely in locked cabinets, locked rooms or rooms with limited access on campus. Audio recordings collected on a mobile device will be encrypted where possible and the device password protected with a strong password. Data will be removed from the mobile device as soon as is practicable. Data will then be removed to a desktop PC or server in a secure location at Maynooth University. On completion of the study, the data will be retained for ten years and then securely destroyed.

What will happen to the results?

The results from the study will be presented as part of a doctoral thesis. They will be seen by the supervisor, second assessor and the external examiner(s) for the programme. The thesis may be publically available in the future and parts of it may be published in research journals and/or presented at conferences. No identifiable markers will be published.

What are the possible disadvantages of taking part?

No negative consequences are envisaged for you taking part in the study. However, it is possible that taking about your own particular experience may cause some individuals distress.

What if there is a problem?

When the interview is completed, you will be asked how you are feeling. If at that stage, or any subsequent time, you feel distressed in any way, you should contact the researcher, Eoin Homan, using the contact details below. You may also contact Dr. Theresa Lowry-Lehnen, nurse at the Institute of Technology Carlow, at 059 9175606 or at Theresa.lowrylehnen@itcarlow.ie.

Who has reviewed this study?

Approval for this study must be granted by Maynooth University Ethics Committee before a study like this can take place. If you need further information, you may contact me, Eoin Homan, at eoin.homan.2017@mumail.ie

Researcher Details:
Eoin Homan,
Doctoral Student,
Department of Adult and Community Education,
Maynooth University,
Maynooth, Co. Kildare.

Supervisor Details:
Dr. Michael Murray,
Department of Adult and Community Education,
Maynooth University,
Maynooth, Co. Kildare.
Email: michael.j.murray@mu.ie
Phone: (+353) 1 708 3591

INFORMED CONSENT FORM FOR STUDENT RESEARCH

Maynooth University
National University of Ireland Maynooth

In agreeing to participate in this study I understand the following:

The research is being conducted by Eoin Homan, doctoral student with the Department of Adult and Community Education. The research is being supervised by Dr. Michael Murray, Department of Adult and Community Education, Maynooth University. The method proposed for the research has been approved in principle by the Maynooth University Ethics Committee, which means that the Committee does not have concerns about the procedure itself as detailed by the student. It is, however, the above-named student's responsibility to adhere to ethical guidelines in their dealings with participants and the collection and handling of data.

Names and contact details of researcher (and academic supervisor):

Role	Name	Department	Email	Phone
Student	Eoin Homan	Dept. of Adult and Community Education	eoin.homan.2017@mumail.ie	
Supervisor	Dr. Michael Murray	Dept. of Adult and Community Education	michael.j.murray@mu.ie	(+353) 1 708 3591

- I have been informed in writing as to the general purpose and nature of the study. ☐ Yes ☐ No
- I am participating voluntarily. ☐ Yes ☐ No
- I have had the opportunity to ask questions about the study. ☐ Yes ☐ No
- I understand that if I have any concerns about participation I may withdraw at any stage, without repercussions. ☐ Yes ☐ No
- I understand that I will not benefit directly from participation in the study. ☐ Yes ☐ No
- I have been informed that the study will involve participation in interview sessions and that these interviews will be audio recorded. ☐ Yes ☐ No
- I understand that all data from the study will be treated confidentially and that no participant's data will be identified by name at any stage of the data analysis or in the final thesis. ☐ Yes ☐ No
- I understand that at the conclusion of my participation, any questions or concerns I have will be fully addressed. ☐ Yes ☐ No

- I have been informed that data from all participants will be compiled, analysed and submitted as part of a doctoral thesis to the Department of Adult and Community Education and that direct quotes may feature as part of the thesis. ☐ Yes ☐ No
- I understand that the data will be encrypted and stored on a PC or secure server at Maynooth University and that it will be deleted after ten years. ☐ Yes ☐ No
- I understand that there are no known expected discomforts or risks associated with participation. ☐ Yes ☐ No
- I understand that if during my participation in this study I feel the information and guidelines that I have been given have been neglected or disregarded in any way, or if I am unhappy about the process, I can contact the Secretary of the Maynooth University Ethics Committee at research.ethics@mu.ie or +353 (0)1 708 6019. I understand that my concerns will be dealt with in a sensitive manner. ☐ Yes ☐ No
- I understand that I may withdraw from this study at any time, and may withdraw my data at the conclusion of my participation if I still have concerns. ☐ Yes ☐ No

By signing below, I agree that I have read and understood the Participant Information Sheet and am participating in the study voluntarily.

