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University College Dublin

Professional Socialisation and the Values of Engineering Education in Ireland

Cormac Deasy

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This thesis is submitted to University College Dublin
in fulfilment of the requirements for the degree of
Doctor of Philosophy

School of Mechanical and Materials Engineering
Head of School: Associate Professor Vincent Hargaden
Supervisor: Dr. Dónal Holland

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FOR EOIN

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Abstract

This thesis investigates the values embedded in engineering education in Ireland, addressing an ongoing debate about the engineering profession's identity and societal role. Engineering represents a contact point between science, technology and society, but it has traditionally focused on technical and scientific content, often to the exclusion of social, political, or ethical considerations. This imbalance has contributed to a culture of disengagement, where social concerns are marginalised, and evidence suggests that engineering education may even discourage social consciousness in students.

Within a social group such as a profession, dominant beliefs and behaviour are perpetuated through selection and socialisation. Individuals with conforming beliefs are attracted to and retained within the profession, while specific behaviours and traits are fostered in new members. Values, which are beliefs about desirable end goals, play a crucial role in decision-making, including career choice. These values can be explicitly stated or implicit, embedded in actions, organisational structures, or norms. To fully understand the culture of engineering education, both explicit and implicit values must be examined. This thesis specifically explores the recruitment and professional socialisation of engineering students through the lens of values and norms.

In this mixed methods study, the personal values of engineering students at different stages of their education were assessed quantitatively using the Schwartz value system, while a thematic analysis of semi-structured interviews, conducted with teaching staff and engineering students at universities across the Republic of Ireland, captured a range of perspectives on the values promoted within Irish engineering education and the wider profession. The university prospectus produced by each university in the Republic of Ireland was examined using thematic analysis to determine how the values of the profession are presented during the recruitment of engineering students.

Findings reveal that engineering recruitment materials primarily emphasise problem-solving, practical hands-on application, and scientific theory, creating a complex and sometimes conflicting portrayal of the profession which may contribute to misconceptions about the nature of engineering work. The ideal engineer, as envisioned by Irish engineering education, is a technically skilled problem-solver who prioritises *universalism*, *benevolence*, and *self-direction*. The value profiles of engineering students in this study fit this description. The value profiles of engineering students at the beginning of their engineering education did not differ significantly from those at the end. However, they did show some significant differences from other sampled groups, supporting the theory that personal values may play a role in the decision to choose to study engineering.

The perceived norms of engineering practice as described in this study require maintaining a degree of scientific detachment and encourage a notable reluctance or inability to embrace or define the social responsibilities of engineers, with an emphasis on fitting within existing industrial structures rather than challenging them. While there is an acknowledgement of the importance of contributing to societal well-being, this is seen as a personal choice rather than an inherent responsibility of the profession. The constraints on the engineering curriculum, which prioritises serving the needs of industry without a strong advocate for the needs of society, perpetuate this limited view of the engineer's role.

Statement of Original Authorship

I hereby certify that the submitted work is my own work, was completed while registered as a candidate for the degree stated on the Title Page, and I have not obtained a degree elsewhere on the basis of the research presented in this submitted work.

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Chapter 1: Introduction

"Engineering interacts with all other forms of life. The future of the profession will see engineers at the centre of planning, not simply asked to join in the execution of particular tasks, but in designing transformation." – President Michael D. Higgins 2016

In this address President Higgins highlights the scope of the role of engineers in society, extending far beyond the narrow technical confines which currently define the engineering identity (Anderson et al. 2010; Murphy, O'Donnell, and Jamesons 2019; Nair 1997; Faulkner 2007; Buch 2022). There is a common misconception that construes engineering work as a purely technical exercise, and that through scientific rationality and objectivity the profession, and by extension the technologies produced, are considered value-neutral (Haraway, 1988; Riley, 2008; Pitt, 2014; Seron et al., 2018). However, technology does not exist in isolation, and cannot be separated from the context and social structures in which it is created and exists (Winner, 1980; Leydens, Lucena and Riley, 2022). Engineers, through their role in developing networks of technological systems, mediate societal dynamics, and so engineering cannot simply be considered an exclusively technical exercise (Feenberg, 1999; Verbeek, 2006; Miller, 2021; Leydens, Lucena and Riley, 2022).

The above quote suggests that engineers in the future will be involved in shaping our society. The reality is that they already are, however the readiness of engineers to tackle such issues is questionable, raising concerns about whether we are adequately preparing engineering students for the complexities of their future role (Bucciarelli, 1996; Martin, 2002; Faulkner, 2007; Colby and Sullivan, 2008; Cech and Sherick, 2015a; Conlon, Martin, Nicolaou, et al., 2018; Martin and Polmear, 2022).

The identity of the engineering profession and its societal role remains a topic of ongoing debate. Engineering work represents a contact point between science and society, however within engineering education the emphasis has traditionally been on technical and scientific knowledge, often at the expense of social considerations (Noble, 1979; Nair, 1997; Downey and Lucena, 2004; Riley, 2008; K. J. B. Anderson et al., 2010; Cech, 2014a; Cech and Sherick, 2015a; Buch, 2022; Kramer, 2022). There is evidence that this has created a culture of disengagement whereby social concerns are excluded from engineering consideration and undergoing an engineering education discourages social consciousness in students (Cech, 2010, 2014a).

There is an internal responsibility inherent in the definition of all professions to serve the public interest (Johnson 2006; Riley and Lambrinidou 2015). The code of ethics for Engineers Ireland, the professional body representing Irish engineering, begins "Members must act at all times with fairness, courtesy and good faith toward all persons with whom the member has professional dealings, and in accordance with the public good." and goes on to say "Members must uphold the values of truth, honesty, and trustworthiness and safeguard human life and welfare, and the environment" (Engineers Ireland, 2023a). The scientific positivist epistemologies valued in engineering culture are considered unsuitable to capturing the full scope of what constitutes human welfare and the public good (Mitcham, 2009; Riley and Lambrinidou, 2015; Kramer, 2022).

The belief among students that engineering is a purely technical discipline is both inaccurate and unhelpful to students, their future employers, and society at large. It has been argued that engineering is far from the depoliticized portrayal often seen in the classroom, and presenting it as such leaves students ill-equipped for the social, political, and ethical complexities inherent in real-world engineering (Cech and Sherick 2015; Faulkner 2007; Bucciarelli 1996). Similarly, it has been posited that engineering education fails to prepare students to navigate the ethical dimensions of their societal role (Colby and Sullivan 2008; D. A. Martin and Polmear 2022; M. W. Martin 2002; Conlon et al. 2018).

This potential lack of preparedness of engineering students constitutes a major problem for the profession, though fortunately, in this, the engineering profession finds itself in more familiar territory. One of the tent-poles of the engineering identity is the focus on problem-solving. While it is a broad and diverse profession, this systematic problem-solving identity is a consistent and fundamental aspect throughout the literature (Downey 2005; Downey and Lucena, 2004; Jonassen 2014; K. J. B. Anderson et al. 2010; Colby and Sullivan 2008; Koro-Ljungberg et al. 2017; Siller, Johnson, and Korte 2021; K. J. B. Anderson et al. 2010). There are many design processes, used in the field of engineering and design, including the IDEO human-centred design thinking process (Smith, 2002), the product design and development process outlined by Ulrich and Eppinger (1995), and The Double Diamond (UK Design Council, 2005). While each takes a slightly different approach, uses different vocabulary, and divides the process according to a different philosophy, each begins with identifying and understanding a problem. That is the purpose of this thesis.

While the culture of disengagement, and decreasing social responsibility beliefs have been detected among engineering students, the formation and nature of these beliefs are less understood (Bielefeldt, 2018). Personal values inform decision making across all aspects of our lives including our choice of career (Campbell, 1963; Rounds, 1990; Schwartz, 1992; Rohan, 2000; Knafo and Sagiv, 2004). Norms are a set of expectations which govern the collective behaviour within a social system. Each field has its own set of norms and in turn, values which justify them. As of yet, it is unclear whether the social responsibility, and engagement beliefs detected in previous work represent learned norms of the engineering profession, or reflect underlying personal values of the individual. Neither is it understood how these beliefs and attitudes compare to the desired outcomes within engineering education.

Within a social group such as a profession, prevailing ideas and behaviours are perpetuated through a combination of selection and socialisation. Individuals who already align with the group's attitudes and beliefs are more likely to be drawn to and retained within the profession, while new members are gradually shaped to adopt these desired traits (Cohen, 1981a; Stets and Burke, 2000; Ajjawi and Higgs, 2008; Cornelissen and Van Wyk, 2008). In order to understand the culture within engineering education, both the selection of students and their subsequent socialisation must be accounted for. This thesis specifically examines the recruitment and professional socialisation, including pre-socialisation, of engineering students in Ireland through the lens of values and norms.

Carl Mitcham wrote that “the true grand challenge for engineering is self-knowledge” (2014). A profession which prides itself on efficiency and productivity sees little use in philosophical discussions on the societal context of engineering work (Herkert, 2000; Riley, 2008; Schneider, 2010; El-Zein and Hedemann, 2013). However, if the profession as a whole is to embrace its societal role and design the transformations spoken of by President Higgins, it will

require critical reflection and understanding about the nature of engineering work and the wider context of the profession. Only then can engineering education claim to understand the problem before us and begin to work on a solution.

1.1 Research Objectives

The purpose of this study is to explore the professional socialisation of students in engineering education in Ireland. Previous work has demonstrated the presence of a culture of disengagement in engineering education (Cech, 2010, 2014a), and the issues in integrating ideas of social justice and social responsibility into the engineering curriculum (Riley, 2008; Baillie and Catalano, 2009; Bielefeldt, 2018; Murphy, Christensen and Conlon, 2022; Xavier, Wint and Orbaek White, 2022). While there is evidence of specific attitudes and beliefs among engineers and engineering students, it remains unclear whether these are learned context-specific norms of the engineering profession or represent deeper changes to the individual at the level of personal values. Furthermore, the extent to which these values are influenced by the educational environment and how they evolve throughout the course of study is not well understood.

Others have highlighted the need for further research into the nature of these beliefs and how they develop in engineers (Bielefeldt 2018). This study aims to investigate the values present in engineering education in Ireland, by answering the following research questions:

- RQ1: What are the values being appealed to during the recruitment of engineering students in Ireland?
- RQ2: What are the values of those who enter engineering education in Ireland?
- RQ3: What are the ideal values of an engineer according to those involved in Irish engineering education?
- RQ4: What are the values promoted by engineering education in Irish universities?

It is not the intention of this thesis to directly propose reforms to engineering education. To return to the metaphor of the design process, this thesis represents four years spent at the problem specification stage.

1.2 Contribution

This work advances the field of engineering education by offering a critical reflection on the professional socialisation of engineering students, and the values implicit in recruitment and educational practices. Where previous work in the field has examined specific attitudes and the formation of the engineering identity, this research uses the concept of personal values to assess the development of engineering students. Much of the previous work on this topic has been carried out in other countries, with a particular concentration in the United States of America (Herkert, 2000; Carberry, 2010a; Cech, 2014a; Canney and Bielefeldt, 2015b; Howland *et al.*, 2024). Value priorities are shaped by the wider cultural and political context in which an individual lives (Schwartz and Bardi, 2001; Schwartz, 2003), and so care needs to be taken when generalising findings internationally. This research contributes to the understanding of the culture of engineering education in Ireland, while the use of values as a lens provides a novel and complementary perspective.

1.3 Researcher Perspective and Worldview

When undertaking research, particularly when using qualitative or mixed methods, it is important to understand the viewpoint from which the researcher is engaging with the material.

I am approaching this exploration of the culture of engineering education from within. As someone who has worked as an engineer, particularly in a role supplying machinery to the oil and gas industry among others, I have witnessed firsthand the detachment with which many engineers approach their work. The environmental and ethical implications of the projects we supported were treated as abstract and did not factor into the decision-making process. Instead, technical rigor and efficiency defined success within that particular environment. I observed this disengagement in my colleagues and peers elsewhere in the field, who often seemed to view their work as purely technical, divorced from its broader consequences. At the same time, I recognized myself rationalising my own involvement as a pragmatic necessity and created a compartmentalized version of myself that separated my personal values from the demands of my professional role. This internal conflict fuelled my curiosity about how these attitudes of disengagement become so omnipresent in the engineering profession.

I was drawn to the engineering field with idealistic intentions though I found that my experience of the industry did not align with my expectations. My sense of self as an engineer did not map to the reality of the profession. As will be discussed in chapter 2, failing to integrate one's identity with that of the profession can indicate a tendency for the individual to be unlikely to persist in the field (Matusovich, Streveler and Miller, 2010; Murphy, Chance and Conlon, 2015). Engineering in the context of academic research and education is a relatively niche field compared to its industrial counterpart. It could be argued that returning to academia constitutes my departure from the core of the profession.

It is not my intention to paint the engineering profession, or my previous colleagues and employers, as the villains of a story. Rather I am drawing on my experience which has led me to question the broader culture of engineering and the ways in which it shapes the perspectives and priorities of those within it, often at the expense of critical reflection on the wider impact of our work.

1.4 Structure of this Thesis

This thesis consists of seven chapters, inclusive of this introduction. Chapter 2 contains a review of the literature which informed this research. This includes an overview of current research into this field, including the research which motivated this study. It also provides a justification for the theoretical frameworks chosen to further the understanding of professional socialisation of engineering students.

In Chapter 3, the methodology employed in this research is outlined, including the choices of paradigm, research design and individual methods used. These methods include document analysis, semi-structured interviews with engineering students and educators, and a cross-sectional survey of engineering students. The chapter contains details of each stage of this research, such as, participant recruitment, data collection and analytical methods. This chapter also outlines the ethical considerations for this research and mitigating measures taken to address these. This research received a low-risk exemption from the University

College Dublin Human Research Ethics Committee (Reference Number LS-C-23-44-Deasy-Holland).

Chapter 4 examines the recruitment of engineering students from a values perspective. This involves investigating the values appealed to during the recruitment of engineering students, and the value profile of those who choose to study engineering.

In Chapters 5 and 6 the socialisation of engineering students during their formal education is examined. Chapter 5 focuses on what participants believe constitutes an ideal engineer, by analysing interviews with students and staff from Irish universities. It examines their descriptions of the ideal engineering graduate, including the skills, societal roles, and values they consider essential.

Chapter 6 builds on this analysis by examining the values embedded in the engineering curriculum. Through interviews with staff and students, it explores how curriculum design influences students' understanding of the profession. This chapter also compares the personal values of first and final-year students with the ideal profiles discussed in Chapter 5, highlighting the socialising impact of engineering education.

This thesis concludes with Chapter 7, which consists of a brief summary of the findings of this thesis. It includes an outline of some of the limitations of this work and suggests possible avenues for future research.

Chapter 2: Literature Review

The purpose of this thesis is to explore the professional socialisation of engineering students in Irish universities. It involves examining why students choose to study engineering, what those in engineering education think an engineer should aspire to be, and what values and norms are promoted during engineering education. This chapter contains a review of the current research on a number of topics relating to this field.

The chapter begins with a brief overview of the motivation for this study and discusses the relevance of examining the culture in engineering education, and the effects that this has on students' approach to their professional role. Following on from this, the processes of professional socialisation are discussed. An overview of some of the theoretical frameworks used in this thesis are then outlined, including personal values, vocational interests, and normative structures. Subsequent sections review the literature on the recruitment of engineering students, the role of the engineering profession in society, issues within the engineering curriculum, and the ways in which this curriculum has influenced students' beliefs. Finally, the chapter concludes by outlining the relationship between the reviewed literature and this thesis.

2.1 Motivation

Engineers are, at their core, problem-solvers. Despite the diversity of interpretations of the engineering profession across cultures, this problem-solving identity is a consistent and fundamental aspect of the identity (Downey and Lucena, 2004; Downey, 2005; Colby and Sullivan, 2008; K. J. B. Anderson *et al.*, 2010, 2010; Jonassen, 2014; Koro-Ljungberg *et al.*, 2017; Siller, Johnson and Korte, 2021). More specifically engineers are technological problem-solvers, meaning engineers both solve problems arising out of technology, but also that engineers solve problems using technology (Downey, 2005; El-Zein and Hedemann, 2013; Carberry and Baker, 2018). Often, the challenges engineers face are complex social and political issues. However, these issues are frequently reframed as technological problems, with solutions that are similarly technological (Perrucci, 1971). This technocratic approach is particularly evident in discussions of the 'grand challenges' for engineering (Cech and NAE's Grand Challenges For Engineering", 2012; Riley, 2012; Slaton, 2015; Grimson *et al.*, 2022). The profession has faced criticism for its double standards: positioning engineering as the solution to these problems without acknowledging its role in creating them, and framing these issues as technical challenges rather than societal problems (Cech, 2012). Natasha McCarthy wrote that "Engineering is about designing solutions to challenges, and building new ways of living and being in the world" and that the key to success in this endeavour would be understanding the needs of society, and what aspects of these needs engineering could make a contribution to (Grimson *et al.*, 2022).

Attempting to address these societal problems with technical solutions leaves the design and implementation of these solutions in the hands of technologists, often with little democratic oversight (Perrucci, 1971; Zimmerman, 1995). As Sarah Bell put it "Science and technology have been left to the engineers and scientists to develop at an objective distance from society and the messy worlds of politics and culture." (Bell, 2011). As technological systems become more intricate and embedded in our social systems, such oversight is impossible as the effects

and implications of these systems become too complex and esoteric for the lay-person to fully understand (Winner, 1980; Zimmerman, 1995; Herkert, 2000; Verbeek, 2006; Cech, 2014a; Cech and Sherick, 2015a). Without the relevant technical knowledge it is not possible to adequately oversee the regulation and direction of technological development (Herkert, 2000; van de Poel, 2001; Riley, 2008) and so the role of “public welfare watchdog” falls to engineers (Cech, 2013). However, as is discussed this chapter, there is a substantial body of literature which argues that the engineers are ill-equipped and uninclined to adequately consider the full breadth of societal implications of technology, and to effectively serve the public interest (El-Zein and Hedemann, 2013; Cech, 2014a; Cech and Sherick, 2015a).

Across the literature in the Engineering for Social Justice field there are numerous examples of how engineering has, and continues to work against the principles of social justice, and in ways which are harmful to society and the environment. Catalano (2007) discusses an analysis of the events around Hurricane Katrina and how engineering work contributed to the disproportionate devastation felt by the poorest citizens of New Orleans. It is found that the management of the Mississippi river, as a commercial shipping lane, and the growth of industry in the area warranted the construction of a system of levees, pumps and other flood defences. This led to the further development of the city into regions of marsh and wetlands which previously provided natural flood defences to the region. Some of the poorest districts in the city were built in these regions. As a result some of those least able to flee the city by their own means in advance of the storm were left in the most precarious position when the man-made flood defences failed. Elsewhere, Baille (2006) describes the significant role that engineering plays in “creating the third world”. Among the examples used here is the railway network built in British occupied India. This network facilitated the exportation of grain into the international market which exacerbated the impacts of famine in the region. While transport was more difficult, grain was sold locally and excess was gathered to local stores. The ability to sell internationally at higher prices, ended this practice resulting in significantly higher death tolls. Both of these authors (Baille, 2006; Catalano, 2007) also highlight the fact that no proletariat existed in pre-industrial times. The industrial revolution brought about an entirely new form of poverty as even medieval peasants had a greater level of security and belonging to an institution than the poor classes during the industrial revolution. The implication here is not that engineers sought to bring about these disasters, but rather that engineering work often has consequences which the initial project brief fails to account for. A thorough and diligent engineer who “successfully” fulfils this brief can unintentionally contribute to societal harm. Langdon winner discusses the political consequences embedded in how a country chooses to generate electricity. He highlights how the adoption of nuclear power brings with it the necessity for a centralised authority in order to adequately secure the materials and facilities. This is in contrast with the more distributed and potentially democratic nature of a grid supplied by renewables. While this example may gloss over some of the nuances and difficulties in managing intermittent power supplies such as solar or wind, it does serve to highlight how an engineering decision is far more than just a technical choice.

It has been suggested that the culture of engineering, and engineering education, hinder the inclusion of public welfare and social justice as valid criteria in the engineering practice (Riley, 2012; Cech, 2013, 2014a). The traditional values of engineering, and the cornerstones of the engineering identity, including themes such as efficiency, engineering problem-solving, technologism and professionalisation (Schneider 2010; El-Zein 2013), are enshrined in the institutions of engineering (Noble, 1979; Layton, 1986; Schneider, 2010; Slaton, 2010). The engineering curriculum, through the narrow focus on technical subjects and limited integration

of social considerations (Colby and Sullivan, 2008; Kabo and Baillie, 2009; Grimson *et al.*, 2022; Martin and Polmear, 2022; Murphy, Christensen and Conlon, 2022; Xavier, Wint and Orbaek White, 2022) promotes this set of values and identity and perpetuates this culture of disengagement (Cech, 2010, 2014a).

2.2 Defining Terms

It would be useful at this point to establish some definitions which will be used in this thesis.

Existing research frequently uses terms like “values” to mean a number of different things. Upwards of seventy different concepts, all of which could be considered to be “values” have been identified (Rohan, 2000). For the purpose of this research, I use the term to refer to personal values, as defined in Schwartz (1992), according to whom values are personal beliefs about what end states are desirable, which serve as guiding principles in decision making (1992; discussed in section 2.2). Values can be implicit or explicit. Explicit values are those which are directly stated, while implicit values are embedded in action, organisational structure, norms of practice, and culture (Schwartz, 2012; Espedal *et al.*, 2022).

A long-standing and useful definition for a norm is a thought or idea that exists among a group, which can be expressed in terms of what a member of that group “should do, ought to do or are expected to do, under given circumstances” (Homans, Hare and Polley, 2017; Weidman, 2020). Norms are generalised rules or standards for behaviour in a specific situation, and can be the practical expression of a value (Schwartz, 2012).

Culture combines the two, and will be used throughout this study to mean “the rich complex of meanings, beliefs, practices, symbols, norms, and values prevalent among people in a society” (Schwartz and Bardi, 2001).

2.3 Professional socialisation

Professional socialisation is the process that shapes the behaviour of an individual as they become part of a profession. Ajjawi and Higgs (2006) identify several of the major definitions of professional socialisation and outline the stages of this process. Broadly speaking, it involves the assimilation by the new recruits of the values, beliefs, norms, skills and culture of the profession they are choosing to join. These are internalised and form part of the professional identity of the individual (Merton, 1957; Cohen, 1981b; Leidner, 2006; Ajjawi and Higgs, 2008; Cornelissen and Van Wyk, 2008). Stets & Burke (2000) describe self-categorization, whereby as an individual develops a sense of social identity within a group, they will learn to “be like others in the group and see things from the group’s perspective”. Leidner wrote that successful socialisation involves “internalising the occupation’s ideology, ethos, traditions, and norms, including criteria for judgement, craft pride, and rules for interacting among themselves and various others” (Leidner, 2006).

Cornelissen and Van Wyk (2008) describe three major changes undergone during this process. Firstly, there is a concretisation of values and norms. As they undergo their education, students are exposed to the values and norms which are prized among the profession. These then interact with the student’s own value system (Weidman, 2020). Secondly, behaviours change in response to value changes. Thirdly, these changes extend to the individual’s sense of self, as they develop a sense of identity within the profession (Cornelissen and Van Wyk 2008).

Formal education represents an important stage of professional socialisation (Simpson, 1979, 29). In the context of engineering education, it has been identified as an area which requires educational reform in the context of defining, or redefining, the role of the engineering profession in the minds of students (Downey, Lucena & Mitcham, 2007). It is a point where students are taking on new skills and knowledge, and where a single institution has a significant amount of control over the image of engineering which the student is encountering. During higher education students engage in an active pursuit of the skills and practices that are considered appropriate to the profession and develop their professional decision-making processes. Students begin to develop their professional reasoning which is informed by the skills and deemed valuable by the profession (Ajjawi and Higgs, 2008).

Within the confines of university education, interaction with peers and faculty shape the values of students through normative pressures (Weidman, 1974, 2006, 2020). Interaction with staff and senior students in the field serve as cues as to the expected behaviours and attitudes for a novice in the field (Weidman, 2006; Ajjawi and Higgs, 2008; Cornelissen and Van Wyk, 2008) as the approval of those within the field becomes a primary influence (Simpson 1967). However, it should be noted that, while the influence of higher education is significant, the university is not an “encapsulated environment” (Weidman, 1974, 2006, 2020). External factors also affect how an individual's values will interact with the professional socialisation process. For instance, the degree to which a peer, senior student or staff member reflects the expectations of a student as to what a professional should represent, influences the degree to which the student will trust, and then accept socialising influence from the individual (Cohen, 1981b; Cornelissen and Van Wyk, 2008). In the case of science some findings show that students in the UK have formed a significant portion of their opinions about the profession by the age of 14 (Archer *et al.*, 2010) suggesting that very early exposure to a field leaves a lasting impression.

There are elements of “anticipatory socialisation” in which individuals prepare themselves by “rehearsing” for the role they imagine they will occupy. This occurs when a person has chosen a career path, and involves them adopting the viewpoint, behavioural traits and societal role that they expect to occupy based on their preconceptions of the profession (Weidman 2020; Cornelissen & Van Wyk, 2008). These preconceptions are shaped in myriad ways from common social stereotypes and portrayal in media to personal knowledge of or relationships with members of the profession (Cornelissen and Van Wyk, 2008; Archer *et al.*, 2012). A significant portion of this process is often subconscious and unintentional (Merton, 2000; Weidman, 2020).

It has also been noted that the process of professional socialisation continues after graduation as the individual transfers from the role of student to the professional setting (Cornelissen and Van Wyk, 2008; Higgs, 2013; Devenish, Clark and Flemming, 2016). A study of professional socialisation of nurses found that a significant stage of professional socialisation involved others in the work environment becoming the primary reference, as those outside the profession are not considered competent judges of performance (Simpson, 1967). Working within a culture shapes the understanding of work practices and behaviour and ultimately the professional reasoning of individuals within that profession (Ajjawi and Higgs, 2008).

There are a number of theories on social reproduction, and how dominant values and social norms are perpetuated. Baillie and Levine (2013) discuss various ways in which the values of a dominant group maintain the status quo and resist change. This includes the work of Gramsci and Fleck and how their concepts of “common sense” (Gramsci and Gramsci, 2012)

and “thought styles” and “thought collectives” (Fleck, 1979) describe the ways in which dominant ideologies become enshrined in social structures. The institutions of society are hubs from which the dominant ideology is reproduced. Be they educational, religious or the media, these organisations play leadership roles in the intellectual guidance of society. Each is vulnerable to a particular set of biases and interests which are projected as the general interest (Levy and Egan, 2003). It is in the self-interest of those who live under the influence of these major apparatus to accept and project these same beliefs and ideologies in order to achieve personal success.

Bourdieu describes a similar effect using his concepts of Field, Capital, Habitus and Doxa (Bourdieu, 2002). A “field” here describes any social grouping, bound by a set of norms and regulations which govern the internal activity of that field (Calhoun 2007). For instance, the engineering profession would constitute a field. Success in a particular social field requires an individual to accept the rules, values and structures of that field (Bourdieu & Wacquant, 1992, p. 98). In this context, “capital” refers to social capital (a network of relationships) and cultural capital (competence in areas relevant to the field) as well as traditional financial and material capital (DiMaggio, 1979). The worth of this capital is determined by the rules of the field, and like financial capital can be traded at a particular “rate of exchange” (Bourdieu and Wacquant, 1992: 114). In the context of engineering, forms of capital might include relevant qualifications, skills and knowledge, as well as desirable jobs and influence within the engineering industry.

“Habitus” describes a person’s set of dispositions and demeanour that they have extracted from their experiences. It is responsible for how they react to a given scenario and can be subconscious (DiMaggio, 1979; Bourdieu, 2005). In Bourdieu’s preferred sporting metaphor, habitus represents an individual’s “feel for the game” (Calhoun, 2007). These three concepts shape each other. Success in a field is often rewarded by some form of capital, while the rules of a field and the habitus of an individual are mutually shaped by a reflexive two-way interaction (Bourdieu, 2005, p. 47). Collectively these shape the “doxa”, or an individual’s taken-for-granted understanding of the world and their place in it. It is an understanding of reality based on an individual’s socially situated perspective. These are pre-conscious assumptions and are seen to be “the correct way to think” (Calhoun 2007).

In discussing “science capital” Archer et al. (2012) use Bourdieusian theory to examine the aspiration and educational participation of students in science. Parental influence can encourage students to pursue a career in STEM subjects (Archer *et al.*, 2012; DeWitt and Archer, 2015). It is found that among middle class families, scientific interest is encouraged in children from an early age, and that developing this scientific capital is an indicator that students are more likely to consider science as part of their post-school plans (Archer *et al.*, 2015). In some cases, families in minority groups may encourage their children to pursue scientific interests as a means of social mobility (Archer *et al.*, 2015; DeWitt and Archer, 2015), though often science careers can appear “less thinkable” to less advantaged minority groups (Archer *et al.*, 2015).

Viewing a profession through the lens of field theory highlights the importance of examining both the individual as well as the professional values and norms in a field. Action cannot be adequately explained based on the determining factors in an individual’s social circumstances, nor can it be seen as an objectively logical decision. Instead, it must be seen as the intersection between an individual’s dispositions and the dynamic social structures in which the action takes place (Bourdieu & Wacquant, 1992, p. 135).

Professional socialisation as described above involves an individual choosing to join a field, thus competing for relevant capital, which results in them developing the habitus of an engineer. In the case of new graduates in engineering, it is unclear how effective formal education can be on their long-term professional values. As new entrants to a field they will have relatively little capital. To be successful in the field they will have to adapt to and play by the rules of the game. As they accumulate this capital their habitus is slowly reformed to suit the field. Those values which are expressed most frequently are strengthened in an individual (Schwartz and Bardi 1997). As such, by the time a “New Engineer” is in a position to affect the broader culture of engineering, their own values may have been shaped to conform to the doxa of an engineer. This is of concern as these values and cultural norms influence their professional reasoning and decision making without being subjected to critical reasoning (Ajjawi & Higgs, 2006).

Successful professional socialisation results in the novice internalising the values and attitudes demanded by the profession (Cohen 1981, 14) as well as accumulating the required professional knowledge and skill set (Cornelissen & Van Wyk, 2008). Students transition from the lay population to professionals, and in doing so begin to adopt the identity of the profession. This internalisation occurs as the individual reconciles their total experience of the norms and values of the profession with their own personal values. They settle at a set of values which the profession has deemed appropriate, and which they themselves have seen as demonstrably effective (Cornelissen & Van Wyk, 2008; Cohen 1981).

2.4 Values

2.4.1 Personal Values

Values are a set of beliefs about which behaviours or end goals are preferable to their opposites (Ball-Rokeach, 1973; Feather, 1995; Schwartz, 2006). They are a key factor in decision-making and have been described as “the dominating force in all life” (Vernon and Allport, 1931; Rohan, 2000; Kraatz, Flores and Chandler, 2020). Values have long been a central concept in social sciences, with both Durkheim and Weber referring to values in their explanations of personal and social organisation and change (Weber and Kalberg, 2001; Durkheim, 2005; Schwartz, 2006). An individual adapts their values throughout their life as they prioritise the values which are attainable to them and downgrade values which they cannot pursue (Schwartz and Bardi, 1997). Throughout the literature, the definition of values varies, with 76 separate concepts being identified by Campbell (1963) as functionally akin to values. The unifying quality between these concepts is the role that they play in guiding behaviour and decision-making (Campbell, 1963; Rohan, 2000).

Values underpin many other concepts such as norms and attitudes. For instance, where an attitude may be used to describe a person’s response to a given specific set of circumstances, a value serves as the abstracted generalised motivation for this attitude. In this regard they can be said to be trans-situational (Vernon and Allport, 1931; Rohan, 2000; Schwartz, 2006). This was among the criteria used by Schwartz when seeking to clarify definitions around values. The Schwartz value theory identifies six features of values from the literature, and which adequately differentiate values from other concepts. Those criteria are as follows (Schwartz, 1992, 2006):

1. **Values are beliefs linked inextricably to affect.** When values are activated, they become infused with feeling. People for whom independence is an important value

become aroused if their independence is threatened, despair when they are helpless to protect it, and are happy when they can enjoy it.

2. **Values refer to desirable goals that motivate action.** People for whom social order, justice, and helpfulness are important values are motivated to pursue these goals.
3. **Values transcend specific actions and situations.** Obedience and honesty values, for example, may be relevant in the workplace or school, in business or politics, with friends or strangers. This feature distinguishes values from norms and attitudes that usually refer to specific actions, objects, or situations.
4. **Values serve as standards or criteria.** Values guide the selection or evaluation of actions, policies, people, and events. People decide what is good or bad, justified or illegitimate, worth doing or avoiding, based on possible consequences for their cherished values. But the impact of values in everyday decisions is rarely conscious. Values enter awareness when the actions or judgments one is considering have conflicting implications for different values one cherishes.
5. **Values are ordered by importance relative to one another.** People's values form an ordered system of priorities that characterise them as individuals. Do they attribute more importance to achievement or justice, to novelty or tradition? This hierarchical feature also distinguishes values from norms and attitudes.
6. **The relative importance of multiple values guides action.** Any attitude or behaviour typically has implications for more than one value. For example, attending church might express and promote tradition and *conformity* values at the expense of *hedonism* and *stimulation* values. The trade-off among relevant, competing values guides attitudes and behaviours. Values influence action when they are relevant in the context (hence likely to be activated) and important to the actor.

According to the Schwarz value theory, the ten universal values are *self-direction*, *stimulation*, *hedonism*, *achievement*, *power*, *security*, *conformity*, *tradition*, *benevolence* and *universalism* (Schwartz, 1992, 2006). Rokeach, on the other hand, put forward his own set of values which he divided into two lists: terminal and instrumental values. These included things like *cheerfulness*, *ambition*, *courage*, *honesty*, *broadmindedness*, *a world at peace*, *a world of beauty*, and *social recognition* (Ball-Rokeach, 1973). Happiness, interestingly, is among those included by Rokeach but omitted by Schwartz, who instead suggested that, while happiness is important, it is achieved by satisfying other values (Sagiv and Schwartz, 2000). In fact many of the items which constitute values in the Rokeach Value Survey (RVS) are considered a "defining goal" as part of an overarching value in Schwartz' theory (Schwartz and Bilsky, 1990; Schwartz, 1992; Rohan, 2000).

Rokeach's Value Survey also lacks the theoretical structure of Schwartz's. The values are put forward with no suggestion of interconnectedness. While completing the RVS a participant is asked to rank each value's importance to them but is offered no indication as to the trade-off involved in prioritising each (Rohan, 2000). Schwartz improved on this by developing a structure which considers the implications of each value priority on the others. He did so by structuring it along two axes of what he called higher order values: *openness-to-change* – *conservation* and *self-enhancement* – *self-transcendence* (Schwartz, 1992, p. 199, 2006; Rohan, 2000). Figure 2.1 shows the ten personal values as well as the four higher order values arranged in a circular structure. The arrangement of values in this structure is such that

prioritising or satisfying a value will necessarily involve a compromise or de-prioritisation of values on the opposing side of the wheel. Similarly, values which are closely positioned in the structure are more likely to share desired actions or outcomes (Schwartz, 1992, 2006, 2012). For instance, an event or activity which is motivated by or satisfying to the value of *conformity* may also satisfy *security* or *tradition*, but is unlikely to satisfy the value of self-direction.

This circular structure was developed using multidimensional scaling to reveal the relationships between values and has been validated by results in over 210 samples across eighty-two countries. These included nationally representative samples from 37 countries (Davidov, Schmidt and Schwartz, 2008; Bilsky, Janik and Schwartz, 2011; Schwartz, 2012). As such the structure has been described as “near universal” (Sandy *et al.*, 2017).

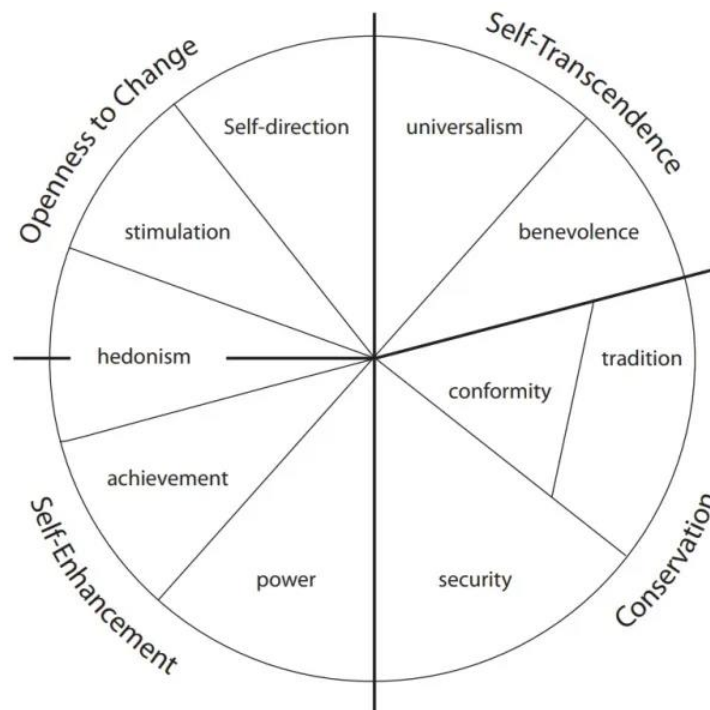


Figure 2.1: Circular Structure of the Schwartz Value System (Schwartz 2012)

2.4.2 Ten Basic Values of the Schwartz Value System-

This section provides a brief outline of each value as well as the motivational goal that it expresses. Schwartz also outlines some traits and value items which represent a manifestation or expression of each value. The definitions as included below are taken from Schwartz (2012).

Self-Direction has the defining goals of independent thought and action-choosing, creating and exploring. It is grounded in the basic human needs for control, autonomy and independence. It includes the defining traits and value items of creativity, freedom, choosing one's own goals, curiosity, independence, self-respect, intelligence, and privacy.

Stimulation has the defining goal of excitement, novelty and challenge in life. It is derived from the need for variety and positive levels of activation. *Stimulation* is characterised by a varied life, an exciting life, and daring.

Hedonism is defined by the goal of pleasure or sensuous gratification for oneself. The value items of pleasure, enjoying life, and self-indulgence constitute hedonistic values.

Achievement as a value motivates the need for personal success through demonstrating competence according to personal standards. Competence is necessary for personal and social success, and so the value of *achievement* emphasises demonstrating this competence and thus obtaining social approval. Ambitious, successful, capable, influential, intelligent, self-respect, and social recognition are all traits and value items associated with *achievement* values.

Power values have the defining goals of social status, prestige, and control or dominance over people and resources. While related to *achievement*, as both values focus on social esteem, *power* emphasises the attainment or preservation of a dominant position within the social system, wealth, and authority.

Security is defined by the goal of safety, harmony and stability of society, relationships, and self. It is derived from basic and individual group needs and generally serves the interests of groups which the individual is a part of or identifies with. It is characterised by a preference for social order, family *security*, national *security*, cleanliness, reciprocation of favours, healthiness, moderation, and a sense of belonging.

Conformity motivates the goal of restraint of action, inclinations and impulses likely to upset or harm others and violate social expectations or norms. These values emphasise self-restraint in everyday interaction, obedience, self-discipline, politeness, honouring parents and elders, loyalty and responsibility.

Tradition stimulates the respect and acceptance of, and commitment to, customs and ideas associated with one's culture or religion. *Tradition* and *conformity* values are especially close motivationally as they both share the goal of subordinating oneself to social expectations. This subordination can be to people, such as parents, teachers and bosses, as well as abstract concepts such as religious customs and ideas.

Benevolence drives the preservation and enhancement of the welfare of those with whom an individual is in frequent contact. Like *conformity*, it is derived from the need for, and facilitates, smooth group functioning. *Benevolence* emphasises voluntary care for the welfare of others. Helpful, honest, forgiving, responsible, loyal, true friendship, mature love, a sense of belonging and meaning in life are all traits and value items attributable to *benevolence* as a value.

Universalism has the defining goal of understanding, appreciation, tolerance, and protection of the welfare of all people and nature. Where *benevolence* has a focus on the in-group, *universalism* is concerned with the welfare of the wider society as well as the natural world. It is characterised by broadmindedness, social justice, equality, a world at peace, a world of beauty, unity with nature, wisdom, protection of the environment, inner harmony, and a spiritual life.

2.4.3 Higher Order Values of the Schwartz Value System

As seen in Figure 2.1 above, the ten basic values can further be categorised into two opposing pairs of higher order values. These include *self-enhancement* and *self-transcendence* as well as *conservation* and *openness-to-change*. Again, these pairs are diametrically opposed meaning it is not possible to prioritise both *self-enhancement* and *self-transcendence* or *conservation* and *openness-to-change* at the same time (Schwartz, 1992, 2006, 2012). In terms of empirical work, while the basic values are assessed directly according to the various tools (described below) the higher order values are derived by taking the average score of

their constituent basic values. Note that as *hedonism* sits on the border of both *self-enhancement* and *openness-to-change*, it is included in both averages (Schwartz, 2006).

2.4.4 The Refined Theory of Basic Values

Schwartz has described the ten values as “an arbitrary convenience” (Schwartz, 2012). They represent useful labels to further the discussion of the overall motivational continuum. As a result, further development of the Schwartz value system has yielded a more precise, fine-tuned iteration of the system. Rather than ten, this system consists of nineteen labelled values. These include thirteen values created from the subdivision of six of the original values as well as the new values of *face* and *humility*. These emerged through examining the multifaceted definitions of the original values (Schwartz *et al.*, 2012; Schwartz, 2017). The structure of the refined Schwartz value system is shown in Figure 2.2.

This refined value system is not intended to replace or invalidate the previous ten value system, but rather offers a more precise granular definition of values to be used as required by individual research projects (Schwartz, 2017; Lebedeva *et al.*, 2019).

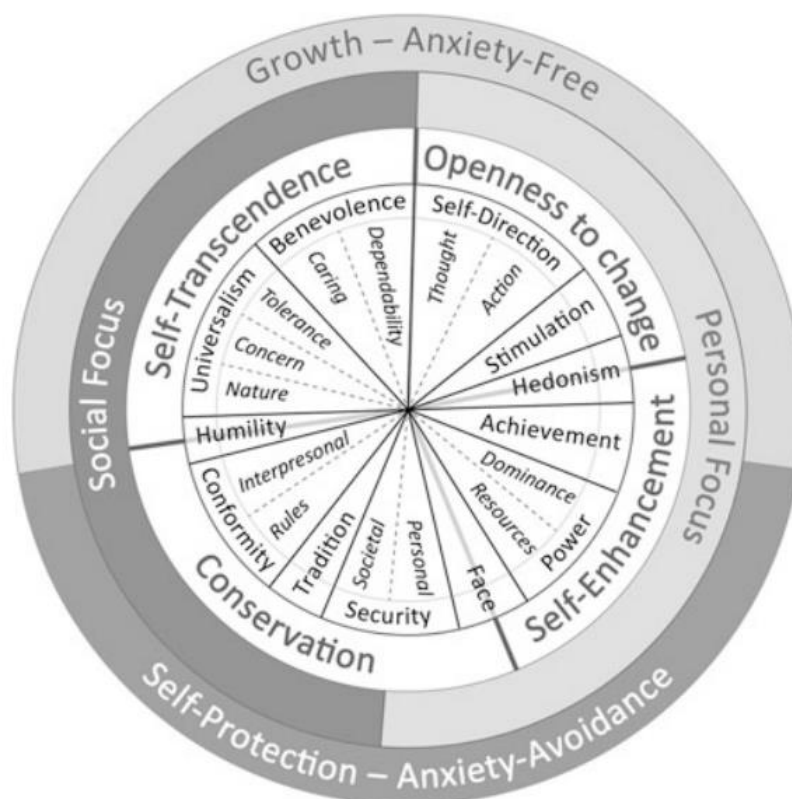


Figure 2.2: The Refined Schwartz Value System (Cieciuch *et al.* 2014)

2.4.5 Assessing Values

A variety of instruments have been devised in order to measure the personal value profiles of individuals. These include the original fifty-seven item Schwartz Values Survey (SVS, S. H. Schwartz 1992), the 40 item Portrait Values Questionnaire (PVQ-40) (Schwartz, 2003), the

fifty-seven item Refined Portrait Value Questionnaire (PVQ-R) (Schwartz *et al.*, 2012; Schwartz and Cieciuch, 2022), the twenty-one item Portrait Value Questionnaire (PVQ-21) (Schwartz 2003), the twenty item value inventory (TwIVI) (Sandy *et al.*, 2017) and the ten item value inventory (TwIVI) (Sandy *et al.* 2017).

The original SVS presents the participant with the values in the form of abstract terms, and the participant is asked to rate the personal importance to themselves on a scale of -1 (opposed to my values) to 0 (not at all important) to 7 (of supreme importance) (Schwartz, 1992, 2021). In later versions, the participant is presented with a short verbal portrait of a person based around a goal which implicitly points to a single value. The participant is then asked to describe how much like themselves this portrait is on a scale of 0 (not at all like me) to 6 (very much like me) (Schwartz, 2003; Schwartz *et al.*, 2012; Sandy *et al.*, 2017). For instance, to assess the value of self-direction, the SVS asks the participant to rate the importance of “Creativity (uniqueness, imagination)” (Schwartz 1992), whereas each of the other surveys presents the same value in the form “thinking up new ideas and being creative is important to him. He likes to do things in his own original way” (Schwartz 2003; Sandy *et al.* 2017; Schwartz *et al.* 2012). The latter approach is believed to be more effective as the mechanism of social comparison is easier for a person to engage with than assigning a numerical score to an abstract value. It also provides a real world context to a value thus helping to clarify differences in interpretation (Schwartz, 2003; Sandy *et al.*, 2017).

Of the instruments mentioned, only the PVQ-RR is capable of producing value profiles according to the refined value system (Schwartz, 2021). However, others such as the PVQ-21 and TwIVI are shorter, and thus are more suitable for applications where time is a factor and where participants may lack the motivation to complete a longer survey (Gosling, Rentfrow and Swann, 2003; Rammstedt and Beierlein, 2014; Sandy *et al.*, 2017; McCutcheon *et al.*, 2021). These are among the reasons that a shorter instrument was selected for inclusions in the European Social Survey (ESS), an academically-driven survey carried out every two years. It is concerned with political, economic and social attitudes and conditions in Europe, and includes among its questions, the PVQ-21. Thirty-eight countries have participated in at least one round, with fifteen, including Ireland, having been sampled in all eleven rounds to date (ESS ERIC, 2024).

2.4.6 Critiques of the Schwartz Value System

The Schwartz Value Theory, while widely utilised, is not without its limitations. The theory reduces complex, interwoven internal beliefs into a finite set of defined values, the theory risks losing important subtleties that contribute to a deeper understanding of human behaviour (Datler, Jagodzinski and Schmidt, 2013; Schwartz, 2017). The reliance on self-reported surveys to assess values introduces another limitation, as responses may be influenced by social desirability bias (Datler, Jagodzinski and Schmidt, 2013; He *et al.*, 2014). Furthermore, the theory does not provide a direct mechanism for translating value data into actionable insights or policy, requiring significant interpretation that could lead to errors or misapplications (Fishbein and Ajzen, 2011; Datler, Jagodzinski and Schmidt, 2013).

2.5 Vocational Interests

2.5.1 The Holland Typology

The Holland Typology, named for its creator John Holland, is a framework often cited in relation to the study of vocational interest. It operates on the basis that aligning an individual's personality type with a corresponding work environment yields greater job satisfaction and performance (Holland, 1958, 1959, 1985, 1996). His theory consisted of six personality types and six corresponding work environments: *Realistic*, *Investigative*, *Artistic*, *Social*, *Enterprising* and *Conventional* (Holland, 1996). Through the use of standardised personality tests, it is possible to determine which combination of these best fits an individual and thus vocational areas to which they are most suited. In the years since its first publication, the theory has gone through a number of revisions and refinements and has been widely used in the field of careers guidance (Holland, 1996; Hogan and Blake, 1999; Nauta, 2010).

Engineering has been categorised into a number of different classifications in the Holland Typology, each of which has a different set of associated values, and traits. In some earlier work into these vocational interests, engineering (at least certain disciplines including mechanical, civil and industrial) are classified as primarily *realistic* (Holland and Astin, 1962, 1962; Holland and Nichols, 1964, p. 196; Holland, 1966). However, in later empirical work, Engineering is generally considered to fall within the *investigative* work environments of the Holland typology (Sagiv 2002; Knafo and Sagiv 2014). The ambiguous placement of engineering is understandable as there are aspects of each which are associated with engineers. Table 2.1 shows the descriptive attributes of the realistic and investigative personality types, while

Table 2.2 shows the description of these two environment types.