Signed: ______________________________ Participant

______________________________ Researcher

______________________________ Date

Appendix 10: Outline Content for Sample Engineering Programmes in Ireland

B Eng (Hons) in Civil Engineering: (Institute of Technology Carlow, 2019)

CW478

NFQ LEVEL 8

Bachelor of Engineering (Honours)

Civil Engineering

Engineers Ireland Accredited

PLACES	POINTS	DURATION	EXIT AWARD	PROGRAMME DIRECTOR
32	390	4 YEARS	NO	Shane Murray BA (Hons), BAI, MSc, HCert, CEng, MIEI E: shane.murray@itcarlow.ie

What is Civil Engineering?

Civil engineering deals with the built environment and encompasses much of what defines modern civilization. Thus civil engineering is responsible for the development of buildings, transport networks, water provision, i.e. all the essentials we depend on. Increasingly the role of the civil engineer in developing sustainable solutions to challenges presented by climate change is becoming more important.

This course provides a blend of academic and practical training across all key civil engineering areas. The course features a strong practical element with students frequently working in our specialised materials, hydraulic and environmental laboratories and workshops.

A work placement module between Years 3 and 4 provides students with the opportunity to enhance their learning in working on real-life design or construction projects as part of a professional engineering team.

What will I be able to do when I finish the course?

Civil engineers can be found working in industries as varied as aerospace, ship building, energy, environment and many more where constructed facilities are involved. Graduates of this course will be qualified to:

- Work independently with contractors, consultants and local authorities in the areas of design and construction
- Identify problems in the field of civil engineering and provide viable solutions to those problems
- Collect, analyse and interpret relevant data
- Work in multi-disciplinary team situations
- Understand the need for the highest ethical standards in the practice of engineering profession.

Graduates may progress to an MSc in Management in the Built Environment or to a Research Masters or Doctoral studies at Institute of Technology Carlow.

What subjects will I study?

YEAR 1

Mandatory Subjects

Civil Engineering Technology
Surveying and Setting Out I
Physics and Chemistry
Engineering Drawing
Material Science
Soils Mechanics
Quantity Surveying and Estimating
Advanced Mathematics I

YEAR 2

Mandatory Subjects

Surveying and Setting Out II
Structures I
Civil Engineering Drawing I and BIM
Geotechnical Engineering I
Civil Engineering Economics and Management
Advanced Mathematics II
Earthworks Analysis

YEAR 3

Mandatory Subjects

Engineering Geology
Highway and Traffic Engineering I
Advanced Mathematics III
Structural Analysis I
Structural Design I
Environmental Engineering I
Hydraulics I

YEAR 4

Mandatory Subjects

Geotechnical Engineering II
Highway and Traffic Engineering II
Engineer in Society
Structural Analysis II
Structural Design II
Environmental Engineering II
Hydraulics II
Work Placement
Dissertation
Advanced Mathematics IV

Special features of this course

- Accredited by Engineers Ireland (EI) and graduates are eligible for membership of EI.
- The course emphasis is on geo-environmental specialities where civil engineering skills save money, resources and lives.
- Strong emphasis on 'hands-on' learning in our specialized civil engineering laboratories and workshops.
- Our lecturers are all Chartered Civil Engineers with many years of national or international experience.
- Our graduates are successful both in Ireland and around the world working in organisations such as ESB, Carlow Precast, WBHO Civil (Perth), PJ Hegarty & Sons, BAM Contractors, SISK Group.