Table 2.1: A Brief Description of Realistic and Investigative Personality Typologies

Attribute	Realistic	Investigative
Preference for activities and occupations	Manipulation of machines, tools and things	Exploration, understanding and prediction or control of natural and social phenomena
Values	Material rewards for tangible accomplishments	Development or acquisition of knowledge
Sees self as	Practical, conservative, having manual and mechanical skills - lacking social skills	Analytical, intelligent sceptical and having academic talent – lacking interpersonal skills
Others see as	Normal, frank	Asocial, intellectual
Avoids	Interaction with people	Persuasion or Sales activities

Table 2.2: A Brief Description of Realistic and Investigative Environmental Typologies

Attribute	Realistic	Investigative
Requires	Manual and mechanical competencies, interaction with machines, tools and objects	Analytical, technical, scientific and verbal competencies
Demands and rewards the display of	Conforming behaviour, practical accomplishment	Scepticism and persistence in problems solving. Documentation of new knowledge, understanding or solution of problems.
Values or personal styles allowed expression	Practical, productive and concrete values; robust, risky, adventurous styles	Acquisition of knowledge through scholarship or investigation
Occupations or other environments involve	Concrete, practical activity; use of machines, tools, materials	Analytical or intellectual activity aimed at trouble-shooting or creation and use of knowledge
Sample occupation	Carpenter, truck operator	Psychologist, microbiologist

The *realistic* category includes occupations like technicians, and tradespeople. The personality types associated with the “realistic” occupations included words and phrases like “practical” and “mechanical” and a preference for working with tools and machines (Holland 1996). Similarly carpenter, mechanic, electrician and welder are included as sample occupations (Holland, 1996, 1997). All of these examples fit a common cultural understanding of what an engineer is and does. For instance, research among school children has shown that engineers are seen as “worker-bees” (Fralick et. al. 2009) and are involved in repair and maintenance work (Knight and Cunningham, 2004). When asked to draw an engineer and a scientist, the image of the engineer was significantly more likely to include tools, civil structures and machines and to depict the engineer in the act of building, making or repairing something than the scientist (Fralick et. al. 2009). In Ireland, the secondary school subject titled “Engineering” appears to fit with this conception. It heavily rewards hands-on skills with 25% of a student’s final grade awarded for a manual fabrication exam, while another 25% is given to a project which combines the design and construction of a device. Baille and Fitzgerald (2000) investigated attrition among engineering students in the UK and found that many expected larger amounts of practical and hands-on work. Others have expected the degree to be suitable for those who are less interested in theory heavy workloads (Ramoo, 2014).

The categorisation of engineering as *investigative* would place it alongside the sciences. The associated personality traits for this group include a preference for “prediction or control of natural phenomena” while the work environment requires “analytical”, “technical”, “scientific” and “problem-solving” competencies (Holland 1996). It is notable that the two potential classifications of engineering include either a preference for avoiding “interaction with people” or a perception of being “asocial” (Holland 1996). These are consistent with the stereotypical image of an engineer described by Riley (2008) in her analysis of jokes about engineers.

It has been argued that as engineering developed into an academic discipline it aligned itself more closely with the existing scientific disciplines. In doing so it distanced itself from the practical training of mechanical and material trade and adopted the norms and values of academic science (Noble, 1979; Nair, 1997; Mitcham, 2003; Buch, 2022). One study at an

Irish institution differentiated between engineering and engineering technology degrees, with the former being more theory driven and the latter being more practical or applied (Murphy et al, 2015). The authors of that study found that there was very little distinction in terms of professional identity between undergraduate students in both types of programme and suggested that the lack of clear distinction in terms of professional identity between the two is responsible for some of the confusion among incoming students.

2.5.2 Values, Vocational Interests and Engineering

Using the Rokeach value system (Rokeach 1973) Munson and Posner (1979) highlighted the differences between the values of engineers in different roles within a company. While the overall value structure of engineers and engineers in management positions was broadly similar, there were a number of significant differences. Engineering managers attached significantly more importance to the values of *"obedient"* and *"pleasure"* and significantly less importance to *"cheerful," "independent," "loving"* and *"wisdom"* than non-management engineers. This study also demonstrated a correlation between engineers' value priorities and a feeling of success in their role with engineers who favoured *"a sense of accomplishment"* and *"responsibility"* feeling more successful in their role while those who favoured *"a comfortable life", "a world at peace", "true friendship" and "cheerfulness"* experiencing a below-average feeling of success (Munson and Posner, 1979).

Daniela et al. (2013) investigated the role of personal values in the formation of attitude towards work, as well as professional and academic success in the field of engineering. This study again used the Rokeach value system (Rokeach 1973) and sampled 60 working engineers and 60 engineering students based in Romania. Among working engineers, positive correlations were found between a positive professional assessment and the value of *"a world of beauty, beauty of nature and art"* and the value of *"peace in the world, a world without wars and conflicts"*. Among female working engineers a negative correlation was discovered between the value of *"freedom"* and positive professional assessment. Among students this same value (*freedom*) correlated positively to academic performance.

In a cross-sectional study of engineering students at a Welsh University (Al Kakoun, Boy and Xavier, 2021) first-year and third-year engineering students were sampled. This study assessed the personal values of engineering students using the refined theory of basic values (Schwartz et al. 2012) and examined the link between personal values and likelihood of students producing communal and socially desirable designs. It was found that there was no significant link between year group and which higher order value was prioritised by students, though third-year students did score significantly higher than first-year students for the value of *tradition*. *Security (societal)* and *conservation* (excluding *humility* and *face*) were also lower for first-years. While the difference was not significant, the effect size was medium to large. Students who scored highest for *openness-to-change* were most likely to produce communal designs, while those who rated *self-transcendence* higher tended to produce work which received higher social desirability scores. The authors suggest that the intention-behaviour gap (Sheeran and Webb, 2016) may be responsible for those in the *self-transcendence* group not producing more socially desirable designs, as students are not equipped with the methodological tools required for this kind of design. They also suggested that the depoliticized nature of engineering and engineering education undermines the ability and inclination of students to engage with socially desirable and communal design criteria (Al Kakoun, Boy, and Xavier 2021).

Some research has revealed significant correlations between personal value priorities and the work environment in which the person is involved (Sagiv, 2002; Knafo and Sagiv, 2004; Tartakovsky and Cohen, 2014; Arieli, Sagiv and Roccas, 2020). In these studies, those whose occupation and vocational interests were in the investigative category (such as engineering) were shown to prioritise the *self-direction*, *achievement* and *universalism* values, while de-emphasising *conformity*. *Tradition*, *hedonism*, and *security* were also rated significantly lower for this group in the study conducted by Knafo and Sagiv (2004). The same study found opposing values for some of these for participants in the realistic category. These latter participants de-emphasised *self-direction* while prioritising *hedonism* and *tradition*. Finally those in the enterprising category were found to emphasise *power* and *achievement* (Sagiv, 2002; Knafo and Sagiv, 2004) and de-emphasise *universalism*, *benevolence* and *tradition* (Arieli, Sagiv and Roccas, 2020). Despite the gender differences in personal values, the patterns of correlations between interests and personal values were found to be near-identical among male and female participants (Sagiv, 2002).

In addition, certain personal traits, such as creativity and empathy have been found to correlate with different personal value priorities. In studies conducted in the USA, creativity has been shown to correlate positively with *self-direction* and *stimulation*, and negatively with *security*, *tradition*, *conformity*. In these studies creativity was assessed based on performance in a task (Dollinger, Burke and Gump, 2007; Kasof *et al.*, 2007; Arieli, Sagiv and Roccas, 2020). A similar positive correlation between *self-direction* and creativity was identified in self-reported data in Portugal, Egypt, and Turkey (Rice, 2006; Sousa and Coelho, 2011).

Correlations with creativity have also been investigated in relation to the refined theory of personal values (Lebedeva *et al.*, 2019). This study examined various aspects of creativity, both general and domain-specific. These included craft, visual arts, performance, theatre, machine graphics, and products for work. The final category here refers to the generation of new ideas, software, hardware, procedures or presentation materials related to work. Once again, this study revealed significant positive correlations between general creativity and the *openness-to-change* higher order value and a negative correlation to *conservation*. Looking at specific values, creativity correlated positively to *self-direction-thought*, *self-direction-action*, *stimulation*, *hedonism*, and *universalism-nature*, and negatively with *tradition*, *conformity-rules*, *conformity-interpersonal*, and *humility* (Lebedeva *et al.* 2019). With specific regard for the “products for work” category, all of the above correlations applied, as well as a positive correlation for *achievement*.

Empathy is another trait which has been shown to correlate with values in the Schwartz value system (Balliet *et al.*, 2008). Participants of this study were business students at a large state university and psychology students at a small Christian liberal arts college. In both samples *benevolence* was the value found to have the strongest correlation with empathy.

Elsewhere, values have been demonstrated as a predictor of prosocial behaviour (Bayram, 2016). It was found that the *self-transcendence* and *openness-to-change* higher-order values correlated positively with an individual's support for foreign development assistance.

In another study it was found that those who prioritised *self-enhancement* values were more prone to unethical decision making (Fritzsche and Oz, 2007). In this study participants were presented with a series of short descriptions of business decisions to make, in which an unethical option was available. They were then asked to indicate the likelihood that they would

take that option. The results of this were then analysed alongside a shortened version of the Schwartz value survey (Schwartz, 1992).

2.6 Norms

2.6.1 Normative Structures and the Mertonian Norms of Science

The next useful concept to understand with regards to professional socialisation is normative structures. Norms are a set of expectations which govern the collective behaviour within a social system. Each institution then should be considered to have its own set of norms and in turn, values which justify them (Merton, 1938). Collectively, these norms create a framework within which an individual is expected to behave. Becoming familiar with and learning to operate within the structures created by a set of norms is part of the professional socialisation process. In studying the field of science, Robert Merton sought to describe the social structure of science by identifying a set of universal norms which guide scientific practice. As a structural functionalist, Merton viewed society as a network of institutions, each with a separate aim. Together, these institutional goals allow for societal stability and progress (Sismondo, 2010). Both the structure within and the relationships between these institutions are necessary for them to function well, and these norms help to define and maintain the institution of science (Merton, 1940).

Specifically, Merton was interested in the moral norms, as distinct from technical norms, of science. While the technical norms are methodological and relate to the reliability and adequacy of empirical evidence, the moral norms govern the behaviour and attitudes of scientists towards each other and their work. Their authority comes from the belief that they are morally right and good (Merton, 1938, 1973). “The institutional goal of science is the extension of certified knowledge” (1973: 270). A scientist is bound by a set of behavioural expectations with regards to their work. These norms, according to Merton, are what steer science towards its societal goal (Merton, 1973).

He arrived at four norms, universalism, communism (or communality), disinterestedness and organised scepticism. These were the four which he felt, though not necessarily exhaustive, had the broadest application to science. A clarification also needs to be made regarding the application of these norms. They should not be seen as absolute rules or a description of perfect behaviour. Though regularly interpreted as such, this was not the intention. They should instead be seen as a set of principles or ideals against which scientists and their actions can be examined (Cole, 2004). To put it another way, rather than absolute dimensions, these norms should be considered the axes of measurement.

Universalism is the idea that all scientific work should be evaluated against impersonal criteria and pre-established scientific understanding. The identity of the person or group making the claim should have no bearing on the acceptance or dismissal of the findings. Specifically racial, religious, class and national identities are mentioned though the spirit of this norm would suggest that others, such as gender or political alignment for instance, should be included in the list (Merton, 1973; Sismondo, 2010).

Communism(sometimes called communality), among the scientific community, refers to the sharing of scientific knowledge and findings. No scientific knowledge is monolithic. Each finding builds on pre-existing work. As such, while the individual who makes a discovery can claim credit for their findings, they have no rights over who uses the knowledge or to what

ends. Methods and works should be published and distributed, both as a means to facilitate further discovery and to publicly lay claim to one's own work (Merton 1973; Sismondo 2010).

Organised scepticism is the gatekeeper for scientific knowledge. No new claim can be accepted without thorough interrogation. In modern terms, this is embodied in the peer review process. This is what Merton believes separates science from institutions like religion. There can be no dogmatic exceptions to this inquiry (Merton 1973; Sismondo 2010).

Disinterestedness, according to Merton, is the reason for "the virtual absence of fraud" in science. It suggests that scientists maintain a separation between their motivations and their scientific judgement. Rather than fame or riches, he suggests "a passion for knowledge, idle curiosity, [and an] altruistic concern with the benefit of humanity" as appropriate motivations for scientific inquiry (Merton, 1973; Sismondo, 2010).

These are the norms, as outlined by Merton, which are "binding on the man [sic] of science".

"They are legitimised in terms of institutional values [and] internalised by the scientist, thus fashioning his scientific conscience" (Merton, 1973, p. 269) If the institution is functioning well, these norms should be enforced through sanctions and reward. It is not surprising that these norms have come under criticism. A significant amount of this is due to interpretation of what these norms set out to achieve; there remains some valid questions about their nature and utility (Mitroff, 1974; Mulkay, 1976; Cole, 2004; Stehr, 2018). With any knowledge of science, particularly in modern industry, it is difficult not to see these norms as somewhere between generous and hopelessly naive.

2.6.2 Counternorms

Merton referred to counternorms in his original paper. These were later expanded upon by Ian Mitroff (Mitroff, 1974; Mulkay, 1976; Cole, 2004; Stehr, 2018). His study of the Apollo lunar missions described the ambivalent relationship that can exist within social institutions between conflicting sets of norms (Sismondo 2010). Each norm has an opposite which can and has been used for the scientific good. Mulkay (1976) went so far as to say that the counternorms could, in certain circumstances, be interpreted "as being essential to the furtherance of science".

One example used by both is in relation to the norm of universalism. Particularism, being the counternorm here, is regularly employed by scientists. When an individual has gained an amount of credibility in a particular field, it is common for colleagues to value their findings over others. This trust would fly in the face of the impersonal scrutiny which the norm of universalism professes. The benefit here is the time and effort it takes scientists to develop their own work (Mitroff, 1974; Mulkay, 1976).

It's possible that this type of action is only facilitated by the faith that scientists put in these same structures. Knowing the reputation of a colleague and having subjected their earlier work to proper interrogation allows for an amount of faith in their abilities and ethics. If one believes that the system of rewards and sanction in science are reputational and effective, then a scientist's reputation could be a reasonable means by which to assess certain claims (Sismondo, 2010).

2.6.3 Utility of Norms

Mitroff has shown that breaches of norms are not met with sanctions. Not only this, but their contravention is often beneficial. Mulkay (1976) suggests that even the inclusion of counternorms does not adequately describe the structure of science. It has also been argued that the “binding” nature of norms as described by Merton cannot be reconciled to a more flexible application. “And if norms do not represent constraints, then they do no scientific work” (Sismondo, 2010).

Mitroff (1974) suggests that these norms form part of the “social stereotype” or the “story book image of science”. Social traits, similar to those in the Mertonian norms, have been identified in various studies of the public perception of science. Mulkay (1976) further outlines how other studies have shown science to use this image as a justification for their own self-governance. Portraying the scientific community as virtuous and self-regulating was useful in maintaining a “functional autonomy” (Mulkay, 1976). If these norms cannot be applied directly as a framework, then they must be interpreted. It has been shown that with enough flexibility, almost any action in science can be portrayed as upholding or breaching the Mertonian norms (Sismondo 2010).

Others have shown that the normative structure of science is latent (M. S. Anderson *et al.*, 2010). This tallies with Ziman (2000): “they do not describe realities. They function precisely to resist contrary impulses”. The implication being that the true scope of the normative structure is only revealed as different strands are challenged. Norms are revealed in controversy. The greater or more frequent the controversy, the more the norm (or counternorm) will be expressed (M. S. Anderson *et al.*, 2010). The Mertonian norms then, can only be said to represent a curation of the more broadly relevant norms. If we are to return to the earlier metaphor and consider the normative structure of science as the axes of measurement for scientific behaviour, then the Mertonian norms can only be considered as one suggestion of the most useful axes to use.

2.7 Recruitment of Engineering Students

As discussed in section 2.3 above, the process of professional socialisation begins before the individual enters formal professional education. Based on their perceptions and expectations of the profession, individuals begin to adopt behavioural traits they believe they expect to be appropriate for the profession (Cornelissen and Van Wyk, 2008; Weidman, 2020). These expectations also influence how further socialisation progresses as students weigh their expectations of the profession against the content being taught, and attempt to reconcile the two (Cohen, 1981b; Cornelissen and Van Wyk, 2008). The behaviours and culture within a group and the public perception of that group are major factors in determining how and if an individual belongs within that group. It sets expectations as to how the group interacts with the wider society. This societal interaction is then imitated by new members (Carberry and Baker, 2018).

There is an implied question here of selection vs conditioning. While a significant portion of professional socialisation occurs within the confines of engineering education, to fully understand the values within engineering education, it is important to understand the values of those who choose to enrol in an engineering degree programme. In a UK study investigating “how ‘social’ considerations are currently being interpreted and addressed within engineering education and accreditation”, one participant suggested that “we’re choosing the wrong people

to be engineers” and that it’s “easier to educate a broad-minded person about calculus than to educate a narrow-minded person about social inclusion” (Xavier, Wint and Orbaek White, 2022). Another study, which investigated the professional social responsibility beliefs of engineering students enrolled in programmes for different engineering disciplines found that the largest differences were evident among first-year students (Canney and Bielefeldt, 2015c). This suggests that students may be self-selecting into programmes based on their preconceptions of the discipline.

Research has been conducted on the recruitment and retention of engineering students, some of which has focused on issues of personal identity (Holmegaard, Madsen and Ulriksen, 2014). Personal values are an important part of an individual’s sense of self (Miles, 2015). A person’s values are a contributing factor in their response to an advertisement (Zaichkowsky, 1994) as well as their choice of career (Rounds, 1990; Sagiv, 2002; Knafo and Sagiv, 2004; Arieli, Sagiv and Roccas, 2020). The public perception of the profession is known to be a factor in the recruitment of engineering students (Holmegaard, Madsen, and Ulriksen 2014).

It has been found that students may choose to not study engineering at third level, despite having an interest in and an aptitude for the subject. A study involving second level students taking part in science and technology classes asked students for their reasons for choosing (or not choosing) to study engineering. In these instances, some of the reasons given included a perception that the image of an engineer did not fit with their sense of self-identity. In some cases, the profession was not seen to be social enough. In others it was seen as rigid and untransferable by students who chose to study other subjects (Holmegaard, Madsen and Ulriksen, 2014). This is despite the fact that students who claim to have selected their degree based on interest in the subject are more likely to complete that degree (Seymour and Hewitt, 1997). The ability to reconcile the perceived identity of the profession with their own personal identity is an important factor in a student’s decision to persist in the field (Archer *et al.*, 2010; Matusovich, Streveler and Miller, 2010; Murphy, Chance and Conlon, 2015).

Matusovich used Eccles’ expectancy-value theory (Wigfield and Eccles, 1992; Eccles, 2005) to investigate the criteria that affect an engineering student’s persistence in the field. “Attainment beliefs”, or the ability of an individual to align their image of the profession were central to this study. When these are low, engineering students experience much more difficulty in persisting in the field. In these cases they require higher Utility values, or potential practical benefits of completing the degree, in order to persist (Matusovich *et al.*, 2008; Matusovich *et al.*, 2009a; Matusovich *et al.*, 2009b).

While the sample size was small, Matusovich noted lower attainment beliefs in female participants. In the annual “I Wish” surveys conducted by a coalition of Irish local government, higher education, and industry groups, Irish second level female students have consistently rated “Being good at it” (the phrasing varies slightly) as one of the most important work related values when choosing a career path (I Wish, 2016, 2017, 2019, 2020, 2021, 2022, 2023). Low attainment beliefs are linked to low competence beliefs (Matusovich *et al.*, 2008). In 2021 only 8% of students who studied Leaving Certificate Engineering were female (The Leaving Certificate is the state-run university matriculation examination in Ireland). That same figure was 13% for Construction Studies, 16% for Design and Communications Graphics, 20% for Technology, 28% for Applied Maths, and 29% for Physics (I Wish, 2021). Participation in these subjects has been shown to be a good predictor of pursuing an engineering degree. While many single-sex female schools don’t offer all of these subjects (I Wish, 2017, 2022, 2023) a wider gap in participation in these subjects, when available, has been observed in mixed

schools than in single-sex schools (Delaney and Devereux, 2019). 77% of respondents to the 2022 I Wish survey, and 59% in 2023, lacked confidence in STEM subjects.

A 2014 study in the UK (Skatova and Ferguson, 2014) found that career goals far outweighed intrinsic interest in the subject matter when it came to engineering students' motivation for choosing the subject. It was found that students were much more likely to refer to the career opportunities that their degree will afford than any personal enjoyment of the subject matter. This study recognised the importance of this finding as it has been established that having a low level of interest in a subject can cause less effective learning (McManus *et al.*, 1998).

McManus *et al.* (1998) also recognised a significant gender divide in their data, with female students favouring “helping” and “interest” as motivators for their degree choice while the male contingent reported “career” and “loafing” (a degree they perceived as easy) as their motivation. Similarly, others have found that female engineers are more likely to cite the good they can do as a reason for persisting in an engineering career (Hewlett *et al.*, 2008; Meyers and Mertz, 2011; Bystydzienski and Brown, 2012; Buse, Bilimoria and Perelli, 2013; Canney and Bielefeldt, 2015d; Fouad *et al.*, 2017). Canney (2015d) also determined that female engineering students reported higher levels of social responsibility than their male counterparts. A survey of Irish second level female students has also found that a desire to help people or contribute to the world has consistently been ranked in the top 5 of 13 work related values (I Wish, 2016, 2017, 2019, 2020, 2021, 2022, 2023). It has, however, never been the top-rated value.

A significant lack of understanding of what it is to be an engineer among second level students (Murphy, Chance and Conlon, 2015), particularly female students (Murphy, O'Donnell and Jamesons, 2019; Salas-Morera *et al.*, 2021). In Ireland, female students have consistently cited a lack of understanding about courses and careers in STEM as a barrier for entry (I Wish, 2016, 2017, 2019, 2020, 2021, 2022, 2023). This is concerning when we consider how important their impression of the profession is when it comes to recruitment (Holmegaard, Ulriksen and Madsen, 2010; Holmegaard, Madsen and Ulriksen, 2014).

This calls into question the kinds of students who are being drawn to engineering degrees, and the marketing messages which are attracting them. A focus on marketing which highlights the career prospects that an engineering degree can offer rather than the subject matter of the degree, may contribute to the recruitment of students who will learn less effectively and are less likely to complete the degree. It may also be a factor in maintaining the gender divide which engineering institutions have ostensibly been working to close in recent decades. It is also important to understand what values of the profession are being highlighted when appealing to the career aspirations of students.

There is a need for research into how Irish universities are choosing to market engineering as a career. Choosing to appeal to particular values will influence what the value profiles of those who choose to apply are. For instance, highlighting the *security* of stable employment could attract students of a different value orientation than those who perceive the career as financially rewarding. It would be valuable to examine both the values identified in the marketing material and the personal accounts as to why they chose to study engineering.

2.8 Values and Norms in Engineering

2.8.1 Socialising Effect of Engineering Education

Formal education is an important stage of professional socialisation. It is where students are taught the relevant skills and knowledge necessary for participation in the profession, and where they develop their sense of identity within the profession (Carberry and Baker 2018). As such, the norms and values which are embedded in engineering education shape the development of future engineers. Investigating how the role of the engineer is understood by engineering educators is informative in a number of ways. This understanding, and their understanding of what constitutes good engineering practice informs the content included in an engineering programme (Murphy, O'Donnell, and Jamesons 2019). Similarly, what an educator chooses to teach is perceived as an endorsement of its relevance to the engineering profession. Choosing to include or exclude social considerations or ethical content informs the beliefs of students (Bielefeldt 2018). Engineering education is a formative process during which the student renegotiates their engineering identity and develops the framework for their professional relationship with society (Downey, Lucena and Mitcham, 2007; Murphy, O'Donnell and Jamesons, 2019). For this reason engineering education is considered a means by which culture in engineering is perpetuated, an opportunity to investigate this culture, and potentially even reform the profession (Colby and Sullivan, 2008; Riley, 2008; Cech, 2014a; Cech and Sherick, 2015a; Murphy, Chance and Conlon, 2015; Al Kakoun, Boy and Xavier, 2021; Leydens, Lucena and Riley, 2022; Xavier, Wint and Orbaek White, 2022).

2.8.2 The Value of Neutrality and Objectivity

The perceived objectivity within engineering, resulting from the scientific principles used in the profession, means that the technology produced by engineering is sometimes considered neutral (Haraway, 1988; Riley, 2008; Seron *et al.*, 2018). Some have argued the case for a Value-Neutrality Thesis (VNT), which states that technology is morally and politically neutral, and that the consequences of technology are attributable to the usage, and thus not the responsibility of the engineer. Perhaps the most famous articulation of this is the paper "Guns Don't Kill, People Kill" (Pitt, 2014). However, this position ignores the social forces which shaped the creation of the technology, and the contexts which it imposes (Leydens, Lucena, and Riley 2022). The consequences of technology stretch far beyond the technical realm, from the increased authoritarianism necessitated by the implementation of nuclear power (Winner, 1980), to the mental-health consequences of those who find their lives limited by the built environment (Hollmann *et al.*, 2024). The physical properties of technological artefacts make them a part of the normative order of the world meaning technology embodies values with long-term implications (Miller, 2021). Technological solutions are inherently value-laden and have significant and far reaching societal consequences (Verbeek, 2006). "Technology is power in modern society" says Feenberg (1999). Those who produce, and distribute technology are power brokers. Langdon Winner outlines some of the ways in which political structure becomes enshrined in technological infrastructure. Technologies build order in our world and enhance the power, authority, and privilege of one group over another. Conversely the implementation of certain technologies can necessitate particular social arrangements and power structures (Winner, 1980; Verbeek, 2006).

Some see the potential of technology as a great equaliser. As far back as 1921 Thorsten Veblen predicted that engineers would emerge as a "Soviet of Technicians", acting as a

revolutionary class and taking control back from the elites (Veblen, 1983). This bears a significant resemblance to current discourse around technologies such as block-chain and crypto-currencies. Advocates of these technologies emphasize their decentralizing nature and their potential to shift the balance of power in favour of individual citizens, challenging the dominance of nation-states and financial institutions (Corradi and Höfner, 2018; Zamani, 2019; Jacobetty and Orton-Johnson, 2023). However, it has been argued that rather than an independent power base, the engineering profession has largely developed as a “servant to power” (Perrucci, 1971).

Some are of the belief that engineers, and indeed all professionals, should strive to remove their own value judgments from their work. Similar debates have occurred in other fields such as law and medicine (Peppin, 1995; Thacher, 2015; Bartlett, 2023). In this imagining of the profession, engineers are experts who should apply their knowledge in the service of their client. All value judgements should be external to the work of an engineer (Johnson, 2006). This image of the “gun-for-hire” engineer (Johnson, 2006) fits with many common conceptions of engineers. Throughout the literature, engineers are depicted as machines themselves, or as loyal soldiers in the service of their employer, or indeed, engineering science (Bucciarelli 2008; Nair 1997; Herkert 2000). Engineering has traditionally aligned itself with external definitions of progress, primarily serving the interests of industry (Downey and Lucena, 2004). This industrial focus can create tension when engineering attempts to address social justice issues, often putting it at odds with business interests (Conlon, 2008). Unlike social and political considerations, which are to be excluded from the engineering calculus under the guise of scientific objectivity, business considerations are frequently regarded as valid criteria in engineering decision-making (Meiksins, Smith and Berner, 1996). A mixed methods study, involving interviews, surveys and a case study, across six engineering firms found that engineers identified their role as problem-solvers for “themselves, for their team, for their organisation and for their client” (K. J. B. Anderson *et al.*, 2010). The values which then become embedded in the work of engineers are those of the employer (Leydens, Lucena and Riley, 2022).

Some have suggested that the centrality of problem-solving to the engineering identity is linked to this externalisation of professional direction. Among the reasons why this is needed is that within the engineering problem-solving mindset “constants” and “design variables” are defined. These establish a limited scope within which the engineer will explore potential solutions. The engineering mindset is conditioned to accept the given parameters as beyond question (El-Zein and Hedemann, 2013). Downey (2005) argues for the need for engineering to take back control of its direction by shifting the core definition of engineering from problem-solving to “problem definition and solution”. Riley (2008) suggests that the abdication of responsibility for problem definition is potentially cause for engineering to not be considered a profession in the sociological sense (Riley, 2008; Baillie and Levine, 2013).

2.8.3 Morally Good Engineering

The alternative position is to see professions as having an inherent responsibility to ensure that their work contributes to the social good. Professionals have both a duty to serve and an obligation to lead (Florman, 1996). This is in keeping with many definitions of what it is to be a profession (Johnson, 2006; Riley and Lambrinidou, 2015). This is the origin of the Engineering for Social Justice (E4SJ) movement, which defines itself as “engineering practices that strive to enhance human capabilities (ends) through an equitable distribution of opportunities and resources while reducing imposed risks and harms (means) among agentic

citizens of a specific community or communities” (Leydens and Lucena, 2018, p. 15). Riley (2008) further extends this definition of social justice to include “the struggle to end different kinds of oppression, to create economic equality, to uphold human rights or dignity, and to restore right relationships among all people and the environment”. To achieve this, proponents of E4SJ suggest that critical theory be applied to engineering in order to interrogate engineering practice and establish a more comprehensively ethical profession (Catalano and Baillie, 2006; Riley, 2008; Kabo and Baillie, 2009; Schneider, 2010; Baillie and Levine, 2013; Leydens, Lucena and Riley, 2022).

It has been argued that engineers do not receive education in the kinds of critical thinking required to orient their work towards social justice (Kabo and Baillie, 2009; Claris and Riley, 2012; Riley and Lambrinidou, 2015). An analysis, by Claris and Riley (2012), of the various inclusions of critical thinking in engineering education found it to be of limited scope specifically with relation to social impacts of engineering work. While most mainstream definitions of critical thinking involve assessing the strengths of an argument on the basis of logic and reason, the fixation on positivist epistemology in engineering limits this reasoning only to criteria which can be derived from the scientific method. A number of definitions which appear in engineering educational material specifically include language such as “scientific principles” and “engineering reasoning” (Claris and Riley, 2012). A limited range of perspectives are taken during this reasoning, resulting in a thought process which is more analytical than critical. It is a thought process more suited for technical analysis than questioning the context or norms of engineering work (Leydens *et al.*, 2018). This difference has been described as thinking critically *in* engineering compared to thinking critically *about* engineering (Claris and Riley, 2012; Riley and Lambrinidou, 2015). The effects of this were observed in a study, which involved working in classrooms with students of social sciences and engineering, found that social science students were very capable of thinking critically and deconstructing any system or technology from multiple perspectives whereas engineering students struggled at this assessment stage and lacked the skills to deconstruct the power dynamics at play. Conversely the engineering students were the ones who could create new knowledge or build ideas as alternatives (Kabo & Baillie, 2009).

Riley and Lambrinidou propose the integration of social justice as a core value for engineering. A number of engineering “cannons”, and ethical principles, are suggested, including service, social justice, cultural and epistemic humility, dignity and worth of the person, importance of human relationships and peace. As well as these there are included a set of responsibilities to the client and to the broader society (Riley and Lambrinidou, 2015). Social responsibility in relation to engineering encompasses areas such as human safety, environmental protection and sustainability, pro bono work, social equality and diversity (Bielefeldt, 2018). The degree to which these have been integrated into engineering ethics and education varies (Martin, 2002; Colby and Sullivan, 2008; Bielefeldt, 2018; Conlon, Martin, Nicoleau, *et al.*, 2018). In general, there is some consensus that areas such as environmental sustainability and human safety are within the remit, whereas debate remains regarding aspects such as equality or social justice (Bielefeldt 2018).

Many groups are recognising the need for engineers with a broader range of competencies. Competencies that they will need to develop effective, sustainable, ethical and responsible solutions to society’s problems. This isn’t a new call, however. Over fifty years ago Robert Perrucci wrote: “The growing centrality of engineering activities in American society calls for a profession that not only has the technical skills to deal with societal problems, but also has

both a strong commitment to serve human welfare and the independent power to determine the way in which its talents are used” (Perrucci 1971).

The focus on the employability of graduates in engineering education has been suggested as one reason for this lack of self-reflection within engineering (Jamison, Kolmos and Holgaard, 2014). The existing culture favours a focus on skills required by employers, rather than the cognitive techniques required to reflect critically on the norms of the profession and the distribution of the benefits of engineering work (Conlon, 2008). Because of this lack of professional ideals directing where engineering should be applying its expertise the profession has been described as philosophically inadequate (Mitcham, 2009). Overcoming this requires significant change to the professional identity of engineering, and the values in engineering education (Murphy, Christensen and Conlon, 2022). Others have suggested that the social organisation required to instigate a cultural shift towards socially responsible engineering is actively hindered by the depoliticisation within the engineering profession (Riley and Lambrinidou, 2015).

2.8.4 Depoliticisation

The central tenets of depoliticisation are that engineering is a purely technical field, and that political and social contexts can and should be removed from the technical core of engineering practice (Cech, 2013; Cech and Sherick, 2015a). A positivist mindset, and scientific forms of knowledge are venerated, while those favoured by disciplines, such as the humanities and social sciences, are to be avoided (Blue, Levine and Nieusma, 2014; Kramer, 2022). Engineering is then “a purely technical space...devoid of socio-cultural complexities” (Cech and Sherick, 2015a). It involves the belief in a technical/social dualism, the idea that technical and social forms of knowledge are, and should be considered, separate (Hacker 1981; Faulkner 2000) and that the technical forms are inherently more valuable in engineering (Cech and Sherick 2015). As a discipline of technological research and practice, engineering has primarily aligned itself with the natural sciences in the academic setting (Perrucci, 1971; Noble, 1979; Nair, 1997; Mitcham, 2003; Buch, 2022) while growing distant from the social sciences and the humanities (Buch, 2022).

There is a misguided assumption that disengagement is required for and promotes technical rigour (Riley and Lambrinidou 2015). Robert Merton’s normative structure of science (1942) included *disinterestedness*, or the idea that a scientist should not have a personal stake in the outcome of an experiment, as one of the four guiding norms of the profession. Similarly, Max Weber claimed “Whenever the person of science introduces his personal value judgments, a full understanding of the facts ceases” (Weber, 1946). Weber made his claim in relation to a scientific journal of social policy. Thatcher (2015) demonstrates the issues with value-neutrality in this context and ascribes them in part to the “moral commitments that practical engagement requires”. In short, he argues that attempts at value-neutrality can create a disconnect between work and the original concern which motivated it. Where science is motivated by discovery, engineering is motivated by problems (Nair, 1997), and as such cannot be effectively disconnected from the needs which motivated it.

2.8.5 Non-Technical Content in the Curriculum

Engineering identity is currently characterised by technical problem-solving and applied science (Nair, 1997; Faulkner, 2007; K. J. B. Anderson *et al.*, 2010; Murphy, O’Donnell and Jamesons, 2019; Buch, 2022). Current engineering programmes reflect this with engineering

curricula rarely including subjects from beyond the scientific and technical fields (Murphy, O'Donnell and Jamesons, 2019). As engineering students learn to solve problems using technology, they come to see the culture of engineering as defined by technology, rather than the problem which motivated it (Nair, 1997; Tonso, 2014; Carberry and Baker, 2018). Jamison (2014) calls for this division to be undone and for engineering to be thought of as both a technical and social activity, and for engineers to be equipped with more than just technical capacities. Learning to integrate the technical with the ethical and social, and recognising the value of doing so is seen as a key obstacle towards a more socially just conception of engineering (Riley and Lambrinidou, 2015). Some have pointed to the need for greater collaborations between the humanities and social sciences and engineering (Christensen and Ernø-Kjølhede, 2012; Buch, 2022; Byrne *et al.*, 2022; Christensen *et al.*, 2022; Trevelyan, 2022). Anders Buch has argued that, as the medium by which technological developments are made useful to society, engineering is the ideal platform to mediate between the natural and social sciences. However, doing so would require a significant realignment of engineering culture. Engineering, as a domain of technological research and practice, has predominantly sided with the natural sciences and, as a discipline, has distanced itself from the social sciences and humanities (Buch 2022).

This debate, over how much material from the humanities, liberal arts or social sciences should be included in the engineering curriculum, has been a recurring theme (Seely, 2005). While more recent accreditation criteria for engineering programmes do include requirements relating to engineering ethics, there have been questions raised as to whether these are sufficient or effective (Conlon, Martin, Nicoleau, *et al.*, 2018; Martin and Polmear, 2022; Murphy, Christensen and Conlon, 2022, See also appendix D). There is some evidence that having these criteria helps programme designers to translate ethical issues into course content, though the authors acknowledge that very little non-technical material is included in current Irish engineering curricula (Seely, 2005; Murphy, O'Donnell and Jamesons, 2019; Murphy, Christensen and Conlon, 2022). In an American context, Cech and Sherick (2015) suggested that the structure of the requirements encouraged the inclusion of these topics in a non-integrative way, and thus further reproduced the technical-social divide already present in engineering education. An assessment of the Irish accreditation requirements revealed a similar structure, with clear delineation between the “hard” and “soft” requirements (Murphy, Christensen and Conlon, 2022). This divide has been highlighted as a recurring issue in a number of studies in engineering education, which have indicated that subjects which deal with social forms of knowledge and non-technical subjects are consistently segregated as being something external to and lesser than engineering skills (Christensen and Ernø-Kjølhede, 2012; Godfrey, Crick and Huang, 2014; Kramer, 2022; Martin and Polmear, 2022; Murphy, Christensen and Conlon, 2022; Xavier, Wint and Orbaek White, 2022).

Throughout the literature some common issues have been identified in terms of integrating non-technical content into engineering programmes. These have included challenges in adding content to an already crowded curriculum, the perceived relevance or irrelevance of non-technical content and the expertise of the staff tasked with delivering this content. The following subsections review the literature dealing with these challenges.

2.8.5.1 Crowded Curriculum

A crowded curriculum has repeatedly been cited as a barrier to the inclusion of additional non-technical content. Particularly in the context of technical content being prioritised above all else, staff have been found to be reluctant to make room for ethical or social justice related

content (Godfrey and Parker, 2010; Martin and Polmear, 2022; Murphy, Christensen and Conlon, 2022). The word “sacrifice” was used by multiple engineering educators in multiple studies in relation to potentially removing technical content for “something that is not engineering” (Martin and Polmear, 2022; Murphy, Christensen and Conlon, 2022; Xavier, Wint and Orbaek White, 2022). Even some of the more tangible transversal skills such as communication and team-work were “seen as taking up time” in an already full curriculum (Murphy, Christensen and Conlon, 2022). Staff in one study described an existing belief among other engineering educators that including additional ‘soft’ subjects would “dilute the engineering call” (Xavier, Wint and Orbaek White, 2022), while others felt that “the fundamental scientific core of the curriculum must be defended” (Murphy, Christensen and Conlon, 2022). The result is that the amount of non-technical material which staff included in their programmes was described as “minimum necessary level” required by the accrediting body (Martin and Polmear, 2022).

2.8.5.2 Perceived as Irrelevant

Even though accrediting bodies now require some degree of content dealing with engineering ethics and the role of the profession in society, the introduction of this content faced resistance as they were not deemed to be relevant skills that industry needs (Xavier, Wint and Orbaek White, 2022). An investigation into the incorporation of social sciences and humanities content into the engineering curriculum reported that some social science academics perceive that engineers believe they “can do [their] job successfully and be successful professionals without this” (Martin and Polmear, 2022). In another, it was claimed that some engineering staff believe that “engineering does not belong with the arts” and that “accreditation is to stop this nonsense” (Xavier, Wint, and Orbaek White 2022). This is consistent with a market-driven “mode” of engineering education as described by Jamison (et al. 2014). In this form, engineering education is described as a production line, forming and equipping students to be effective employees. The attitudes described in the above studies are examples of engineering education being defined by the ability to produce graduates with the skills to meet the needs of industry, without reflection on the wider needs of society.

2.8.5.3 Lack of Expertise

Engineering educators are primarily traditionally trained engineers, and so are less well versed in delivering content relating to social considerations. Social and ethical considerations were not a significant part of their own education (Martin, 2020; Xavier, Wint and Orbaek White, 2022) and so staff felt that they “don’t have the tools” and would require significant training in the social sciences and humanities in order to integrate these topics successfully (Xavier, Wint, and Orbaek White 2022).

There are also issues with having these subjects delivered by an external department. It has been found that the “language barrier” is an obstruction in both directions, as staff from the humanities struggle to effectively communicate this content in a way which is engaging to engineering students (Xavier, Wint, and Orbaek White 2022). Claris and Riley (2012) had some success teaching students to apply ideas relating to critical theory to their engineering work, though they clarify that this is not a replacement for courses on Science Technology and Society (STS) or Philosophy of Engineering/Science taught by the relevant expert. Rather this is to compliment these courses and cement their relevance and encourage students to question the norms of engagement of engineering (Claris and Riley 2012).

Another aspect to this lack of expertise is on behalf of the accrediting body themselves. It was noted in one study that the accreditation panel is generally composed of traditionally trained

engineers. When engineering academics attempt to introduce social topics they struggle, as the accreditation panels lack the expertise needed to assess its relevance (Grimson and Murphy, 2013; Jamison, Kolmos and Holgaard, 2014; Murphy, Christensen and Conlon, 2022; Martin and Conlon, 2023)

2.8.6 Ethical Approaches in Engineering Education

Investigations into the inclusion of engineering ethics in education have repeatedly identified shortcomings (Martin, 2002; Colby and Sullivan, 2008; Baillie and Levine, 2013; Harris, 2013; Conlon, Martin, Nicoleau, *et al.*, 2018). Engineering ethics in education have generally been structured around a professional code of ethics, case studies, and dilemmas while emphasising environmental or safety impact rather than social considerations (Conlon 2022; Colby and Sullivan 2008; Bell 2011; Martin 2020). They are framed around the actions of the individual engineer, and as such are insufficient for navigating the power structures in which engineering operates (Bucciarelli, 1996, 2008; van de Poel, 2001; Conlon, 2022). Herkert (2000, 2005) is among those suggesting that engineering ethics needs to shift to a macro-ethical focus.

Ethics has been described as a “disempowered subject within engineering education (Martin and Polmear, 2022). It has been claimed that ethics textbooks don’t address social justice effectively or adequately (Bielefeldt, 2021). The engineering ethics topics covered in Irish degree programmes were described as “primarily code of conduct stuff” (Murphy, Christensen and Conlon, 2022) and fail to address the wider role of the engineer in society (Martin, Conlon and Bowe, 2021b; Conlon, 2022). University teaching staff felt that the accrediting body was satisfied with the level of ethics currently in their programme (which their accreditation would seem to corroborate), stating that “what they’re looking at is the skills that graduates need for working in an office as opposed to how they’re going to address social injustice issues” (Murphy, Christensen and Conlon, 2022).

Various proposals have been made to alter the approach taken to engineering ethics. These include, among others, holistic engineering ethics (Conlon, Martin, Nicoleau, *et al.*, 2018), ethics of care (Nair, 1997; Campbell and Wilson, 2011; Campbell, 2013), aspirational ethics (Harris, 2013). Ethics of care were used in the “framework for the development of social responsibility in engineers”, which has had some success in raising levels of awareness societal impacts, ethical decision-making, and the commitment to public welfare among engineering students (Canney and Bielefeldt, 2015a). Conlon (2022) concludes that an ethics centred on critical realism may be a more effective tool with which to equip engineering students.

2.8.7 Existing Literature on Engineering Students’ Beliefs

Some work has already been done investigating the social responsibility beliefs of engineering students. A cross-sectional study examining social responsibility beliefs among engineering students in a U.S. university found that different streams of engineering education held significantly different beliefs. Environmental engineering students scored more highly for social responsibility than civil engineering students, who in turn scored more highly than those studying mechanical engineering (Canney and Bielefeldt, 2015c). Furthermore, it was found that the differences were greater among first-year students, suggesting that more socially responsible students chose particular degree courses rather than this being an effect of the degree programme. It has also been found that female students display higher levels of social

responsibility, though, again, this difference was larger among first-year students than senior students (Canney and Bielefeldt, 2015d).

An investigation into social justice attitudes in Irish engineering education found a broadly positive attitude towards its potential inclusion. In a cross-sectional survey of engineering students, respondents showed significant support for the inclusion of a broader curriculum including subjects such as social justice, the responsibilities of an engineer, and the societal impacts of engineering. 64% of students supported the statement that “My engineering education should have a focus on addressing inequality in society” while only 34% supported the statement “My engineering education should focus on technical subjects only” (Murphy, Christensen and Conlon, 2022).

The results are less positive when fourth year students were asked about the content of their degree. 56.2% of participants reported that their degree “has had a focus on technical subjects only”, with 34.5% agreeing that their degree “Has helped me to understand the importance of social justice in engineering”, and 37.5% agreeing that it “Has had a focus on addressing inequality in society”. Perhaps most concerning, 87.5% of these students agreed or strongly agreed that the degree programme “Has allowed me to understand my responsibilities as an engineer” (Murphy, Christensen and Conlon, 2022). It appears from this data that there is a significant portion of these students who believe that they are fully prepared for their role, to which social justice and inequality are entirely irrelevant.

Erin Cech, in an influential longitudinal study, demonstrated “a culture of disengagement” within engineering education (Cech, 2010, 2014a, 2014b). In these works, several social engagement metrics of engineering students were repeatedly tested as they progressed through their degree programme and into their early careers. The results showed a downward trend in these metrics including level of focus which they believed their degree placed on social and ethical issues, the importance to a successful career of social engagement and the personal social consciousness of the participants. A subset of these results is shown Figure 2.3.

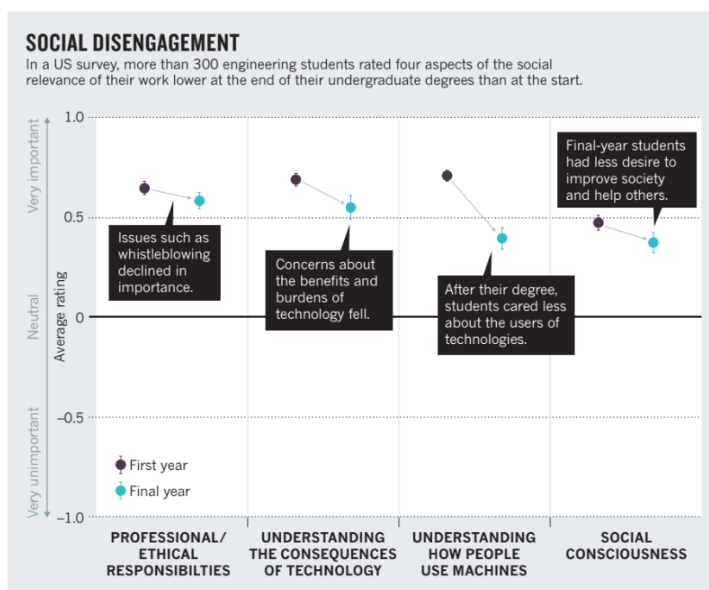


Figure 2.3 Downward Trend in Students' Social Engagement (Cech 2014b)

In contrast to this, a more recent study found that the levels of social consciousness remained steady among their examined cohort of engineering students over the course of four years of their engineering degree (Howland *et al.*, 2024). Participants in this study were based in three American universities, and also showed small but significant increases in various ethical competency scores. This study also asked students to rank “engineering work and practice considerations”. The authors highlight that health and safety, technical and ethical

considerations, in that order, were ranked as most important by participants, and that environmental considerations climbed from 6th to 4th position over the course of their degree

programme. It is suggested that this is evidence against the culture of disengagement described by Cech (2014), though it should also be noted that participants in this study had consistently rated social considerations as least important to engineering practice (Howland et al. 2024). The authors offer the explanation that “the rather broad, vague nature of this one item may have caused it to be less understood and, therefore, ranked lower compared to other options”, which in itself could be considered evidence for the techno-social divide described by Cech (Cech, 2010, 2013, 2014a; Cech and Sherick, 2015a). This misunderstanding speaks to the way that social considerations are considered among those in engineering education as vague and unscientific, as well as calling into question the scope of the ethical considerations and concern for the wellbeing of the public which these participants rated more highly. Rather than a positive sign, a narrow focus on health and safety has actually been a source of criticism for engineering ethics (Martin, 2002; Herkert, 2005; Colby and Sullivan, 2008; Harris, 2013; Conlon, Martin, Nicoleau, *et al.*, 2018; Xavier, Wint and Orbaek White, 2022).

2.9 Conclusions

Teaching engineering as depoliticized is inaccurate and unhelpful to the student, their employer and the wider society. Engineering, in practice, is not as depoliticized as the classroom depiction implies and teaching it as such leaves students unprepared for dealing with the multitude of social, political and ethical concerns that real-world engineering entails (Bucciarelli, 1996; Faulkner, 2007; Cech and Sherick, 2015a) and ill-prepared to navigate the ethical aspects of their role in society (Martin, 2002; Colby and Sullivan, 2008; Conlon, Martin, Nicoleau, *et al.*, 2018; Martin and Polmear, 2022). The skills required for this role are far more broad than a strictly technical education can provide (Conlon, 2008; Christensen and Ernø-Kjølhed, 2012; Riley and Lambrinidou, 2015; Martin, 2020).