- Micro-ethical treatment in misc. modules relating primarily to health and safety related issues.
- The 'Engineer in Society' module learning outcomes (LOs) include:
    - Appreciate ethical issues associated with the Engineering profession
    - To demonstrate an understanding of human resource management, project management, safety management and the management of other resources in a construction environment

B Eng (Hons) in Civil Engineering (Institute of Technology Sligo, 2019)

IT SLIGO PROSPECTUS
Start Here!

AWARD / LEVEL:
Honours Degree (Level 8)

CAO CODE:
SG342

DURATION:
4 Years

OTHER IMPORTANT INFORMATION:
As an exception to the normal minimum entry requirements set out on page 148, a minimum of a H5 in Mathematics is required.

For students who do not have a H5 grade in Higher Level Mathematics, IT Sligo has a special Mathematics Examination, which is equivalent to Higher Level Mathematics.

For further information on this examination, please visit itsligo.ie.

NUMBER OF PLACES:
32

POINTS:
403

Bachelor of Engineering (Hons)

Civil Engineering

Course Description:

The overall focus of the course is the development of skills in core civil engineering areas, including structures, geotechnical engineering, materials, hydraulics, highway and transportation engineering and environmental engineering. This is supplemented with modules in communication, information technology, personal development and project management.

Course Structure:

The course is a blend of formal lectures and practicals to enhance understanding of module topics and projects to apply learning outcomes to civil engineering applications. The early part of the course is designed to allow students to develop an understanding of science and technology, which are the underlying principles of engineering. Written and verbal communication skills are continuously developed through presentations and technical writing. A final year project allows the student to demonstrate his or her research skills.

Modules include computer aided design (CAD), information and communication technology, civil engineering materials and engineering science, surveying and construction technology, environmental engineering, geotechnical engineering, hydraulic engineering, structural analysis and design, project management and highway and transportation engineering.

Career Opportunities:

Graduates work as professional civil engineers in the research, design, management, supervision, construction and maintenance of civil engineering projects for local authorities, government agencies, engineering contractors and consultants.

Further Study Opportunities:

Graduates may progress to taught and research Masters of Engineering at IT Sligo or at other higher education Institutions.

Professional Recognition:

The course is accredited as meeting the educational standard for Chartered Engineer Membership of Engineers Ireland, in conjunction with an accredited MEng in Civil Engineering course.

B Eng (Hons) in Civil Engineering: Institute of Technology, Sligo (continued)

Course Description:

This course is a blend of formal lectures, relevant practical classes to enhance understanding of topics and projects to apply the information learnt to typical Civil Engineering applications. The early part of the course develops an understanding of science and technology which are the underlying principles of engineering. Gradually the students are introduced to the core Civil Engineering areas of structural, hydraulic, geotechnic and highway engineering as well as project and site management. Written and verbal communication skills a continuously developed through presentations and technical writing. At the end of this course graduates hav the skills demanded by current employers.

Civil Engineering is a dynamic industry, which is continuously evolving and changing. The Civil Engineering courses at IT Sligo teach the necessary skills for graduates to be active participants in this exciting industry. Graduates of this programme can progress to a taught or research Masters degree at IT Sligo or oth third level colleges.

This programme offers ideal preparation for employment as a Civil Engineer. The programme is accredited a meeting the educational standard at Level 8 (along with an approved Level 9 qualification) required for **Chartered Engineer Membership** (http://www.engineersireland.ie/membership/registered-titles/chartered.aspx) of Engineers Ireland. Graduate Engineers work alongside and support Chartered Engineers in the successful implementation of Civil Engineering schemes. As a result of **Engineers Irelanc** (http://www.engineersireland.ie/home.aspx) accreditation your IT Sligo qualification is recognised through the Sydney Accord in **Australia, Canada, Hong Kong, China, New Zealand, South Africa, United Kingdom** and the **United States, thus offering exciting opportunities for work and travel abroad**