In the words of a former Dean of Engineering at the University of Tennessee, “the ideal engineer is a composite. ... He [sic] is not a scientist, he is not a mathematician, he is not a sociologist or a writer. But he may use the knowledge and techniques of any or all of these disciplines in solving problems” (Dougherty, 1972, p. 33). The former director general of Engineers Ireland included this quote in an address, adding, “The question can be asked is there an ideal all-encompassing engineering curriculum that ‘ticks all the boxes’ and the answer is simply no; it is impossible. What is needed then is a variety of programs with different footprints that collectively provide the profession with in-depth but wide coverage.” (Grimson *et al.*, 2022). However, various investigations into the curricula of engineering education programmes have demonstrated a culture, that venerates technical and mathematical prowess while devaluing the sociologists and writers mentioned by Dougherty. Engineering students learn to solve problems without the accompanying appreciation for non-technical forms of knowledge and social engagement required to consider how the outcomes of their work, positive and negative, are distributed. This lack of central social good for engineers to aspire to is a potential hindrance to the development of more socially responsible engineering (Riley and Lambrinidou 2015).

The effects of this have been seen internationally. Over the course of their education, students appear to internalise the ideology of depoliticisation and learn to bracket the social considerations as separate to “real engineering” knowledge (Cech, 2014a; Cech and Sherick, 2015a). Despite the significant and far-reaching impacts that their future careers will make students in Irish engineering education appear to be graduating with the belief that their role

is unrelated to issues of social justice. There is evidence of the personal social engagement beliefs of students being affected as they become socialised into the engineering profession (Cech, 2010, 2014a). However, subsequent studies claim to have found conflicting results (Howland *et al.*, 2024). Research of this kind is situated in a particular time and place and can be affected by a range of external factors. Elsewhere it has been shown that the social responsibility beliefs of those enrolling in various engineering programmes vary significantly, raising questions as to the influence of the selection and condition effects at work (Canney and Bielefeldt, 2015c, 2015d).

This thesis investigates the professional socialisation and values in Irish engineering education. Bielefeldt (2018) highlights the need for more research into the beliefs of engineers and how they are shaped. Personal values are fundamental beliefs which guide our actions (Braithwaite and Law, 1985; Schwartz, 1992), and have been shown to have some correlations to engineering project outcomes (Al Kakoun, Boy and Xavier, 2021). Using the framework of the Schwartz value theory, this thesis will assess the values of students at various stages of engineering education. It will examine the recruitment of engineering students and how their choice of an engineering degree relates their values. The goals of engineering education will be investigated, as will the role of values and social considerations in the resulting programmes. The values of both students and educators will be explored and the effects of engineering education on students' values will be analysed. This thesis aims to contribute to the understanding of how engineering education influences the development of values, and thereby inform future educational practices. The next chapter will discuss the methods and approaches used in the thesis.

Chapter 3: Methodology

The purpose of this thesis is to explore and understand the professional socialisation of engineering students during their formal education from a values perspective. In order to achieve this, it is necessary to explore the values of those recruited into engineering education, to examine the objectives of engineering education, and to investigate how undergoing the process of engineering education influences the values and beliefs of engineering students. This thesis aims to answer the following research questions:

RQ1: What are the values being appealed to during the recruitment of engineering students in Ireland?

RQ2: What are the values of those who enter engineering education in Ireland?

RQ3: What are the ideal values of an engineer according to those involved in Irish engineering education?

RQ4: What are the values promoted by engineering education in Irish universities?

This research is interested in both implicit and explicit values. Explicit or stated values are more often directly expressed and may form part of an organisation's mission statement (Espedal *et al.*, 2022; Løvaas, 2022). However, as other forces can influence practice, understanding explicit values is often insufficient. Implicit values can be subconscious, and are embedded in action, organisational structure, norms of practice, and culture (Schwartz, 2012; Espedal *et al.*, 2022). While the focus of this research is on values, it will inevitably involve assessing norms and other aspects of the culture in engineering education. The study of implicit and explicit values require different methodological approaches and are more suited to particular research paradigms (Dose, 1997; Espedal *et al.*, 2022). In this research pragmatism was selected as the research paradigm and a mixed methods approach was taken. This chapter begins with an overview of research paradigms and their use in values research is discussed. The methods used in this research and their suitability for answering the specific research questions are then outlined along with a detailing of specific procedures used in the collection, storage and analysis of data. Finally, the ethical considerations involved in the execution of this research are discussed.

3.1 Research Design

3.1.1 Research Paradigms

A paradigm refers to a set of beliefs which a researcher must make about the nature of knowledge (epistemology) and reality (ontology) as well as the values which drive the researcher to undertake the work (Guba and Lincoln, 1994; Heron and Reason, 1997; Farrow *et al.*, 2020). The formulation of research questions and the selection of methods used are informed by the chosen research paradigm which also determines the nature of the conclusions which should be drawn from the research (Guba and Lincoln, 1994).

Traditionally, natural sciences have operated using the positivist approach. According to this, the role of science is the gathering of empirical data through scientific experimentation, this data is an entirely accurate description of reality, and this data should be interpreted without any preconceived beliefs. This was also the approach initially taken in social sciences, before being largely replaced by postpositivism. This latter framework acknowledges that it is never

possible to fully separate data collection from theory, and that it is never possible to definitively prove the accuracy of a particular theory, and so posits instead that scientific work should focus on developing conjectures that can be “falsified” experimentally. In this view, theories can never be definitively proven, but they can be disproven. Beyond this quite fundamental shift, postpositivism maintains many of the practices of positivism and the methods of the natural sciences (Willis, 2007), such as favouring quantitative data and ensuring that all efforts are made to remove subjectivity (Creswell, 2009).

Interpretivism represents one of the major alternative approaches to positivism and postpositivism in the social sciences. Under this paradigm, researchers must accept that all data and observation is filtered through socially constructed lenses, and that while an objective reality exists, it is not directly observable to us and hence objective truth cannot be discovered (Creswell, 2009; Farrow *et al.*, 2020). Instead, the existing subjective social meanings in the world must be interpreted by the researcher and used to build theory (Goldkuhl, 2012). Rather than attempting to isolate the subject of study like a specimen in a lab, interpretivism encourages the full inclusion of context in order to fully understand social systems (Willis, 2007; Farrow *et al.*, 2020).

3.1.2 Pragmatism

Alternative paradigms have been developed that embrace a plurality of methods and assumptions (Løvaas, 2022). Pragmatism is a philosophy that is oriented towards practical outcomes rather than focussing on metaphysical views. It is seen as a paradigm which occupies a middle ground between the dominant positions outlined above, and offers a means of bridging the divide between science and morality (Johnson and Onwuegbuzie, 2004; Kraatz, Flores and Chandler, 2020). Pragmatism operates on the basis that the researcher can and should alternate between inductive and deductive methods as required and that the particular circumstances of the research project determine the research practice. Neither data nor theory alone can adequately drive research and so the researcher should consider the practicalities of both (Morgan, 2007).

In terms of epistemology, pragmatism takes the view that knowledge is not reality (Rorty, 1992). Instead knowledge is considered good if it usefully enables us to navigate and interact with lived experience (Goldkuhl, 2012; Kaushik and Walsh, 2019). Pragmatists view the constant changing of the world and our understanding of it as the focus of inquiry. They focus on human action as driving this change and evaluate theory based on the consequences of these actions (Johnson and Onwuegbuzie, 2004; Goldkuhl, 2012). As a result, pragmatism endorses fallibilism, meaning that research findings can never be absolute or perfect. Instead the researcher must be content knowing that they have contributed to the validity of a theory which is functionally useful (Dewey, 1941; Goldkuhl, 2012). Pragmatists decide what they want to research based on their personal value systems. They study what they think is important. They conduct research in anticipation of results that are congruent with their values. This is considered the way that many social scientists work in practice (Teddlie, 2005). Pragmatists also place greater importance on the methodological considerations rather than metaphysical concerns (Doyle, Brady and Byrne, 2016).

It has been argued that the entrenchment of different academic disciplines in seemingly opposing paradigms has inhibited transdisciplinary work, and prevented engineering and the natural sciences from engaging fully with the social sciences and humanities (Buch, 2022; Christensen *et al.*, 2022). Buch suggests that a “pragmatist recovery of engineering” could

offer a path for engineering to become the ideal mediator between the natural sciences and social science and humanities. He leverages the “practical” and “problem-solving” strengths of engineering as a potential means to circumvent the esoteric philosophical differences which have prevented conversations between the disciplines from truly prospering (Buch, 2022). Similarly pragmatism is described as “a method for more practically-minded researchers” suitable for working towards “solving practical problems in the real world” (Rorty, 1992; Morgan, 2007; Creswell and Plano Clark, 2009; Kaushik and Walsh, 2019). As such it represents an appealing prospect for researchers from an engineering background to explore topics previously considered the realm of social scientists. As well as this, Løvaas (2022) suggests that values research can benefit from the flexibility afforded by the pragmatic research paradigm due to the range of methods it supports.

3.1.3 Research Methodologies for Values

In examining the values held by individuals and groups, researchers must use methodologies that effectively capture the full range of these values. This may involve assessing both explicit values, which are readily articulated, and implicit values, which are embedded in behaviour and context. Quantitative studies are typically used to assess personal and professional values at an individual level and collectively among a population. Qualitative research allows for a deeper understanding of how these values are expressed and experienced (Espedal *et al.*, 2022). Employing a combination of quantitative and qualitative approaches provides a comprehensive understanding of how values are expressed and experienced.

Personal value studies typically focus on explicit values and are assessed using self-reporting surveys. Numerical values, Likert scales and ranked importance are used to derive quantitative results (Dose, 1997; Løvaas, 2022). As discussed in Chapter 2, value research of this type includes the Rokeach value survey (Ball-Rokeach, 1973), Schwartz value system (1992) and the various instruments designed to assess this (Schwartz, 1992, 2006; Sandy *et al.*, 2017; Schwartz and Cieciuch, 2022). These assess the values of an individual, and can be aggregated to understand the makeup of individuals within an organisation (Espedal *et al.*, 2022).

Implicit values are more often researched using qualitative methods. As they are embedded in action, norms and culture, rather than stated, they require a greater richness of data to uncover than quantitative methods generally allow for. Using qualitative methods it is possible to explore the subtleties of values and how they manifest (Brigstocke *et al.*, 2017; Espedal *et al.*, 2022). Løvaas (2022) outlines the diversity of ways which qualitative methods have been used to investigate values in terms of value conflicts (De Graaf and Paanakker, 2015; De Graaf, 2021), values and organisational identities (Wæraas, 2022), and the ways in which values emerge and persist within organisations (Wright, Zammuto and Liesch, 2017). The richness of findings from research methods such as observations, interviews and analysis of documents (Askeland, 2014; Wright, Zammuto and Liesch, 2017; Wæraas, 2022) is preferred in these investigations as they facilitate a greater depth of understanding (Espedal *et al.*, 2022).

This methodological divide, in which qualitative research investigates implicit values and quantitative research is used for explicit values is not absolute though it does represent the norm (Løvaas, 2022). However comprehensive values research should aim to account for both explicit and implicit values and should be interested in both identifying and understanding

these. Therefore mixed methods represent a suitable research approach for the field (Espedal *et al.*, 2022).

3.1.4 Mixed Methods

Mixed methods, or multi-strategy research designs refer to the combination of qualitative and quantitative research methods within the same study. Robson (2011) further adds that most mixed methods research includes clear specification of the sequencing and priority of the various modes of data collection and the ways in which findings will be integrated. The research paradigm which underpins mixed methods is often pragmatism, although this may not be explicitly stated in all cases (Denscombe, 2008; Robson, 2011; Doyle, Brady and Byrne, 2016).

Using mixed methods allows researchers to offset some of the weaknesses that a strictly qualitative or quantitative approach might have (Robson 2011). For instance, the bare quantitative data produced by value surveys is given greater context when supported by detailed qualitative findings. The depth of insight available through methods such as interviews can put “meat on the bones” of survey data (Bryman, 2012). Conversely, having quantitative data on hand during the interpretation of interviews can enable the researcher to establish whether the participant is representative of the norm or an outlier. Using a multi-strategy/mixed methods approach, with multiple sources of data, can enable the researcher to triangulate findings and bolsters the validity of the research (Robson 2011).

The specific details of research design become more important in multi-strategy design, as it can prove challenging to integrate the findings and produce disjointed work if the researcher does not adequately understand and present the logic of their design (Mason, 2006). Care needs to be taken that the qualitative elements are not simply “ornamental” (Bryman, 2004). This is among the reasons it is recommended to use relatively simple statistical methods alongside qualitative analysis (Friedrichs and Kratochwil, 2009). There is also a greater skills requirement for the researcher, who needs to be adequately trained in both forms of research (Robson 2011).

3.1.5 Chosen Research Design

This research involves investigating several social and psychological phenomena. The complex and intertwined forces involved work both intra and inter-personally and may be both explicit and implicit. Some of these, namely personal values, as defined by Schwartz (1992, 2006), and social consciousness, as defined by Erin Cech (2010), can be investigated quantitatively, other aspects like professional norms and perceptions are more suited to qualitative research. As such this research adopts a concurrent triangulation research design (Creswell, 2009, 2014). This type of multi-strategy design allows for quantitative and qualitative findings to be usefully integrated and to accurately understand relationships between variables in the data. Multi-strategy designs are commonly used with a pragmatic research philosophy, which is being adopted for this research (Denscombe, 2008; Robson, 2011; Doyle, Brady and Byrne, 2016).

The research aims of this project are stated above. The overall objective is to understand the socialising effect of engineering education. This necessitates *describing* the implicit and explicit values of those in engineering education at various points. The explicit aspects of these values are best investigated quantitatively using a self-reporting cross sectional survey (Lovaas 2022; Knafo and Sagiv 2014; Cech 2010; Sandy et al. 2017; Schwartz 2003;

Schwartz et al. 2001). Implicit values require qualitative investigation (Løvaas 2022). The thematic analysis can be used to extract implicit values from interview transcripts and advertising materials (Braun and Clarke, 2006; Wæraas, 2022). Combining these methods will allow for more in-depth insights to be drawn from the findings.

The research objectives of this project are to *explore* and *understand* the values of those in engineering education. As such this study prioritises qualitative data. Various quantitative aspects of the professional socialisation of engineers have been demonstrated in previous work, albeit in different cultural contexts. As such this project will focus on qualitative methods to understand the socialising experience of engineering education from a values perspective. The quantitative values survey will provide context for the qualitative findings.

In this concurrent triangulation research design (Creswell, 2009, 2014) multiple data-sources and methods are being used. The details of each method used are discussed below in section 3.2. Table 3.1 shows which of the various methods will contribute results under each of the four research questions.

Table 3.1: Mapping Research Methods to Research Questions

	RQ1: What are the values being appealed to during the recruitment of engineering students in Ireland?	RQ2: What are the values of those who enter engineering education in Ireland?	RQ3: What are the ideal values of an engineer according to those involved in Irish engineering education?	RQ4: What are the values promoted by engineering education in Irish universities?
Discussed in Chapter	4	4	5	6
Prospectus Analysis	☑			
Staff Interviews	☑		☑	☑
Student Interviews		☑	☑	☑
Values Survey		☑		☑

Research questions 1 and 2 deal with the recruitment of engineering students into the field. To explore the role of values in the recruitment of engineering students this study uses a thematic analysis of the university prospectus documents. This was examined in conjunction with interview data from students, relating to how and why they made the decision to study engineering, as well as interview data with university staff relating to the design and use of the prospectus. The implicit and explicit values found during this analysis were then examined alongside the results of a quantitative value survey which sampled the value profile of first-year students at an Irish university. This provided a means of comparing the value profile of those students who choose to study engineering against those who choose other professions, namely nursing and law, as well as a sample of Irish eighteen- and nineteen-year-olds taken from the European Social Survey.

Research question 3 is intended to establish the objectives of engineering education with regards to values. Interviews with student and staff participants were analysed for descriptions

of what is considered a 'good engineer'. Some of this was explicit and in response to direct questions, while other evidence was inferred from aspirational descriptions of ideal graduates and the role of engineering as described by students and staff. This included explicit values which staff and students believed the ideal engineer should prioritise as well as the implicit values embedded in their descriptions of engineering practice and the role of engineering. Students and staff were asked to create the value profile of the ideal engineering graduate, using the 10 values of the Schwartz value system (1992).

Finally, research question 4 deals with the value promoted over the course of engineering education. Formal education is one of the major venues of professional socialisation (Simpson, 1967). This study aims to understand the values which are fostered in engineering students during their degree programs at Irish universities. Interviews with staff were used to investigate both the explicit values they consciously promote in students, as well as the content of the degree and their educational aims and the implicit values embedded in these. While these present the values as "transmitted" during engineering education, interviews with students were used to assess how these messages were received by students, and other values which they perceived to be promoted by engineering education. The results of a cross-sectional survey of personal values among engineering students in an Irish university were analysed with the aim of measuring the difference between the value profile of new entrants and those nearing the end of an engineering education.

The quantitative data describing the values of those in their final years of engineering education were then examined alongside the idealised value profiles created by interview participants, to discern whether engineering education is producing graduates with desired value priorities.

Cross-sectional analysis such as this is effective for mapping the values of those within a population at a given moment in time. The findings of this study can be used to *describe* the values of those at different stages in engineering education. However, to attempt to "explain" these values would require a longitudinal experimental/quasi-experimental research design (Lovaas, 2022). Research on values in organisations rarely takes the form of experimental studies (Aadland & Schramer, 2017 ; Lovaas, 2022). The research presented here does not claim to have proven a causal link between the personal values of students and engineering education. In this regard it is in-line with previous research in the field which investigates personal values in terms of correlation, without specifying the direction of this effect (Arieli & Sagiv, 2018; Knafo & Sagiv, 2004) although it has been shown that values which are expressed more often are increasingly prioritised in individuals (Kohn and Schooler, 1982; Schwartz and Bardi, 1997), suggesting a socialising effect.

3.2 Methods

3.2.1 Document Analysis

Thematic analysis of the university prospectus affords an opportunity to detect and understand patterns in the way engineering schools market themselves to potential students (Braun and Clarke, 2006). NVivo12 was the tool used to analyse the content. Thematic analysis of documents is effective in analysing both implicit and explicit values in a range of data types (Wæraas 2022). This method was used by Mogaji and Yoon (2019) in their analysis of UK prospectuses to see how universities were communicating with their prospective students, and by Hartley & Morphew (2008) to examine university viewbooks in the USA. By focussing

on the engineering programme prospectus, this thesis uses this method to understand the ways in which values are being used to appeal to prospective engineering students specifically.

3.2.1.1 The University Prospectus

The university prospectus is an important source of information for students when choosing which degree to pursue. Second level students are not very well informed about the realities of an engineering career (Baillie and Fitzgerald, 2000; Colby and Sullivan, 2008; Salas-Morera *et al.*, 2021). Female students in Ireland have consistently reported being under-informed about opportunities in STEM subjects (I Wish, 2017, 2018, 2022, 2023).

The legitimacy of universities is based on their reputation. The value of a degree only exists as long as there is social trust placed in the quality of the education it provides. As such, universities occupy a position of trust for prospective students. Bradley (2013) suggests that this may exempt the prospectuses produced by these universities from the same degree of scrutiny that other advertising is met with.

In the past the prospectus would have simply been a booklet containing dry factual information about the courses on offer. These were usually produced by the academic staff of the university with limited other influence (Shahnaz, Fatima and Qadir, 2022), however the marketisation of third level education has changed the relationship between students and the institutions. It has been argued by some that students now occupy a role closer to that of consumers (Gibbs, 2002). Coinciding with this, the prospectus has adopted many of the techniques and styles from modern advertising (Steele, 2007). Mogaji and Yoon (2019) identified multiple advertising techniques being used by universities to appeal to students. Their thematic analysis of 121 UK university undergraduate prospectuses revealed that the predominant messages focused on location, courses, student experience, credibility, and career progression, all of which were presented in an engaging and appealing manner to create a sense of compatibility and belonging for prospective students.

The literature shows that the prospectus has historically been the starting point for students researching their future choice (Euesden, Gough and Whittaker, 1990; Stanley and Reynolds, 1994; Moogan, 2020). That research recognised the increasing importance of digital marketing for universities, but also noted the persisting influence of the prospectus. Of course, with much of the same information available on the university website, this is often the source that students will access. However, as the information presented is largely the same, the prospectus remains a valuable tool for researchers analysing educational advertising (Hartley and Morpew, 2008; Bradley, 2013; Henslee *et al.*, 2017; Rutter, Lettice and Nadeau, 2017; Mogaji and Yoon, 2019; Shahnaz, Fatima and Qadir, 2022; Saltmarsh, 2024).

3.2.1.2 Sample

The prospectuses for each of the nine educational institutions in the Republic of Ireland with university status in the year 2021 were analysed. In recent years, a number of former Institutes of Technology have been merged to create Technological Universities (TUs). This change was made in line with Ireland's National Strategy for Higher Education to 2030 (2011). For instance, Cork Institute of Technology and the Institute of Technology, Tralee were merged to create Munster Technological University. These TU's are intended to focus on science and technology programs with an industrial focus and so will contribute significantly to the engineering education landscape of Ireland in the coming decades (Hunt *et al.*, 2011). For this

study all institutions with university or technical university status for the 2021/22 academic year were included.

The 2021 undergraduate prospectuses for these nine universities were accessed in April 2021 and downloaded in PDF format. The academic structure of each institution was then accessed online. This was used to determine which programmes fell under the remit of their universities' college, school, or department of engineering. The primary criteria for inclusion were degree programmes which lead to a Bachelor or Masters of Engineering either through direct entry or via a common entry general engineering programme. Due to the different academic structures across the various institutions engineering programmes were sometimes listed along with architecture, science or computing degrees. In these cases, only the programs which offered a Bachelor or Masters of Engineering were extracted from the prospectuses and uploaded to NVivo12 for analysis. In total 66 programmes were included in this analysis. This includes "general entry" and "undenominated" programs. In cases where various national framework of qualifications (NFQ) levels were offered, the prospectus pages were examined for differences. If they were found to be significantly different, they were coded separately in full. In cases where identical sections of text were used, these were only coded once. Any unique material was coded fully. The complete list of universities and number of degree programs offered is included in Table 3.2. The web page for each degree program on the university website was also examined to ensure that it resembled the messaging included in the prospectus.

Table 3.2: Universities and Programmes Included in Prospectus Analysis

Name of Institution	No. of Programmes included
Dublin City University	6
Munster Technological University	10
University of Galway	7
National University of Ireland, Maynooth	1
Technological University of Dublin	16
Trinity College Dublin	7
University College Cork	5
University College Dublin	7
University of Limerick	7

3.2.1.3 Data Analysis

The data was analysed in line with the six-phase process outlined by Braun and Clarke (2006, 2013; Clarke and Braun, 2017). The analysis involved both an inductive and deductive approach to coding the data. Purely inductive coding is rarely possible due to the prior knowledge of the researcher which can rarely, if ever, be fully excluded from the process, while purely deductive research with predefined codes limits the possible findings and is usually insufficient to capture implicit values (Braun and Clarke, 2013; Wæraas, 2022). The coding process was carried out in NVivo12, with each code acting as a "node". Each document was systematically read through and coded over the course of two passes. A number of codes became apparent in the first reading, and so a second reading was carried out to ensure

uniform coverage. This research is interested in both latent and explicit values and so codes were created for direct references to values as well as the beliefs and actions associated with these values (Espedal *et al.*, 2022). These codes were examined and grouped to form themes and sub-themes. Shared meaning, common motivation and a central concept which could unite individual codes were used to establish these groupings (Braun and Clarke, 2006, 2013). The more prevalent themes were then refined in the next phase in which the working titles were adjusted to fully express the content of the coded data.

3.2.2 Values Survey

3.2.2.1 Survey design

Section 1 of the questionnaire was derived from Cech's 2010 study. Ten Likert scale questions measured the importance of three major variables: programmatic focus on ethical engagement, importance of public engagement to a successful career, and personal social consciousness. As this study involved disciplines outside of engineering, some changes were made to the original questions in order to allow them to be used more broadly. For example, one question as used by Cech in the original study read: "Rate the importance to a successful career in engineering of each of the following...". For this study it was altered to read "Rate the importance to a successful career in your chosen profession of each of the following...". The specific questions contributing to each of these are included below.

Section 1

Q1 Programmatic focus on ethical engagement:

With regards to your current programme of study, rate the following on a scale 1-4 (1=very unimportant to 4=very important) :

- A. The importance to your programme of ethical and/or social issues.
- B. The importance to your programme of broad education in the humanities and social sciences.
- C. The importance to your programme of policy implications for engineering.

Q2 The importance of public engagement and social consciousness to a successful career:

Rate on a scale of 1-5 (1=very unimportant to 5=very important) the importance to a successful career in your chosen profession of each of the following:

- A. Professional and ethical responsibilities
- B. Understanding the public consequences of your work
- C. Understanding how the public interact with the products of your profession.

Q3 Personal Social Consciousness

Rate, on a scale of 1-5 (1=very unimportant to 5=very important), the personal importance to you of:

- A. Improving society.
- B. Being active in my community.
- C. Helping to promote racial understanding.
- D. Helping others who are in need.

To measure the basic human values on the Schwartz Value System the Twenty Item Values Inventory (TwIVI), developed by Sandy (Sandy et al. 2017) was used. This is the shortened version of the original fifty-one item SVS (Schwartz, 1992) or the forty item PVQ-40 (Schwartz, 2003; Schwartz et al., 2001). This version has been specifically designed for use in research where the longer PVQ-40 is impractical. In this study, participation is voluntary, and no incentive was offered to participants. University students are also a heavily sampled group and can receive multiple surveys per academic semester. As such the shorter instrument was chosen to lessen the effort required on behalf of the participants.

This instrument assesses values according to the original ten value SVS (Schwartz, 1992) rather than the nineteen values of the Refined Theory of Basic Human Values (Schwartz et al., 2012). As discussed in sections 2.4.4 and 2.4.5 this refined model is intended to give more granular detail when necessary rather than replace the original model. For instance the value of *power* is further divided into *dominance* and *resources*, and *self-direction* is broken down into *self-direction of thought* and *self-direction of action*. This research uses data taken from the European Social Survey, which uses the original 10 value SVS as a point of comparison. For this reason the 10 value SVS was used in the current research.

The TwIVI consists of twenty statements, each implicitly describing the importance of a particular value to an individual. The participant is asked how much like themselves, this person is on a scale of 1 (not like me at all) to 6 (very much like me). Each of the 10 basic human values is assessed using two items from the TwIVI. While the original TwIVI contains two versions of the survey, with either male or female pronouns, the researcher here chose to use gender neutral language. This is in line with modern guidelines in psychological research and have been shown to be effective and inclusive in situations where the gender of the participant is unknown (Keener and Kotvas, 2023). The question was presented as follows:

Section 2

Here we briefly describe some people. Please read each description and think about how much each person is or is not like you. Indicate, using the 6-point scale from “not like me at all” to “very much like me”, how alike you this person is:

1. They believe they should always show respect to their parents and to older people. It is important to them to be obedient.
2. Religious belief is important to them. They try hard to do what their religion requires.
3. It's very important to them to help the people around them. They want to care for their well-being.
4. They think it is important that every person in the world be treated equally. They believe everyone should have equal opportunities in life.
5. They think it's important to be interested in things. They like to be curious and to try to understand all sorts of things.
6. They like to take risks. They are always looking for adventures.
7. They seek every chance he can to have fun. It is important to them to do things that give them pleasure.
8. Getting ahead in life is important to them. They strive to do better than others.
9. They always want to be the one who makes the decisions. They like to be the leader.

10. It is important to them that things be organised and clean. They really do not like things to be a mess.
11. It is important to them to always behave properly. They want to avoid doing anything people would say is wrong.
12. They think it is best to do things in traditional ways. It is important to them to keep up the customs they have learned.
13. It is important to them to respond to the needs of others. They try to support those they know.
14. They believe all the worlds' people should live in harmony. Promoting peace among all groups in the world is important to them.
15. Thinking up new ideas and being creative is important to them. They like to do things in their own original way.
16. They think it is important to do lots of different things in life. They always look for new things to try.
17. They really want to enjoy life. Having a good time is very important to them.
18. Being very successful is important to them. They like to impress other people.
19. It is important to them to be in charge and tell others what to do. They want people to do what they say.
20. Having a stable government is important to them. They are concerned that the social order be protected.

The prior research carried out by Erin Cech (2010, 2014) focused on longitudinal change within the engineering students sampled. It did not include any point of comparison between engineering students and those outside the discipline. The research presented here offers two points of reference to help understand the results of the survey.

Firstly, students in nursing and law programmes were also sampled. This research deals with the measurable values as well as socially expected norms of the engineering profession. The perceptions of incoming students are an important factor in recruitment. By choosing two professions with well-established and widely understood norms, it provides better context for the numerical data which the survey produces. In this case, Law was chosen as it represents a profession which applies technical codes in a clinical manner to social issues. It is also another example of an investigative profession (Holland, 1985, 1996) and is a profession which has long featured discussions around value-neutrality (Thacher, 2015; Bartlett, 2023). Nursing, as a social profession, provides a contrast to this. As a social profession “caring” is among the traits listed for those suited to this path (Holland, 1997). As a profession which deals personally with caring for others it provides a contrast to both engineering and law, where the impacts of the work are often far removed from the individual carrying it out. However, an ethics of care have been suggested as an alternative approach for engineering education (Nair, 1997; Campbell and Wilson, 2011; Campbell, 2013; Canney and Bielefeldt, 2015a).

The second point of comparison included in this study is data retrieved from the European Social Survey (ESS). This cross-national survey has been conducted every two years since 2001 and includes questions assessing personal values using the Schwartz Value System

(Schwartz, 2003; ESS, 2023). The 10th round of the Irish branch of this survey (ESS10) took place from November 2021 to December 2022 and includes participants of a wide range of ages from across the country. By selecting the data for those of the equivalent age of the engineering students being studied in this research, the data from the ESS represents the national average value profile for the age range in question.

3.2.2.2 Sampling and distribution

This study sampled students enrolled in the schools of Law, Nursing & Midwifery, and the College of Engineering and Architecture at University College Dublin (UCD). As well as being the largest traditional university in Ireland, UCD has the largest engineering department in the country (*UCD College of Engineering & Architecture*, 2024). The online survey platform “Qualtrics” was chosen to host the survey. A series of near-identical surveys were created on the platform including separate surveys for each of the following groups:

- First-year Bachelor of Engineering students
- Final year Engineering students (including 4th year BEng and 5th year MEng)
- First-year Nursing or Law students

The university which these students attend offers two pathways to graduation for engineering students. The first-year is common to all engineering students. Students then choose their sub discipline, which determines the following two years of their studies. At this point students may choose to enter a final 4th year and progress towards a Bachelor of Engineering degree (BEng), or commit to two further years and enter the first year a two-year Masters of Engineering degree (MEng). For this research, both the 4th year BEng and 2nd year MEng (5th total year of their studies) students were sampled as both were in their respective final years.

As well as the values instruments described above, the surveys contained some basic questions to capture demographic information from participants. The information required varied between participant groups. Creating multiple surveys reduced the total number of questions each participant was required to answer which was hoped would increase the number of completed surveys.

This online questionnaire was distributed to first-year students enrolled in the schools of Law and Nursing & Midwifery at University College Dublin, and to engineering students in first-year, as well as in the final year of both the bachelor and masters engineering programs at the same university. Due to privacy concerns regarding access to student email addresses (see section 3.4.1 for details), the questionnaire was distributed via the relevant school offices. An invitation email which included the link to the questionnaire was provided to the school offices, who then distributed it to the relevant student groups. Participation in the survey was voluntary on an opt-in basis.

The survey was distributed in the academic year, 2021-2022. The invitation email was sent in November of 2021 and the survey remained active until February of 2022 to allow ample time for participants to complete it. The questionnaire response data was downloaded in March 2022 and merged into one database for analysis. Incomplete and invalid responses were filtered out to determine the final sample. Section 1 of the survey received 153 complete responses, representing a sample of 10-13% of the various groups. A breakdown of these groups is shown in Table 3.3. Section two of the survey received fewer responses. The breakdown of responses to this section are shown in Table 3.4.

Data from the ESS10 was accessed in March 2024. Using the datafile builder the required variables were chosen. In this case those were “Gender, age and household composition” and “human values scale”. Based on the ages of the responses to the student survey the age groups of 18 to 19 years old, and 21 to 23 years old, were selected to represent the peers of the student groups being sampled. Data for these groups was isolated and analysed alongside the responses to the student survey. Survey Data was accessed in March 2022, at which point data from all surveys was downloaded and merged into one database for analysis.

Table 3.3 Makeup of Survey Section 1 Participant Groups

School	Year of Study	Group Name	Number of Participants (N)	% of total group sampled	He/ Him	She/ Her	Unlisted/ Prefer not to say
Engineering	1 st Year	Eng1	45	12.97%	28	15	2
Engineering	4 th Year	Eng4	24	10.17%	18	5	1
Engineering	5 th (2 nd year MEng)	Eng5	19	10.11%	13	6	0
Engineering Total			88	11.41%	59	26	3
Nursing	1 st Year	Nurse1	31	11.57%	0	29	2
Law	1 st Year	Law1	34	12.32%	6	27	1

Table 3.4: Makeup of Schwartz Survey Responses with ESS data

School	Year of Study	Group Name	Number of Participants (N)	% of total group sampled	He/ Him	She/ Her	Unlisted/ Prefer not to say
Engineering	1 st	Eng1	42	12.10%	26	14	2
Engineering	4 th	Eng4	21	8.90%	16	4	1
Engineering	5 th (2 nd year MEng)	Eng5	11	5.85%	10	1	0
Engineering Total			74	9.6%	52	19	3
Nursing	1 st Year	N1	27	10.07%	0	25	2
Law	1 st Year	L1	27	9.78%	4	22	0
European Social Survey	18-19 years old	ESS1	29	N/A	20	9	-
European Social Survey	21-23 years old	ESS4	33	N/A	17	16	-

3.2.2.3 Data analysis

For questions in section 1, each response was first converted to a numerical value. These ranged from 1-4 for question 1 and 1-5 for questions 2 and 3. Three additional measures were then calculated for each participant. The first of these, “programme mean”, was calculated by taking the mean response of each participant to questions 1A, 1B and 1C and represents the overall focus that the student believes their degree programme places on public engagement and social consciousness. The second, “career mean” is calculated by taking the average response by each individual to questions 2A, 2B, and 2C. This represents the level of public and social engagement they believe their chosen career will require. Finally, each individual’s “personal social consciousness” was calculated by taking their mean response to questions 3A, 3B, 3C and 3D.

The mean score of each sampled group was then calculated for each of the thirteen measures in section 1. These were used to compare beliefs of first-year engineering students to their peers studying law and nursing, as well as assessing the difference in responses of engineering students at various stages of their education. Two-tailed t-tests were chosen as the tool to assess whether the differences between means of each group was significant.

For the questions in section 2, Schwartz values were converted from Likert scales to numerical values. In line with previous work, the values were centred around the individual’s mean score. This within-individual centring is important as it highlights the relative importance of each value rather than the absolute value. This relative importance is what guides decisions and behaviours (Schwartz, 1992, 1996, Rudnev et. al.; 2018; Sandy et. al., 2016). This was done by first calculating the average response of each participant across all items of the TwIVI. This figure was then subtracted from each of that individual’s responses. 3.5 was then added to each to re-centre the responses on the original 1-6 scale. This process corrects for an individual’s tendency to cluster their responses at a certain point on the scale while maintaining the relative importance of values (Schwartz, 2016; Sandy *et al.*, 2017; Rudnev, Magun and Schwartz, 2018).

The value score for each of the 10 values was then calculated by taking the average of the two survey items which assess a given value. The higher order values were then calculated by averaging the individual scores for each of its constituent values.

Table 3.5 shows which survey items contribute to each value and in turn which values contribute to each higher order value.

Initially, an ordinal ranking of values was created according to the mean value score of each group. This was used to compare the relative importance of values between groups.

T-tests were conducted to determine if the mean score for each value of engineering students differed significantly from that of each of the other groups. As this was exploratory work without a predefined set of hypotheses regarding the direction of the differences in values, two-tailed tests were used.

The mean scores of first-year engineering students were compared to first-year students studying nursing and law as well as the results of the ESS1 group and engineering students at later stages of their education. This determines whether the absolute prioritisation of each value differs between groups. However, the relative importance placed on each value is also important in terms of how values guide behaviour. For this reason, the ordinal rankings of each group were examined to determine which value pairings were prioritised differently among the

various groups. A difference score for each pairing was then calculated by subtracting the value score which Eng1 students rated lower, on average, from the value which they rated more highly. This was done for each individual participant. The difference scores of Eng1 students were then compared to each of the other groups using two tailed t-tests to determine whether the average difference between the values for Eng1 students differed significantly from that of the other groups.

The higher order values of participants were plotted on the dual axes of *openness-to-change/conservation* and *self-transcendence/self-enhancement*. This was done by subtracting each individual's *conservation* score from their *openness-to-change* score, and subtracting their *self-enhancement* score from their *self-transcendence* score. This enabled each individual to be placed on a 2-dimensional scatterplot.

Analysis comparing Eng1 students to the ESS1, Law1 and Nurse1 groups, can be seen in Chapter 4. For comparison between Eng1 students and engineering students at later stages of their education, as well as comparison between late-stage engineering students and the ESS4 group, see Chapter 6.

Table 3.5: Structure of Higher-Order Values, Personal Values and contributing survey items

Individual Value Profile	Higher Order Value	Personal Value	Survey Item
	Conservation	Security	Q10, Q20
		Conformity	Q1, Q11
		Tradition	Q2, Q12
	Self-transcendence	Benevolence	Q3, Q13
		Universalism	Q4, Q14
	Openness-to-change	Self-Direction	Q5, Q15
		Stimulation	Q6, Q16
		Hedonism	Q7, Q17
	Self-enhancement	Achievement	Q8, Q18
		Power	Q9, Q19

3.2.3 Interviews

Between April 2023 and May 2024, 30 semi-structured interviews were conducted with university staff and students involved in engineering education at Irish universities. Interviews lasted between 50 minutes and 2 hours. The majority took place in one session, with two being split over two sessions due to scheduling issues.

Semi-structured interviews were chosen as the preferred method for collecting staff and student views on the research topic. This type of interview allows for the investigation of pre-determined topics while allowing the participant room to express their thoughts and to highlight areas they deem of note (Bryman, 2012; Adeoye-Olatunde and Olenik, 2021). Semi-structured interviews are a particularly suitable method when the interview subjects are all taken from a limited range of groups (Bryman 2012), in this instance students and staff from university engineering departments. This allows for more focused interviews and prevents the need for extremely extensive and time-consuming in-depth interviews (Robson, 2011). Similarly, in this research interviews are not dealing with sensitive subject matter. As such, it was not necessary to afford excessive time to carefully and tactfully approach an issue which a subject might find distressing.

This research is also interested in the aspects of the profession that are neglected by engineering education. By allowing staff and students to express themselves at length about their personal and professional values and giving them time to reflect on the wider profession, it was possible to identify the areas which are omitted by participants, and therefore may be seen as less important.

A detailed list of questions and discussion prompts was created. This served as a guide for the researcher to ensure that all relevant topics were covered without preventing the researcher from exploring subjects which arose naturally. Each participant was also asked to complete an exercise during the interview which involved ranking the 10 items from the Schwartz value system in terms of how they believed an ideal engineer should prioritise them. As discussed in Chapter 2, the concept of values is one which can have a broad range of meanings. As the participants were not expected to be experts on this topic, including this structured exercise was useful to clarify the definition and to facilitate a more productive discussion. This exercise was conducted in the latter stages of the interview. This was to allow for participants to first express their views on the subject in their own terms and to avoid a priming effect. The discussion which followed this exercise often revisited previous topics which were then discussed more explicitly in terms of values.

The focus of the interviews with students was on their perceptions of the engineering profession prior to beginning their studies, as well as any ways in which these have changed since enrolling. Participants were asked about their motivations behind choosing engineering, the role of the profession in society, as well as what they think constitutes a “good engineer”. The role of student-run engineering societies was also discussed. These societies offer a level of agency to students in shaping their own university experience and so how they choose to exercise this gives an interesting insight into what they feel is otherwise lacking.

The staff interviews followed a similar format to those with students. They too were asked to rank the Schwartz value items in terms of how they would like their ideal graduate to prioritise them. This facilitated a discussion on how they felt an engineering degree promotes (or doesn't promote) these values in students. It also informed their description of the ideal engineer, and whether this aligns with the graduates they see their programmes producing. The staff perspective shed light on what the aims of the institutions are in the recruitment and formation of new engineers. They were also asked about their role in producing recruitment material and their thoughts on the wider profession. By examining these along with findings from student interviews, we can see whether the intended message and that received by students differ.

3.2.3.1 Data Collection

Before each interview, the participant was given time to read a participant information sheet and were offered the opportunity to ask any questions. The recording then commenced with a verbal confirmation of consent from the participant. Each interview was assigned a code, which served as a pseudonym for the participants during analysis and reporting. Academic staff were assigned codes beginning with “A” followed by a number. The codes for students began with “S” followed by a number while marketing staff were assigned codes beginning with “M”.

The interviews were recorded in audio only. In the case of in-person interviews a hand-held recorder was used. Immediately after interviews were complete, the audio file was transferred from the device and stored in a secure drive. In cases where participants chose to carry out the interview remotely, the video calling service, “Zoom” was used. The audio from the call was recorded, downloaded from the Zoom website, then stored on a secure drive.

After each recording, the file was stored for one month before transcription began. This was to allow participants an opportunity to opt out, after which the audio files were uploaded to the automated transcription service “Sonix”. These transcriptions were then read through while listening to the audio file to check accuracy and correct any transcription errors. At this point, all identifiable information was removed from the transcription.

3.2.3.2 Student Sampling

Students involved in engineering-related student societies were initially selected to participate in interviews. The invitations were sent to the society committee by email, and from there distributed to members. The initial participants were those students involved in running societies. These individuals have a greater say in the activities of their societies and have experience of the kinds of events which generate interest among their peers. They also have increased contact with a wider number of engineering students meaning their thoughts on the “typical engineering student” are more informed.

Snowball sampling was also used here as participants suggested friends and peers to take part. The total number for student interviews was 13. These were spread across 4 institutions and represented seven different student groups. Students from 2nd year of their undergraduate degree and above were included as well as two postgraduate students. Table 3.6 shows the breakdown by year of student participants as well as a list of the student organisations which participants were involved in.

Eighteen organisations across 6 universities were contacted. However, in the wake of the Covid-19 pandemic and subsequent restrictions a number of these organisations had suspended operations. At the time of this study not all had been reestablished and so many requests went unanswered.

Table 3.6: Student Interview Participant Group Breakdown

Academic Year	Number of Participants	Student Organisations
2 nd Year	3	Engineering Society (Eng Soc), UCD
3 rd Year	2	Young Manufacturing Leaders, UCD
4 th Year	4	Engineering World Health, UCD
5 th Year	2	Mechanical Engineering Society, UCD
Post-Graduate	2	Electronics Society, TUD
		Women In STEM (WiSTEM) Galway
Total:	13	Engineering Society, DCU

3.2.3.3 Staff Sampling

Care was taken to select participants from a variety of engineering backgrounds and disciplines. Staff members who were/are the heads of major undergraduate degree programs and those with responsibility for coordinating common-entry 1st year programs were initially selected. These groups were targeted as their positions give them a wider perspective of the overall programs which students are following as well as a higher degree of input into the content of the degree. Staff at both traditional and technological universities were invited to participate. The initial invitations targeted heads of mechanical, civil, electrical & electronic, and biomedical engineering. From there, snowball sampling was used as participants discussed colleagues or particular modules in their programme which they felt were relevant to the research topic. Those staff were then invited to participate. In total, 15 academic staff members from nine institutions agreed to participate in this study. Table 3.7 shows the breakdown of participants according to their engineering discipline and the type of university where they are employed. Among the sample are also included the following:

- A director of undergraduate teaching and learning;
- Two design module coordinators;
- Three 1st-year general entry programme coordinators;
- A director for a mechanical and sustainability engineering degree programme;
- A “Professional Engineering and Management” module coordinator; and
- University marketing staff

Table 3.7: Staff Interview Participant Group Breakdown

Engineering Discipline	University	Technical University	Total
Mechanical Engineering	2	2	4
Civil Engineering	2	1	3
Electrical & Electronic Engineering	1	2	3
Biomedical Engineering	1	-	1
Miscellaneous	6	-	6
Totals	12	5	17

3.2.3.4 Data Analysis

Thematic analysis was again used to investigate the values evident in the interview data. NVivo 12 was once more the chosen software for carrying out this process. The same 6-phase process outlined by Braun and Clarke (2006, 2013) was followed. As this analysis took place after the analysis of the prospectus documents, a number of themes detected during that research formed *a-priori* codes for the interview analysis. As was the case with the prospectus documents, further codes emerged during two coding passes. These served as “nodes” and were later grouped to form themes and sub themes. Working titles were assigned to these themes, before each theme was re-examined and the titles were adjusted as needed to ensure suitability. The findings from this analysis are discussed in Chapters 4, 5 and 6.

During the coding phase, the Schwartz value rankings established by students and staff were extracted from the transcripts. These ordinal rankings were collected and collated. Numerical values from 1-10 were assigned and some average rankings were calculated. Four rankings were determined with a separate ranking each for students, university staff, technological university staff, and a collective staff group.

3.3 Research Ethics

This research project was assessed by the University College Dublin Human Research Ethics Committee. Both the interviews and the survey received low-risk exemptions (Reference Number LS-C-23-44-Deasy-Holland). The ethical concerns and considerations as well as the steps taken to mitigate them are outlined in this section.

3.3.1 Survey

Participation in this study was voluntary and anonymous. The sample group included engineering students. As the researcher held a teaching assistant role within the School of Mechanical and Materials Engineering, it was important that there was no coercion of students to participate. Students were invited to participate through an email which was distributed by the relevant school offices. The researcher did not have access to student email addresses. The invitation email emphasised that the study was voluntary and anonymous and contained relevant information relating to the privacy policy of the study. The survey contained no identifiable information and so at no time was it possible to determine which students had participated in the study.

3.3.2 Interviews

The primary ethical concern of this study is in relation to the power dynamic between the researcher and the student interview participants. At the time of the interviews, the researcher held a teaching assistant position within the school of Mechanical and Materials Engineering at UCD and so students may have felt some pressure to participate, or to speak only positively about the school and/or programme. To ensure that there was no perceived coercion, students who volunteered for the study, and who were enrolled at that time in a module in which the researcher is a teaching assistant, had their interviews scheduled after the end of the trimester so that all grading for their assignments was completed and could not be affected by their participation. It was made clear to all participants that their data would be anonymised during transcription, and that any quotes which were included in any publications resulting from the research would be anonymous. Therefore, no staff members, at any of the included universities could attribute statements to a particular student. This also helped to alleviate some of the potential effects of social desirability bias in this research.

The staff participants were being interviewed primarily in their professional capacity. However, as the research topic includes subjects such as their perceptions of the engineering profession and their experiences in engineering education, some of the resulting data included personal experiences and opinions. As such some participants may have been concerned about expressing views which could reflect negatively on their employer or colleagues. This risk is again mitigated through anonymising the data and removing identifiable information during transcription.

Staff members were contacted via their university email address. These are publicly available on the university websites. The committee members of the university societies were contacted via the society email address. These too are publicly available on the university website. Finally, the non-committee member students were recruited by asking the committee of their society to circulate an invitation to their members meaning the researcher did not access the student email addresses or initiate contact directly.

Verbal consent was obtained from all interviewees. Participants who responded to the recruitment material were provided with a document including all relevant information regarding the study, including a detailed participant information sheet. At the beginning of the interview, the researcher verbally confirmed that the participant had read and understood the consent form and that they agreed to participate in the study. The audio recording of this served as proof of consent.

There is a risk that interviews, which may contain personal information, could be unintentionally made public. To prevent this care was taken to ensure that audio files were stored securely and were deleted at the earliest possible time after transcription and that all identifiable information was removed from the transcript immediately following transcription.

These interviews were recorded in audio only. The participants were not asked their names directly during the recording. In the case that identifiable information arose during the conversation it was removed during transcription. The audio files were stored on a secure drive. A one-month waiting period was included after each interview before transcription began, in order to afford participants an opportunity to opt-out of the study and have their recording deleted. The recording was then stored until the transcription was complete or for up to a maximum of 3 months. The audio files were then deleted. The de-identified transcripts will be destroyed when the project and related publications are complete.

3.4 Conclusion

This thesis set out to examine the professional socialisation of engineering students during their formal education, starting from the point of recruitment, through the lens of values. To achieve this, it is essential to investigate the values of those entering engineering education, analyse the objectives of engineering education, and explore how the educational process shapes the values and beliefs of engineering students.