Key Skills:

The early part of this course is primarily concerned with developing a good understanding of the underlying science and technology of engineering. Subjects studied include:

- CAD/ drawing
- Civil Engineering materials
- Construction technology
- Engineering science and chemistry
- Information and communication technology
- Mathematics, statistics and numerical methods
- Surveying

In the final two years the emphasis moves to the core Civil Engineering topics. Subjects include:

- Environmental engineering

  - Geotechnical engineering and geology
  - Highway and traffic engineering
  - Hydraulic engineering
  - Project management and law
  - Structural mechanics, analysis and design

- Micro-ethical treatment in misc. modules relating primarily to health and safety related issues.

B Eng (Hons) in Civil Engineering (Technological University Dublin, 2019)

What is Engineering?

DT066 is the common first year entry point for the majority of four year Level 8 Engineering Degrees in DIT. Students specialise in second and subsequent years and may choose:

- DT021A - Electrical & Electronic/Computer & Communication Engineering
- DT022 - Mechanical Engineering
- DT023 - Manufacturing & Design Engineering
- DT024 - Structural Engineering
- DT026 - Building Engineering
- DT027 - Civil Engineering

Learning Outcomes

What will I Study?

DT066 Students learn fundamental principles (Mathematics, Physics and Chemistry), Engineering Applications (Mechanics and Electrotechnolgy) and Applied Skills (Technical Graphics, Computing and Professional Development). Throughout the year the theoretical subjects are supported by laboratories and a comprehensive programme of design projects including a robot building project, a bridge building project and an energy efficiency project.

What are my Career Opportunities?

DT066 is the stepping stone to an exciting and rewarding career as a professional engineer. DIT's Engineering degrees are accredited by Engineers Ireland and our qualifications are recognised worldwide.

What other options do I have after completion?

Students who have reached the appropriate honours standard may have access to a wide range of Masters Degrees and Research Degrees in DIT and elsewhere in Higher Education

Module Listing

Years One

Mathematics I Engineering Physics I Mechanics I Chemistry I Technical Graphics I Electrotechnology I Engineering Computing I Instrumentation for Engineers I Engineering and Society I Design Projects

What is Civil Engineering?

Civil Engineering is a broad professional discipline that includes the planning, design, construction, operation and maintenance of the physical and naturally built environment that our society depends on. Civil Engineers design roads, bridges, airports, railways, ports, roads, buildings, water, waste and energy systems.

Learning Outcomes

What will I Study?

Students will study a wide variety of subjects including fluid mechanics, structural engineering, geotechnical engineering, hydraulics, mechanics, highway engineering, construction management, materials, environmental engineering and scheme design.

What are my Career Opportunities?

Our graduates have gone on to gain employment in consulting engineering design offices, on-site with contractors and in surveying and construction management. Civil Engineers are also highly sought after in business and financial institutions.

What other options do I have after completion?

Students who have reached the appropriate honours standard may have access to a wide range of Masters Degrees in DIT and elsewhere in Higher Education. The School of Civil and Structural Engineering in DIT offers Masters (Level 9) and PhD research degrees.

Are there study abroad options?

There are Erasmus opportunities to live and study abroad

Module Listing

Year Two - Four

Geotechnical Engineering I Civil Engineering Hydraulics I Professional Development I Surveying I Engineering Mathematics I Concrete Technology I Environmental Engineering I Highway Engineering I Structural Mechanics I Design Project I Design of Structural Elements I Construction Management & Economics I Advanced Environmental Engineering I Hydraulic Structures I Advanced Highways & Transportation I Structural Design of Steel & Concrete I Civil Engineering Practice & Law

- Micro-ethical treatment in misc. modules relating primarily to health and safety related issues.
- 'Engineering and Society' module in common engineering programme (year 1); LOs include:
  - Describe the ethical and social responsibilities of a chartered engineer
  - Identify the responsibilities of engineers as set out in the Code of Ethics
  - Discuss the principles of sustainable development;
  - Describe the communications process and the principles of good communication