This chapter began by arguing that a pragmatic research paradigm, allows for the methodological flexibility required to answer the research questions being addressed here. A mixed methods design has been selected. This has the advantage of being able to offset the weaknesses inherent in purely qualitative or purely quantitative research. In this case qualitative methods, including document analysis and semi-structured interviews will be used to capture rich, detailed insights, and uncover implicit values embedded in the norms of practice and culture of engineering education. The strengths of these methods lie in the ability to explore the nuances of how values are expressed and experienced, offering greater understanding than numerical quantitative data alone. The quantitative methods employed here, namely the self-reporting values survey, are effective at capturing explicit values. They provide numerical comparable data which can highlight trends and offer context during the interpretation of qualitative data. A concurrent triangulation design will allow for these methods to be usefully combined.

Research questions 1 & 2 will be addressed in Chapter 4. This chapter uses thematic analysis of prospectus documents produced by universities in Ireland, along with an analysis of semi-structured interviews conducted with university staff and students from Irish engineering departments. These methods investigate the values appealed to during the recruitment of engineering students, while the results of a values survey carried out among first-year engineering students assesses the value profile of those who choose to enrol.

Research question 3 (Chapter 5) seeks to determine the objectives of engineering education concerning values. To address this, interviews with students and staff are analysed to identify descriptions of what constitutes a 'good engineer'. These descriptions included both explicit values, directly mentioned in response to questions, and implicit values, inferred from aspirational statements about ideal graduates, good engineering practice, and the role of engineering as perceived by the participants.

Research question 4 (Chapter 6) investigates the values promoted throughout engineering education. Interviews with staff were conducted to identify both the explicit values they aim to promote, and the implicit values embedded in the curriculum and their educational objectives. To understand how these values are received, interviews with students were analysed, along with a cross-sectional survey that compared the personal values of new entrants and those nearing graduation. By examining the survey data and the idealised value profiles described by staff, the study aims to determine whether engineering education effectively cultivates the desired values in its graduates.

Combined, these methods effectively address the research questions of this thesis. The methods employed here were approved by the University College Dublin Human Research Ethics Committee. The results of this work are documented in the coming chapters.

Chapter 4: Recruitment

The purpose of this thesis is to explore and understand the professional socialisation of engineering students during their formal education from a values perspective. Value priorities are formed over time and are shaped by multiple influences. Professional socialisation during formal education plays a role in this process though it is not the only influence. The preexisting value priorities of an individual affect their choices and may guide them in choosing a profession. One of the aims of this thesis is to understand the degree to which the value priorities of a graduate engineer are instilled in the students during their education and to what extent they are present in students as they make the choice to become an engineer. This chapter assesses the values of the profession as presented by universities during the recruitment of engineering students and the values of those who choose to pursue an engineering degree.

Educational institutions shape an individual's identity both during the education process and at the recruitment stage, as students seek to match their own values, beliefs and norms with those of the profession (Carney, Strange and James Banning, 2001; Murphy, 2015). The perceptions that an individual has of the profession can influence their behaviour even before they begin their formal education through anticipatory socialisation. This refers to the time before the formal socialisation process when an individual begins to adopt the social and psychological adjustments they believe are required for the role. This is based on any foreknowledge or impressions that the individual has about the group they are joining, in terms of expected behaviours, norms and values (Cohen, 1981; Appelbaum and Chambliss, 1997, 76; Cornelissen & Van Wyk, 2007).

There is a lack of clarity among second level students about the realities of what it means to be an engineer, both in Ireland (Murphy et. al. 2015) and abroad (Colby, 2008; Salas-Morera, 2019). A common cultural misconception exists in which engineers are associated with repair and maintenance work and are likened to mechanics or other tradespeople (Fralick et. al. 2009; Knight and Cunningham, 2004) and that an engineering degree is suitable for people who prefer hands-on rather than theoretical work (Baille & Fitzgerald, 2000; Ramoo, 2014). This misunderstanding of the profession is consistent with older research using the Holland typology which frequently categorised engineering as a "realistic" occupation (Astin & Holland, 1961, Holland, 1962; Holland & Nichols, 1964; Holland 1966; Holland, 1969). However, more recent work generally categorises engineering as an "investigative" occupation, likening it to the natural sciences (Sagiv 2002; Knafo and Sagiv 2014). As discussed in Chapter 2, workers in each of these occupational categories has been found to follow particular trends with respect to their personal value priorities (Sagiv, 2002; Sagiv & Werner, 2003; Arsenijević & Bulatović, 2012; Knafo & Sagiv, 2014).

Personal values are an important factor in career choice (Sagiv 2002, Rounds 1990) and significant correlations between value priorities and work environments have been detected in previous studies, including some conflicting correlations for realistic and investigative professions (Sagiv, 2002; Knafo and Sagiv, 2004; Arsenijević, Bulatović and Bulatović, 2012; Arieli, Sagiv and Roccas, 2020). Elsewhere it has been possible to distinguish between engineers and management within a company based on value profiles (Munson and Posner 1979).

As well as values, the ability to reconcile personal identity with the professional identity of an occupation has been shown to affect students' decisions to choose and persist in engineering (Matusovich et. al. 2008, 2010; Murphy et al, 2015 ; Holmegaard et al, 2010, 2016). A perception that the subject is rigid and untransferable, and that the profession is not social enough has been cited as a reason not to choose engineering (Holmegaard et al, 2010). The values and norms within engineering culture, including depoliticisation, technologism, and a technical/social dualism have been described as a "culture of disengagement" have been attributed to a socialising effect during engineering education (Cech, 2010, 2013, 2014; Schneider, 2010); however others, while investigating the integration of social concerns into engineering education, have remarked "we're choosing the wrong people to be engineers" (Xavier, Wint, and Orbaek White 2022). This chapter aims to contribute to our understanding of that selection process.

The university prospectus is an important source of information for students when choosing which degree to pursue and is often the starting point for a student researching their future choice (Hartley and Morphew 2008, Moogan 2009, Eusden et al., 1990; Ivy and Naude, 2004; Stanley and Reynolds, 1994). Even with the increased importance of digital marketing, the physical prospectus has remained relevant to both students and to researchers investigating academic marketing (Hartley and Morphew 2008; Bradley 2013; Henslee et. al. 2017; Rutter et. al. 2017; Mogaji and Yoon 2019; Mogaji 2019; Shahnaz et. al. 2023; Saltmarsh 2024). Advertisements such as the university prospectus are an opportunity for these institutions to communicate with their prospective students. They are intended to be both informative and appealing to students. Students are relatively uninformed about what it is to be an engineer when they are choosing their degree. This has been shown to be particularly true of female students. As well as this, universities occupy a position of trust in society meaning the prospectus may not be subject to the same degree of scrutiny as other advertising (Bradley 2013). As such the university prospectus can have a considerable influence on students' choice of degree.

The prospectus is the opportunity for universities to put their best foot forward, and to present a cultivated image which students will find attractive. Research has identified multiple advertising techniques being employed in the university prospectus such as presenting an appealing depiction of student life and experience (Steele, 2007/2009; Mogaji and Yoon, 2019). As such what can be seen in these documents can be considered a somewhat idealised version of the institution, the degree, and the profession. This chapter examines the image of the profession put forward by engineering departments in the university prospectus. By analysing the values and role of the engineering profession as presented here, we can gain two key understandings: firstly, what are the value which the academic institutions are promoting as the strengths of their profession; and secondly, what values are those who choose to enrol in an engineering degree being attracted by.

An individual's personal values also influence how they will respond to advertising (Zaichowsky, 1994) as well as their attitudes towards issues like social justice and environmental justice (Stern & Dietz, 1994). There is a need for research into how Irish universities are choosing to market engineering as a degree choice and as a career, in order to understand the values of the students being recruited. Choosing to appeal to particular values will influence what the value profiles of those who choose to apply are.

In this chapter the recruitment of engineering students is examined using three methods. Firstly, a document analysis of the programme prospectuses produced by each of the nine universities (including technological universities) in the Republic of Ireland for the 2021-2022 academic year was carried out. This amounted to 66 engineering programme prospectuses. A thematic analysis of these documents, using the methods outlined by Braun and Clarke (2006), is used to examine the values of engineering education as presented by the various institutions when recruiting students. This document analysis is combined with interview data from university staff and students. Fifteen academic staff involved in designing and delivering these programs, and two administrative staff who work in student recruitment were interviewed as part of this research. Both of these groups are involved in the production of marketing materials and are in a position to better understand the process and the strategies employed when advertising engineering degree programmes to prospective students. An analysis of 13 interviews with students will then examine their motivations for choosing to study engineering as well as their impressions of the profession and the role of engineering in society. Finally, the results of a survey, which assesses the personal values and social consciousness attitudes of first-year engineering, nursing and law students will then be examined. These results were combined with a data set retrieved from the European Social Survey (ESS). Comparison with other students at the same university will reveal some significant differences in the value profiles of students who choose engineering over these other disciplines, while the ESS data will provide a baseline of the average Irish person of an equivalent age. Taken together, these methods will contribute to our understanding of the value profile and motivations of incoming engineering students. For a full description of the methods, samples and analytic strategy used, please refer to Chapter 3.

4.1 Results and Discussion

4.1.1 Prospectus Design Process

The process of putting the engineering section of prospectus together was broadly similar across the different universities included in this study. Typically, three groups are involved in the process. The university-wide student recruitment office has control of the overall design of the prospectus booklet. They make decisions about the graphic design, the overall length of the document, and the production of the physical booklet. They create a series of guidelines which they distribute to the individual department marketing staff who then “secure the content to go within that parameter” (M1). These guidelines include word count, dimensions for images and required information such as entry requirements.

The engineering department marketing staff are responsible for producing the final pages to represent each programme on offer in their school, as well as any additional pages which may be included in their section. The academic staff are relied on to provide the factual information which populates the pages. They act as a “point of contact in terms of the academic side for each of the disciplines” (M2) and provide the “key information in terms of what they’re learning, how they’re learning and all the good stuff that students want to know” (M2). There is a back-and-forth process of tweaking the wording but “the academics ultimately get the final say as far as the content goes” (M1).

The typical prospectus includes testimonials from previous students; these are written by the students in question. One department marketing staff member described reaching out to students who had previously been involved as student ambassadors to request a testimonial.

Alternatively, they have asked academic staff to suggest a student to request a testimonial from. Once all of the content has been collected, it is passed back to the university student recruitment office for final review and production.

The process outlined above is primarily as described by the marketing staff, and for the most part was confirmed in interviews with the academics. While the mechanics of the process were typically consistent there were some discrepancies in terms of who had control of the process. The level of input that academic staff describe varies. Some describe being "heavily involved" (A13) and "have oversight on the content" (A1). Others reported being less involved and see it as primarily the responsibility of the marketing department. "I don't design it. They bounce it off me before they publish it" (A3). "I've never really given the prospectus an enormous amount of thought and as I say, it's kind of put together by the marketing team" (A4).

The academic staff describe their role as checking for factual inaccuracies in the prospectus. "I get to see it, and correct mistakes and things" (A3). There is a greater focus on checking for accuracy within the document than in trying to convey messages around the societal role or values of the profession. In this sense, they describe the document, or at least their role in its creation, as being value-neutral.

While the final document is value laden, the perceived role of academic staff is simply to provide information, rather than shaping beliefs about the profession. This does not preclude the possibility that others, such as the marketing staff, may choose to "spin" the content included, but it absolves the academic staff of that responsibility. This mirrors certain views on the role of wider engineering profession found in the literature, whereby the engineer's realm of responsibility extends only as far as the technical and scientific aspects of a project, and the responsibility for how the technology is utilised lies elsewhere (Bucciarelli 2008; Nair 1997; Herkert 2000; Johnston et al. 1996; van de Poel 2001; Riley 2008). In the present research the academic staff are fulfilling the brief as outlined by the marketing department.

While the staff did acknowledge that they play a part in shaping prospective students' expectations of the profession, through providing examples of the types of work that they might expect to engage in, they did not report having considered this aspect of their role closely in the past. Instead, they believe that they are simply conveying the reality as accurately as possible. As such we can consider the image of the engineering profession described in the prospectus, and the latent values identified by this research, to be their honest assessment of it. One participant highlighted the importance of documents such as the prospectus in terms of informing student's impression of the profession. "Our marketing material needs to put out the right image" (A3). However, even in this context it was discussed in terms of delivering factual information. They went on to say, "I wouldn't be confident that 16-year-olds would have a good understanding of what engineering means" (A3), once again describing the issue as an information deficit rather than an issue of image or identity.

The content of the prospectus remains broadly consistent over time according to university staff. While the document is reproduced annually, "Year on year there's not much change" (M1). "A lot of this [prospectus] has been in existence for a long time" and "has evolved" (M2). Given that they choose not to make many changes both marketing and academic staff appear to be satisfied that the prospectus document reflects the degree on offer. There is the possibility to review the content each year, however only "fairly minor changes" (M1), if any, are made. One member of academic staff acknowledged that their programme's prospectus "probably is overdue a rewrite" (A3) but when asked didn't have any specific changes in mind.

Revisions are only made when something is deemed “out of date” (A3) and are described as “incremental rather than huge” (A1). The most frequent changes are often updating the student testimonial “every year or two” (M1) or changing lists of modules to reflect changes to the curriculum. Participants described the prospectus as having “been written historically” (A1). The previous year’s prospectus is used as the basis for creating the new version meaning that staff “don’t start with a blank page every year” (M2). Much of the content is carried over year-on-year with the current programme director making changes as they see fit. This process means rather than being designed from the ground up and being shaped solely by the current director, the prospectus represents the accumulated contributions of various programme directors and retains a degree of institutional memory.

4.1.2 Relevance and Impact

The importance of the prospectus, as described in the literature, was also described by participants in this study. It was considered one of “the biggest drivers of recruitment” (M1), and “a very hardworking document... particularly in the domestic market” (M2). Marketing staff described their strategy in terms of a chain of recruitment material or events or “a funnel” (M2). The prospectus is an important link in that chain. It was reported that “the first way that they will probably engage with us is our prospectus” (M1). This is consistent with findings by previous researchers (Moogan 2009; Eusden et al., 1990; Ivy and Naude, 2004; Stanley and Reynolds, 1994).

The same is true of the persistence of the prospectus alongside the university website. Despite the increase in digital marketing and social media, the hard copy of the prospectus is still seen as a major part of the marketing strategy. Even though for environmental and sustainability reasons “the number of prospectuses that have been printed has been cut significantly and [some universities] are trying to push people towards the digitised version...it’s really hard to get them to fully go digital on this. They still want it in their hands” (M2). The physical copy “is something that tends to sit on the kitchen table” (M2). One suggested reason for this is that it can be distributed directly to students by schools. According to one marketing staff member, students are “going to be in schools reading our prospectus first” (M1). This reinforces the significance of the prospectus as it is being presented to students by a person in a position of trust.

This is just one way in which university staff acknowledged the role of parents, teachers and school guidance counsellors as a “guiding influence” (M1) to students making their choice. The marketing staff confirmed the prospectus is intended for use by multiple groups and have taken this into account in its production. “Parents, guidance counsellors and students are all looking at the prospectus” and so the document is designed “to appeal to all of those” (M1).

The prospectus is considered an important method of informing students about their choice of degree. As has been discussed in previous literature (Salas-Morera, 2019; Baille and Fitzgerald, 2000; Murphy et. al. 2015), students are often under-informed about engineering. Multiple participants in this research recounted being asked in a very general sense “what is engineering?” at open days or information sessions. The prospectus was considered among the first places a student should go to inform themselves further. A member of marketing staff described answering this question as follows: “if they’re coming to us with ‘what is engineering?’ and they haven’t done a lot of research, then it’s a case of directing them to go through the prospectus, go on our websites, go look at more information” (M1). In this case the prospectus and similar marketing materials are being specifically recommended for

potential students who have shown a low understanding of the field. This heightens the influence that the materials have, as the student is receiving the information from a trusted institution such as a university, and has demonstrated a lack of contextual knowledge against which to assess it.

4.1.3 Common Entry

Each institution included in this study now offers a “common entry” or “general engineering” programme for first (and in one case, second) year students. This type of programme “was designed for the student who knows they like engineering but just aren't sure about which discipline” (A11). This has become common across Irish universities and was reportedly introduced in part to help overcome the misconceptions or lack of information that institutions felt students had about specific engineering disciplines. One participant described it as “an absolute game changer” in terms of both “bringing in more students and being able to retain more students” (A13). Participants described finding some disciplines to be “a hard sell” (A11) to secondary school students “because of the uncertainty” and “because they're just not sure when they come in” (A8). This task was seen as easier once the students had some first-hand experience of the material in their first year university. Another suggested that students were previously blinded by choice, and that there was “just too much information in there for them... and I think that's why common engineering has been such a success”(A13).

4.1.4 Typical Prospectus

Each university produces their own prospectus which usually has a consistent style across all of their programmes. There are similarities in the content and structure of the engineering programme prospectuses. Just over half of the prospectuses included in this study afforded each degree programme a single page. In the prospectuses from the remaining four institutions, each degree was spread over two pages. In these cases the same materials were covered as in the more concise prospectuses, though the extra space was generally used to provide more detailed information, or additional student testimonials and images. Figure 4.1 shows a synthesised example of the kinds of content typically presented in an engineering prospectus.

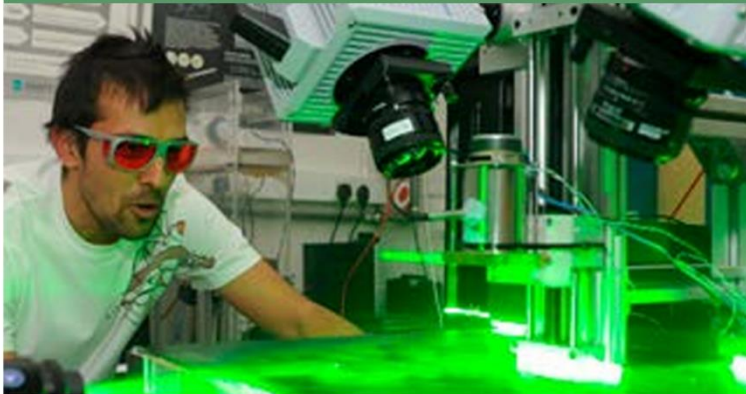
Course Title and Reference Code

Mechanical Engineering

CAO Code: ENG001

Degree Levels Available

BSc (Engineering Science)
(NFQ Level 8 Leading to ME
(NFQ Level 9) or BE (Hons)
(NFQ Level 8)



Entry Requirements

CAO Points for 2022: 520-625

Course Duration: 3 years(BSc)+
2 years (ME) or 4 years(BE)

Leaving Cert Subject Entry Requirements

H4 in Mathematics
H6 in a laboratory science
O6/H7 in English, Irish and two
other recognised subjects

Other Entry routes: See
universitywebsite.ie/admissions

What is "Mechanical Engineering"

The prospectus opens with a brief outline of the subject. In this section the focus is on the field in general, rather than the specific content of the degree course. In the case of Engineering it is filled with examples of the kinds of technology that are produced by engineers, either in terms of personal consumer goods that the reader has direct experience of, or slightly more removed contributions like medical technology or unseen infrastructure. This section will often end with a forward looking statement about how the field could shape the future and how the student can expect to be part of this.

Career Prospects

Here the writers of the prospectus highlight the opportunities available to graduates of their degree program. It includes lists of companies that graduates have gone on to work for, as well as the kinds of roles they can expect. Any external accreditation which the degree may have is mentioned here along with any internship or work placement which is incorporated in the degree.

Is Engineering for me?

Here we see the prospectus outline the kinds of candidates who are seen as the ideal fit for the profession. This covers both secondary school subjects in which an aptitude is useful, as well as more innate traits which are seen as desirable. For instance, an engineering course may recommend those who have excelled in mathematics and physics, as well as those who enjoy problem solving.

What Will you Learn

At its most basic this section contains a dense list of the modules included in the course. In some cases it is presented as a list of module titles, while in others more descriptive language is used to communicate the topics covered over the course of the degree. It can also include information on the type of learning involved. For instance if a course involves significant lab sessions, site visits or field work, it will be mentioned here.

Images

Two main approaches are taken with images in these documents. Some universities include an image for each course, while others include a full page of imagery at the beginning of the Engineering department section of the prospectus. In the later case, they may include an image of the student/graduate who is included in the testimonial.



Testimonial

It's common for a prospectus to finish with a testimonial from a current or past student. They will typically say a few words about why they chose the course, often relating it to the subjects they preferred in school. It also includes a brief summary of their careers since finishing the degree.

Sometimes these are written from the student's perspective in the first person. Other times it's a third person description of the student's career path since graduating from the course followed by a few quotes from the student.



ACCREDITED PROGRAMME

Figure 4.1: Recreation of a Typical Engineering Programme Prospectus

4.2 Themes and Findings

This section presents the themes identified in the recruitment material and interviews with staff and students. Individual topics from the thematic analysis have been arranged into four major themes for discussion.

The first theme covered is the various ways in which engineering as a discipline is defined and understood. This theme addresses the public understanding of what an engineer does, and some of the major misconceptions which persist among incoming students. Next the various motivations for choosing engineering are identified, including the career opportunities, the opportunity to make difference via engineering work, and an intrinsic interest in technology. The subsequent theme deals with the content of an engineering education. Here the kind of subject matter which engineering departments present in their marketing material, and the impression that this gives students is discussed. Finally, messaging involving the type of student who should choose engineering is identified. This involves the kinds of traits which are used to identify a student as a good candidate for engineering, as well as looking at some specific marketing which is being used to try to increase the number of female students choosing engineering.

4.2.1 What is Engineering?

4.2.1.1 Problem-Solving

Problem-solving is, by a considerable margin, the most common activity mentioned across the engineering programme prospectuses. It was also included in every single definition of engineering offered by both staff and student interviewees. Throughout the prospectus documents it is identified variously as a desirable trait for incoming students, and as a key aspect of the programme content. It's described, in the prospectuses, as a trait inherent to an engineer, who *"is a problem-solver by nature"* (U7).

Virtually every programme prospectus refers to problem-solving. It is portrayed as one of the primary identifiers of an ideal engineering candidate and a motivation for students to choose the degree, with one student testimonial stating, *"All I knew for certain was that I liked maths and I enjoyed solving problems"* (TU1). It was suggested that *"the reason [students] become engineers is because...most of them like the problem-solving end of it...That's what engineers do"* (A8). In this regard the opportunity to problem-solve in and of itself is a motivation for students to choose engineering.

While participants reported that they perceive confusion among the public about what it is to be an engineer, the idea of engineers as problem-solvers does seem to have permeated the common cultural understanding. One participant joked that their *"own mother-in-law, aged 82, is delighted to tell [them] that engineers are problem-solvers. And these are her words that she heard from newspapers, radio, or whatever"* (A4). Another described it as *"a trope"* but believed that *"It's a cliché for a reason"* (A11).

4.2.1.2 Applied Science or an Academic Trade?

As well as the identification of problem-solving as a main goal, are the tools, methods and approaches that engineering uses to tackle these problems are outlined. Primarily both interview participants and the prospectus documents identified the use of *"technical, mathematical and information based and rooted in physics and science to solve problems"* (S5) as being the main work of engineering. The prospectus documents are required to be reasonably concise and so there is not room for an enormous amount of detail, however it is

notable then that some version of this definition appears so frequently. It appears to have become the universally accepted definition used during recruitment and before. As one participant explained, "I think engineering is the application of sciences to solve problems. That's how I'd explain it to my children" (A6).

This definition, and some of the vocabulary used alongside it may contribute to one of the more common misconceptions about engineering. As we have seen in the literature regarding the Holland typology, engineering has been classified in both the realistic category, alongside tradespeople and technicians, and in the *investigative* category alongside the sciences (Astin and Holland, 1961; Holland and Astin, 1962; Holland and Nichols, 1964; Holland, 1966; Sagiv, 2002; Knafo and Sagiv, 2004; Arieli, Sagiv and Roccas, 2020).

In the prospectuses analysed here, there is a clear emphasis that the subject will involve using maths and science, but some of the messaging in these documents also reinforces the image of engineering as a hands-on and practical discipline. This study found evidence of students who felt they, or their peers, had been misled or misinformed about the nature of the profession in this regard. This is discussed further in the following two sections.

Applied Science

The disciplines of engineering and science share a lot of common theoretical territory. As such a common definition of engineering is the "*application of science and mathematics to solve problems*" (TU1). This is evident in many of the prospectus texts and was repeated in some form by a number of student and staff interviewees. While seemingly widespread, this definition has been contested elsewhere.