B Eng (Hons) in Civil Engineering (University College Cork, 2019)

CK600

COURSE PAGE ONLINE
www.ucc.ie/en/ck600/civil

CONTACT INFORMATION
School of Engineering Office
T:+353 (0)21 490 2210
E: engineering@ucc.ie
www.ucc.ie/en/civileng

KEY FACTS

- Recognised as the leading civil engineering degree in Ireland
- National and international professional placement at the end of Year 3
- Design studios taught by leading professional engineers from industry
- Internationally accredited degree gives graduates mobility and freedom to work anywhere in the world as professional engineers

Civil, Structural and Environmental Engineering BE

Introduction
Civil, Structural and Environmental engineers design, construct and operate a wide range of environmental infrastructure, vital to the needs of a modern economy. All the infrastructure around us, including roads, bridges, hospitals, universities, airports, water and wastewater and energy facilities, is the product of civil, structural and environmental engineering.

Why Study
Civil, Structural and Environmental Engineering is essential to economic development and graduates have rewarding, well-remunerated careers. Civil, Structural and Environmental Engineering Graduates are highly sought-after not only by the engineering sector, but also by employers in such diverse areas as finance, information communication technology, energy, and research and development.

Careers
Civil, Structural & Environmental engineering graduates progress to a wide range of rewarding careers in many sectors including:
- civil and structural engineering design (Malachy Walsh & Partners; Ove Arup; RPS Group)
- engineering project management (Project Management Group)
- management consultancy (McKinsey & Co.; KPMG; Accenture)
- renewable energy (Element Power)
- environmental engineering (Fehilly Timoney).

PAUL COLLINS
DIRECTOR, MALACHY, WALSH & PARTNERS

"We are a large consulting engineering practice. We employ UCC Civil Engineering graduates because they are flexible, and ready to go!"

Year 1 Modules

REFER TO CK600 ON PAGE 214-15

Year 2 Modules

Structural Design – Elements and Systems; Engineering Mechanics with Transform Methods; Numerical Methods and Programming; Solid and Structural Mechanics; Fluids; Measurement and Surveying; Modelling and Visualisation; Heat and Mass Transfer; Mathematics for Engineering

Year 3 Modules

CORE: Computer Aided Design; Solid & Structural Mechanics; Mechanics of Soils; Construction Project Management; Hydraulics; Geology for Engineers; Applied Probability and Statistics

ELECTIVES: Environmental Engineering; Energy in Buildings; Information Modelling and Analysis; Materials and Sustainability; Sustainable Energy; Management and Organisation; Enterprise Planning and Processes

CHOOSE ONE OF FOUR STREAMS CONTINUED TO 4TH YEAR:
(A) Structural Engineering and Construction;
(B) Environmental Engineering (Wet);
(C) Building Energy Engineering;
(D) IT in Architecture, Engineering and Construction

Year 4 Modules

CORE: Design Studio; Dissertation; Architecture and Planning; Structural Analysis; Geotechnical Engineering; Water and Wastewater Treatment
YOU WILL CONTINUE THE CHOSEN STREAM FROM YEAR 3

ELECTIVES: Civil Engineering Systems; Design Studio; Applied Elasticity; Transportation and Energy; Traffic and Highways; Environmental Hydrodynamics; Harbour and Coastal Engineering; Biomedical Design; Fire & Safety Engineering; Work Placement; Entrepreneurship Practice and Opportunity Recognition; Bridge Engineering; Entrepreneurial Business Start-Ups

		Engineering
YEAR 1: Explore your Options	Modules	Mathematics for Engineers; Chemistry for Engineers; Engineering Computation and Problem Solving; Engineering Thermodynamics; Mechanics; Physics for Engineers; Introduction to Process & Chemical Engineering; Introduction to Energy Engineering and Engineering Ethics; Introduction to Structural and Civil Engineering

- Micro-ethical treatment in misc. modules relating primarily to health and safety issues. Engineering ethics in common engineering (year 1).

Civil Engineering

Bachelor of Engineering

NFQ Level 8 Major Award Honours Bachelor Degree | *Baitsiléir Innealtóireachta in Innealtóireacht Shibhialta*

Entry Route: LM116 Engineering (Biomedical or Civil or Design & Manufacture or Mechanical) Common Entry

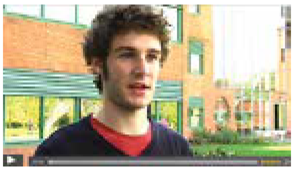
COURSE INFO

Course Director:
Michael Quilligan

Enquiries:
Email: admissions@ul.ie
Tel: 00 353 61 202015
www.ul.ie/admissions-askus

LM116 Online

The Student Experience



Course Description

Want to know more? Go to: www.ul.ie/courses/LM116.html

About you

This course will be particularly attractive to you if you are interested in the application of scientific and technical knowledge to the solution of real world problems.

Why study Civil Engineering at UL?

The Civil Engineering programme at UL is fully accredited by Engineers Ireland and uses a student-centered approach to teaching, using techniques such as problem based learning and active learning. From year one of the programme, you will develop your ability to work on a team, to plan and present, to undertake research and to apply your knowledge. Entry route to Mechanical Engineering at UL is via LM116 Engineering Common Entry.

Civil engineering is a broad field of engineering dealing with the design, planning, construction and maintenance of fixed structures or public works as they are related to earth, water, or civilization and their processes. Most civil engineering today deals with structures, roads, bridges, railways, water supply, transportation and traffic, waste water, protection of the environment, flood control and power plants. Three short videos describing the programme are available at www.ul.ie/civileng

What you will study

Civil engineering at UL is built around a 'learning-by-doing' process and focuses on three areas:

1. Water and the Environment
2. Energy in Civil Engineering
3. Buildings & Infrastructure

When you join the civil engineering team at UL, you learn to be an engineer from day one. Working in small teams, you will solve interesting problems. The challenges presented are open-ended and increase in complexity as you progress through the years. Your ingenuity and creativity are required to explore many viable solutions. Drawing from what you have learned and with the shared knowledge of your team, you will design, analyse and (in many cases) test your creations. Lectures are provided along the way to fill in gaps in your knowledge.

In year one you will be part of the LM116 Bachelor of Engineering Common Entry programme where you will develop broad engineering skills while receiving insights into the different engineering disciplines. In the spring semester students interested in Civil Engineering will undertake a 'learning by doing' project where you will be tasked with providing a safe means for a person to cross a waterway. Starting with a blank whiteboard you will work in teams to develop your ideas which you will then build and test at the end of the semester.

In year two you will learn how to design and construct earthen dams to protect structures from flood waters or detain rainwater to supply the university campus with an environmentally friendly supply of water. Heritage and cultural interests are incorporated at every opportunity. You will learn about the history of King John's Castle as you design and construct timber siege towers in a re-enactment of the 1690 Siege of Limerick.

In year three you will get a real experience of being an engineer when you take a multi-storey library (or similar structure) and engineer the design of the foundations and reinforced concrete frame, based on the results of your structural analysis. This project involves interaction with the design architect, land surveying, health & safety issues and forms the core of the first semester in year three. The project is followed by an eight-month Co-op placement with an engineering contractor/consultant in Ireland or abroad.

In year four you will learn about energy efficient buildings, wind energy and how to design water treatment systems. A unique feature of the programme is learning from the engineering mistakes of the past; in doing so, you will investigate actual engineering failures in collaboration with law students. As a student engineer, you will act as an expert witness in a moot court (simulation) and have your expert opinions tested through examination and cross-examination by the student lawyers.

Your final year project allows you to specialise in the area of civil engineering that intrigues you most. Clear and effective communication is an essential skill for the civil engineer and is carefully fostered in every project throughout the programme. You will develop verbal, written and poster presentation skills in addition to creating video documentaries, participating in a moot court and ethical debates, and you will also act as a technical guide to creative arts students on special projects.

LM116 Engineering

(Biomedical or Civil or Design & Manufacture or Mechanical) Common Entry

NFQ Level 8 Major Award Honours Bachelor Degree | *Baitsiléir Innealtóireachta*

COURSE INFO

CAO Points 2017: 443
Course Length: 4 Years
Course Director:
Mr Ross Higgins

Enquiries:
Email: admissions@ul.ie
Tel: 00 353 61 202015
www.ul.ie/admissions-askus

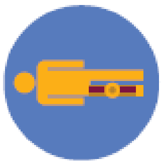
ENTRY REQUIREMENTS

Applicants are required to hold at the time of enrolment the established Leaving Certificate (or an approved equivalent) with a minimum of six subjects which must include:
Two H5 (Higher Level) grades **and** Four O6 (Ordinary Level) grades **or** four H7 (Higher Level) grades. Subjects must include Mathematics, Irish or another language, and English.

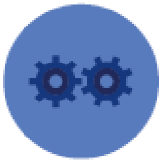
In addition, applicants must hold a minimum grade H4 in Mathematics and grade O6/H7 in one of the following: Physics, Chemistry, Physics with Chemistry, Engineering, Technology, Design & Communication Graphics/ Technical Drawing, Biology, Agricultural Science, Applied Maths, Construction Studies, Computer Science.

A Special Mathematics (Higher Level) Examination will be offered at UL following the Leaving Certificate results for those students who did not achieve the Mathematics requirement. We welcome applications from mature students. Mature applicants must apply through the Central Applications Office (CAO) by 1 February.

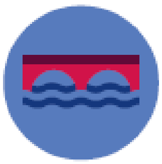
Engineer Your Own Degree at UL
Choose from:



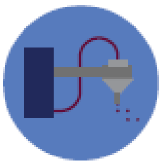
Biomedical Engineering



Mechanical Engineering



Civil Engineering



Design and Manufacture Engineering

About you

Are you the type of person that has an inquiring mind and is good at mathematics and science? Do you want to know how and why things work? Do you like to solve problems? Engineering requires each of these personal characteristics, is interesting and varied and has excellent career prospects.

Why study Engineering at UL?

Engineers are concerned with developing economical and safe solutions to practical problems, by applying mathematics and scientific knowledge while considering technical constraints. LM116 Engineering common entry is designed to provide you with a gateway to your preferred engineering discipline. You will complete a broad first year which will introduce you to various topics in engineering. Having gained a better understanding of each subject area, you then choose your preferred pathway to specialise for the remaining 3 years of your degree programme. At UL, you get to try before you decide.

LM116 Engineering is the gateway to a degree in either:
- BE Biomedical Engineering OR
- BE Civil Engineering OR
- BE Design and Manufacture Engineering OR
- BE Mechanical Engineering

The programmes above start in Year 2.

Having selected LM116 Engineering you will be given time to understand and ask questions about the various options and engineering paths available. During Year 1 you will be requested to rank the various engineering degree programmes in order of your preference. In the event that a programme is over-subscribed, places will be allocated based on UL exam performance. In all these programmes, industrial work experience is provided through a positive and motivating thirty-week period of Cooperative Education. This will provide you with experience of the practice and application of your chosen area of engineering in a suitable working environment. Students are typically paid by employers for this work which will take place during Year 3.

What you will study

In Semester 1 you will study a wide range of topics from Maths to Computing which are important for any engineering career. You will also have an introduction to engineering modules which will introduce you to the various engineering options and the differences between them.

This will broaden your knowledge base as you find out more about the many areas of engineering. You will be exposed to the fundamental principles of each discipline, the programmes of study and the career paths open to you upon graduation. Guest professional engineers will describe their experiences in their field of engineering. You will therefore be empowered to make an informed choice as to your own programme of study.

- Micro-ethical treatment in misc. modules relating primarily to health and safety issues.