Sismondo (2009, Ch 8) outlines many of the major arguments which dispute that definition by claiming that engineering develops its own original knowledge. One interview participant in this research expressed a similar dissatisfaction with this definition because "it... puts engineering in a subsidiary position" (A3). The arguments laid out by both Sismondo, and this interview participant point out that "There can be some new ideas coming out of engineering as well... That's why we've got all these research students like you" (A3). Sismondo, citing Constant (1984), makes the case that engineers and technologists have developed their own knowledge traditions.

This persistent conflation between science and engineering can have a significant impact on the image of the profession which is being presented during the recruitment of engineering students. The commonly held definition of science is the pursuit of knowledge and understanding or as a participant here explained "the principal goal is the pursuit of knowledge, while engineering is the pursuit of solutions" (A9). Merton (1973) included "universalism" and "disinterestedness" as two of the core norms of science, implying that scientific methods could and should remove personal bias from its practice and decision making and that a scientist should not be invested in the success of an experiment. Scientists should strive to remain value-neutral in their work. The definition of engineering as the application of maths and science would seem to contribute to the idea of engineering as a non-political or value-neutral profession.

However, within the pages of the prospectus documents, major social issues are listed as being within the scope of engineering to solve, while simultaneously the skills and subject students are being equipped with are almost entirely scientific and mathematical. Some general language such as "*improve people's lives*" (U7) is used throughout, as well as discipline-specific objectives such as "*Create buildings and cities in which millions of people*

can live happily and securely" (U4). Another prospectus claims that engineering *"is a profession in which mathematics, chemistry, and other natural sciences are applied to develop innovative and effective ways of using materials and energy for the benefit of society"* (U5). If engineering is to work for the benefit of society, then it appears counterintuitive that it should adopt the detached disinterestedness of science.

Previous authors have described depoliticisation of engineering in which engineering work attempts to achieve value-neutrality and objectivity through scientific methods and through this objectivity looks to rise above the messiness of social, political and cultural concerns (Cech 2013; Seron et al. 2011 ; Faulkner 2000; Haraway 1988). This phenomenon is evident in the prospectus texts which, at times, appear to go out of their way to avoid introducing a personal element to engineering work. Humans are discussed as organic components within a technical system rather than living people. For example, *"Mechanics – how things like cars, wind turbines and rugby players move, deform and break"* (U4) or *"Biomedical Engineering combines engineering with an appreciation of the functioning of the human body, whether healthy, injured or diseased"* (TU1). These are just two examples of the dissonance which comes from trying to apply cold scientific detachment to something as value-laden and complex as society.

An Academic Trade

While there's an acknowledgement of the shared academic theory with science, engineering defines itself by focussing on practical application. Phrases like *"real world problems"* (U2) and *"practical"* (U4) are often used in relation to problem-solving in the prospectus texts. By focussing on the application, rather than the exploration of knowledge, and using language like *"make a real contribution"* (U5) these documents portray engineering as a profession of action rather than just theory. Marketing staff confirmed that this is one of the main messages they want to convey to potential students. "It's a very practical, hands-on degree. They're the kind of strengths that we're trying to convey" (M1). In an international context there is evidence of engineering students self-identifying with this image. Trevelyan (2022) gives the example of the motto for the main engineering student social club in the University of Western Australia which translates as *"people who do not talk but do things"* (non loqui sed facere).

In the documents analysed, engineering is heavily marketed towards people who prefer *"learning-by-doing"* (U2) which again reinforces that sense of action. This appears both in text and in a number of images in which students or professionals are operating equipment and machinery. There is also evidence in the literature that some believe engineering is a good degree for those who find theory heavy work boring or unengaging (Baille and Fitzgerald, 2000, Ramoo, 2014). This message appears to have been effective in recruitment. A number of students suggested that this learning style drew them to engineering. For instance, one participant preferred to "learn things by doing things and copying what my dad would do in his workshop back home....that's why I chose engineering" (S2) and "that's how I learn, by doing it instead of like just listening about the theory" (S10). Many programmes look to emphasise how much *"practical"* (TU1) work they include and that they are suitable for students who prefer a *"hands-on"* (U7) approach. It's described in terms of the *"balance between theory and practical problems"* (U1).

A number of interviewees referred to the Irish secondary school subject of Engineering, which heavily rewards hands-on skills. In the state exams for this subject 25% of a student's final grade is awarded for a manual fabrication exam, while another 25% is given to a project which involves the design and construction of a device. In this context, and with the common public

misconception of the engineering profession, the extensive use of language such as “hands-on” and “practical” may be misleading to students in communicating the theory-heavy nature of university engineering programmes. The level of understanding of what it is to be an engineer among secondary school students has previously been shown to be relatively low (Salas-Morera, 2019; Murphy et. al. 2015) and an expectation that university engineering programmes would have a similar focus on hands-on work has already been observed (Baille and Fitzgerald, 2000; Murphy et. al. 2015; Ramoo, 2014). The current study had similar findings with the level of hands-on work being one of the dominant misconceptions among students. One student participant recalled classmates who made this particular mistake saying that they “came in expecting like, ‘Oh, I’ll be doing a lot of practical hands-on stuff’. And then you’re sitting there, you’re doing maths and physics and chemistry” (S4).

Again, this echoes the confusion over engineering’s placement in either the *investigative* or the *realistic* categories of the Holland Typology, with the secondary school subject better describing the activities of a career in the *realistic* category. That category indicates a preference for working with tools and machines as well as a self-identity for having manual skills, and in terms of values it has positive correlations with *hedonism* and *tradition* and a negative correlation with *self-direction*. These value correlations are not shared by the *investigative* category, under which a modern engineering career typically falls (Knafo and Sagiv, 2004).

This appears to be a known issue among staff in both academic and marketing roles. One member of the marketing team described feedback from students who “were expecting maybe that it would be more hands-on and practical in the sense that you would be doing more metal work, or you would do more woodwork or something rather than lab-based activities” (M1). As well as the content of the degree, this confusion extends to the expected career of an engineer. Both students and staff reported that they believe that the public perception of an engineer is closer to a fabricator or technician. In such a technology-laden field, solving problems appears to have been equated to fixing things. The public impression of an engineer was described as “someone standing there with a spanner ready to, you know, tighten something” (A6). Similarly, it was reported that “people think you’re a mechanic” (A12) and “assume that an engineer could fix a car” (S4) and that it’s “very dirty and greasy. It’s a very dirty job, engineering. ‘Oh, you’ll be wearing a hard hat and overalls for the next 40 years’ ” (A15). Marketing staff are specifically looking to address this in their material by “trying to move away that traditional look and feel of engineering... of yesteryear, which is, you know, yellow hard hat, high vis jacket which there was an awful lot of” (M2) in previous generations of engineering recruitment materials. Some of the confusion around the identity of the profession can be attributed to the various uses of the word “engineer” internationally. For instance, “in Britain, an engineer comes to fix your washing machine... and in America, an engineer drives a train” (A3). However, given that this is a known issue, there may be a need to address this in the recruitment of engineering students.

There is reason to believe that emphasising the relevance of “hands-on” work contributes to the persisting gender divide in 3rd level engineering. Aside from outdated traditional gender roles which may be instilled in young women, there is an issue of perceived professional identity. Practical subjects like Construction, Design and Communications Graphics and Engineering remain less commonly offered in all-girls schools in Ireland. In 2022, female participation in Leaving Certificate Engineering reached 9%, or just 219 female students (I Wish, 2023), with similarly low figures being recorded in Construction Studies and Design &

Communications Graphics (CSO 2019). In this study a female engineering professor, when discussing the practical subjects listed above replied “you listed off three courses there that I didn’t have an opportunity to study at Leaving Cert level... because I went to an all-girls school” (A6). Lower competence beliefs are associated with lower attainment values (Eccles et al., 1983), meaning a lack of experience in the “practical subjects” from secondary school could make it more difficult to align self-image with the profession. One female participant in this study described a prevalence of “imposter syndrome” among her female peers, and told of how in her all-girls school “there was no applied maths and physics. You’d have to go down to the boys’ school” (S6). This is consistent with recent findings in which 59% of surveyed female students in Ireland lacked confidence in STEM subjects (I-Wish 2023).

A Blended Identity

While it’s wrong to say that engineering is just applied science, the reality of an engineering education appears to be much closer to that than to any other discipline. As one participant put it “you’ve got to distinguish engineering as a practice and a discipline... from engineering academia... Engineering academics are fundamentally engineering scientists” (A9). It is in the common understanding of the profession that the division becomes clearer. The perception of the profession as one of action appears to be a lot more clearly defined, than the indistinct boundaries between the content of an engineering and scientific education. However, this distinction comes at the cost of creating confusion between engineering and the role of trades people and technicians, and fostering the idea that engineering should be considered as a realistic profession. This may explain the dissonance between the very practical and applied public perception of the profession, and the student view that “a lot of people think it’s really hands-on and it’s not actually. It’s a maths and science degree where you’re doing a few more projects” (S4). These conflicting messages appeal to different aptitudes, as well as different personal value priorities, and appear to be responsible for certain groups of students feeling unsuited to, or dissatisfied with, engineering education.

4.2.2 Why Study Engineering?

Three major motivations for students to choose to study engineering emerged from the prospectus analysis. Firstly, there are the career opportunities that an engineering degree provides. This category refers specifically to the tangible benefits of an engineering career in terms of employability, salary and career progression etc, rather than the kinds of work that an engineer might undertake. Secondly, the opportunity to make a difference and to do something good is used as a motivation for students to choose engineering. The role of the profession in society as a vehicle to bring benefits to the world is used to attract students who may have noble or idealistic aims. The final major motivation is an intrinsic interest in engineering. This refers to those students who choose engineering as a career path because they see it as aligning with their personal interests. In many cases these are the students who discussed having hobbies which align with their idea of what an engineer does. All three of these motivations are evident in the prospectuses in statements such as “if you’re interested in helping create a better world or just interested in the technologies, this course offers you a great opportunity to start a rewarding career” (TU2). Similarly, while discussing the recruitment of students, marketing staff reported that “the students themselves want to make sure that they are picking courses that they can do well at, that they’re not going to be struggling at, that they will enjoy and that they will get good jobs at the end of the day” (M1). Each of these motivations are discussed in greater detail below.

4.2.2.1 Career Opportunities

Employability

Highlighting the ability of their graduates to find employment upon graduation is a common trend across all data in this study. It is the most commonly highlighted strength of an engineering degree across the prospectuses and was frequently discussed in interviews with staff who reported that “many of our graduates have multiple job offers” (A1) and “we have 100% employment rate at this stage” (A11). Every one of the 66 course prospectuses included in this study pointed to the employability of their graduates as a strength. Many of these included some percentage of recent graduates who had found employment. Phrases such as “*great employment prospects upon graduation*” (U7), “*career prospects for all graduates are extremely positive*” (U6), and “*energy engineers are highly sought after*” (U5) are common throughout. In total there were 181 separate references to the employability of engineering graduates across the prospectuses analysed.

Companies where graduates have found employment are often listed in the prospectuses. As well as giving a sense of the kinds of industry a prospective student may find themselves working in, this also lends a sense of credibility-by-association to the degree program. While the complete list of companies mentioned contains a mixture of industries it is heavily skewed towards large private multinational corporations. A total of 126 separate companies were listed in the documents. The most frequently occurring of these are large, well-known businesses. The likes of De-Puy, ESB (Electricity Supply Board), and Intel each appear in seven or more places, along with other significant names in Ireland’s engineering and technology industry such as Boston Scientific (6 mentions), Accenture (5 mentions), and Arup (6 mentions). In the same vein, interview participants listed similar companies in order to emphasise the number of opportunities available to students. “We have Analog Devices, we have Qualcomm, we have cadence, we have Microchip, we have Apple, we have EMC, Dell... all the big names” (A11). Choosing large, established companies helps establish a sense of stability in the employment market that a graduate will be facing. Staff also explained that this name recognition is used to help explain the role of a particular kind of engineer in that “if they don’t know, say what a chemical engineer does, sometimes knowing the companies... helps them kind of get their minds around that” (M1). It also addresses a frequently-asked question from parents. A typical exchange with a parent at a careers fair or similar event was described as “‘So my kid is interested in mechanical engineering. Can you tell me all the types of careers that your past students got into? What’s your employment rate like and what type of companies?’ So we always have a career section in there as well” (M2).

This focus on employment is heavily linked to an emphasis on work placement. Sometimes called internships or co-operative education, the prominence of this aspect of the programme in the marketing material indicates that the institutions consider it a major strength of their program. It is variously described as “*a key element of our degree*” (U5), and as “*integral*” (TU1 & U2). Not only does this message appear in the main text of virtually every programme prospectus (only three of the 66 programs did not mention work placement), but it is frequently included in testimonials from current or past students. One such testimonial highlighted the influence that this placement has had on their professional development. As well as acknowledging the benefits in terms of their engineering skills and learning, they described their work placement as “*invaluable ... in deciding the direction of my career after graduation*” (U6). This once again underlines the importance of the kinds of companies which these

engineering departments choose to partner with, as it can have an impact on the engineers that they produce even beyond graduation.

There is a real focus on assuring the reader that earning an engineering degree is a near-guarantee of employment on graduation. This messaging appeals to the *security* values of a prospective student. One student participant was of the opinion that “for engineering students... the stability is quite an attractive aspect” (S4), however, *security* is a value which investigative professionals, including engineers, have been shown to attribute low importance to (Knafo and Sagiv, 2004). On the other hand, placing importance on *conservation* values, including *security*, has been shown to increase with age (Robinson, 2012). Mogaji (2016) identified the role that parents play in a students’ decision of which university or programme of study to choose, something which university staff are aware of. “Parents will be... advising the students and... they do listen to them, you know” (A2), and “from research, parents thumb through [the prospectus]” (M2). Other participants specifically described finding messages about employability more effective when talking to parents. “I’m speaking to the student and the parents, I’m selling the “you can work anywhere, pretty much” pitch to them, and that will appeal very much. I think more so to the parents” (A8). Though it was explicitly stated that “students absolutely want to know [about career prospects] as well. But sometimes the parents are just a little bit further down the line on that” (M2).

In an extreme case one staff member described a conversation with a student who had been pushed into an engineering degree by his parents. “He said... ‘but I don’t want to be an engineer’. And I said, ‘really? So why did you end up here?’ he said, ‘my parents forced me’” (A15). In less drastic cases, students reported that their parents supported their choice of engineering “because it’s a good degree to do. Because it’s a respectable degree... Your parents just want you to get a good degree” (S4). It has previously been found that parents may encourage the pursuit of STEM interests, potentially as a means of social mobility (Archer *et al.*, 2012; DeWitt and Archer, 2015). Highlighting the job prospects of an engineering degree may appeal to the *security* values of parents and be a factor in their support of this career path.

In contrast to the *security* of employment, self-employment or entrepreneurship would appear to appeal to an individual who places importance on *self-direction*. While there were some mentions of graduates who had started their own companies, they were far fewer in number and received less attention than those who had found a position within a large company. *Self-direction* is a value which has been shown to be prominent in Investigative professions (Sagiv 2002; Sagiv & Werner, 2003; Arsenijević, Bulatović, & Bulatović, 2012; Knafo and Sagiv 2004). This would seem to conflict with the workplace power structure that working for a large corporation involves. Sixteen total references to engineers as entrepreneurs were found in these documents, including four that were included among the testimonials from graduates.

Earning Potential

Interestingly, despite the obvious focus on employability, there are relatively few mentions of the salary a graduate can expect in the prospectus documents. Compared to the 181 references to employability, there were only 12 mentions of salary. Of those, five were internal comparisons between different engineering disciplines rather than external comparisons to other careers. One university claimed that their Chemical and Bioprocess Engineering “*graduates are among the best paid engineering professionals*” (U1), while another claimed that “*Building engineers are one of the most sought after types of engineer and were the highest paid engineer category in the construction sector in 2019*” (TU2). This second case

aligns with interview findings. Two participants who were from a civil engineering background highlighted that “salaries are probably slightly lower for civil engineering” (A14) compared to other disciplines and that “that will feature in a decision about what branch of engineering [students] might actually take” (A2). Students appear to share the belief that “in Ireland, engineers are not exactly paid the best” (S4) and so an internal comparison like this might be an attempt to divert attention away from these broader concerns.

In two cases where an engineering degree is framed as leading to a higher salary than another discipline, it is when those with engineering degrees move into management or other non-engineering roles. It is pointed out that “*Many mechanical engineers also progress into general management roles where their analytical skills are greatly valued*” (TU1), and that “*33% of top chief executive officers on the Standard & Poor 500 stock market index hold undergraduate degrees in engineering – higher than any other discipline. By comparison, only 11% have degrees in business administration*” (U7). This presents engineering as a viable option for those with the ultimate aspiration of climbing the management ladder within a corporation. “Yeah, there's definitely a lot of engineering students who will be aiming towards management. It's seen as a good way to get into management positions” (A5). There is evidence of this in enrolment numbers for an “Engineering with Management” degree. While it originally had lower entry requirements than other engineering degrees at a particular institution, “that's flipped maybe 8 or 9 years ago and now it's a higher [entry requirements] programme” (A9).

In previous work, Matusovich found that *utility* values, such as employment prospects and earning potential, are only rated highly among engineering student motivations when *attainment* and *interest* values are low (Matusovich, Streveler and Miller, 2010). Similarly, increased financial rewards appeal to someone who prioritises the values of *power* or *achievement*, neither of which correlates to those in investigative professions like engineering (Sagiv, 2002). A similar sentiment was expressed here by students and staff with one staff member describing a financial motivation for choosing engineering as “quite trite and superficial” (A9) while a student participant suggested that those with financial motivations “tend to not stick around for master's programs and who tend to pivot off into business and consultancy” (S4). Management aspirations are more closely associated with the *enterprising* personality type (Eccles, 2005), which has previously been shown to correlate positively to the values of *power* and *achievement* (Knafo & Sagiv). The same study did see a negative correlation between the *enterprising* personality type and *Universalism*. Students who see less congruence between their sense of self and what it is to be an engineer, or a student with less intrinsic interest in the subject matter of an engineering degree are more likely to view engineering as a pathway “*into technical management roles with high salaries*” (TU2). Conversely students with a high interest in the subject matter and who identify with their idea of what it is to be an engineer, are less likely to respond to advertising which highlights the utility of the degree. These are the students “who don't really want anything to do with management. They just want to be technical engineers” (A5).

The students interviewed did not highlight the importance of employability or potential salary as motivation for themselves to the same extent as the staff or the prospectuses. A common sentiment was that participants felt that financial rewards were less important than satisfying or enjoyable work, however this was always with the caveat that the salary would meet some loosely defined personal living standards. “Enough to get by on” (S2), “put food on the table and a roof over my head” (S13) and “enough to make rent” (S9) were just some of the kinds of language used to describe this lower limit. Participants expressed that they felt that an

engineering career would likely meet this standard for them and that everyone with an engineering degree “lands on their feet” (S4). It may be the case that having the confidence that these basic needs will be met affords students the luxury of focusing on other aspects of their future career.

It is worth noting that students did discuss feeling that salary was a bigger factor for their peers in engineering education than for themselves. In one case a student recounted a discussion which occurred at a careers workshop which was held for their class. When asked where they saw themselves in ten years “the answers that were shouted were like, ‘In ten years I’m seeing myself having a six-digit salary’ ” (S2). Over the course of that discussion the participant felt that “pretty much the biggest motivator [among his peers was] ‘How much money will I make?’ ” (S2). Similarly, a 2014 study in the UK found that career goals outweighed intrinsic interest in the subject as a motivation for engineering students’ choice of degree (Skatova and Ferguson, 2014). It is possible that the students being interviewed felt some kind of social pressure to downplay the importance of money to them, and so their reports on the views of others may offer valuable insights.

4.2.2.2 To Make a Difference

Another common approach that these documents take is to highlight the role that engineers play in society. There is no shortage of bold claims about the potential influence of engineering in these documents.

We can see, in these claims, evidence of the divide that exists about the value-neutrality of the profession. Some of these are simply claims about the magnitude of the impact that engineering and technology can have, using lofty language and imagery to describe the role of engineering in society. According to these texts, engineers “*can move the world*” (U7), “*make things possible*” (TU2) and “*expand the frontiers of society*” (U4) These are claims about the power of engineering and technology rather than its merit. Similarly, claims made by staff such as “I would say engineering is central and core to the evolution of humankind. So it’s really critical, really central” (A1) portray engineering as important without suggesting that the profession is working towards any kind of public good. Any of these statements could be accepted as true and be consistent with a value-neutral conception of engineering.

However, others explicitly state that the goal of engineering is to benefit society. There is a definite message that engineering as a profession is a force for good, which focuses on what engineering has achieved for society. We see an example here of engineering taking a technocratic approach to social problems which allows the profession to engage with these, while maintaining a sense of depoliticisation. The achievements of each field of engineering are laid out and the benefits of this technology to society are highlighted. It is specifically stated that “*As a mechanical engineer you will work as a professional using technology to make the world a better, safer place*” (U4). Among the descriptions of what the aims of engineering were a number of variations on “to improve technology...for the benefit of society” (A6), which again clearly suggests that part of the mission of engineering is to “help society and help humanity” (A2). By framing an engineering career as a means to “*help improve our world*” (U1) and “*Engineer a better future for all*” (U7), these documents appeal to the values of *universalism*. Placing importance on this value has been shown to correlate positively with investigative professions (Sagiv, 2002).

While *benevolence* and *universalism* are closely positioned in the Schwartz value system, it is interesting to note how much these engineering prospectus documents appeal to

universalism while giving *benevolence* relatively little attention. This mirrors the divide in personal values that has been seen elsewhere in individual engineers. Knafo and Sagiv (2004) found that those in investigative professions were likely to value *universalism* over *benevolence*. While the value of *benevolence* is in enhancing the welfare of those immediately surrounding an individual, *universalism* looks at the needs of those beyond this group. Engineering solutions, as discussed in these documents fit this description. Problems are framed at a system level, viewed from 10,000ft. They are described in terms of their benefits to humanity as a whole rather than to individual humans.

Conversely, we see evidence for the idea of engineering as a value-neutral profession in these documents also. In places, the role of engineering is described as a response to the demands of society. Objectivity or disinterestedness is a desirable trait in scientific work (Merton, 1973). It is consistent with the "mercenary engineer" who sees moral and ethical judgement as external to engineering work and more suited to those in management or government (Riley 2008, Johnson 2006; Bucciarelli 2008; Nair 1997; Herkert 2000). The detached language used in the marketing material, and the focus on *universalism*, rather than *benevolence* would support this definition. Whereas in some places engineers are "*leading the way*" (U1), or are "*driving how we live, work and play*" (TU1), in others engineering is framed as an obedient servant which needs to adapt "*to the shifting requirements of industry and society*" (U4). In these cases, a value-neutral conception of the profession appears to make sense. It implies that engineering acts according to the will of others. The use of the words "industry and society" (U4) is notable. They are positioned as equally important or in alignment with each other. This, along with the focus on employment by private companies in these documents, is illustrative of a prevalent attitude within engineering that externalises responsibility for shaping the profession's future, focusing instead on serving private interests (Downey and Lucena, 2004; Conlon, 2008; Leydens, Lucena and Riley, 2022).

Shifting the agency off of the engineer, narrows the scope of what the profession is responsible for. In this case, the engineer is simply "*solving society's innovation and production tasks*" (TU2). This mirrors a way of framing the role that was discussed by Johnson (1996) as a way of obfuscating responsibility for the consequences of the work. There is a conflict here in which engineering is both claiming credit for the achievements while accepting none of the responsibility.

The motivations offered by students varied. Many students broadly understood that engineers could have a large impact on society. As one noted "I think if you kind of philosophise this, then I'd say society kind of relies on progress and innovation" (S1). When discussing what kinds of thoughts they had about the engineering profession while making their choice of degree one student noted "I was sort of thinking about innovation and driving society forward" (S4).

Some were adamant that they had gotten into engineering with a view towards helping people. They describe their reasons for getting into engineering as "improving the quality of life of people all around the world" (S2). These participants suggested that the public good was part of their understanding of what engineering is and that "if you're inventing something that doesn't help anyone, is there a point?" (S1). Another told of how they were inspired by a TV series called "The Big Life Fix... where they would pair these engineers and designers off with people that would have a disability, and ... try to find a solution... actually, this is one of the reasons why I chose biomedical engineering" (S10).

This example highlights how the divide between *universalism* and *benevolence* was less evident among student participants than in the marketing materials. While the prospectuses often describe global challenges, a number of students expressed a preference for the immediate, tangible outcomes of their work. One participant noted, "there's something nice about the fact that you might be helping one person. Which sounds strange because surely you'd like to help a million. But I just prefer the... immediacy of the interaction, I suppose, rather than designing a part of a phone network or something that everyone's using" (S12).

For others, the ability to make a difference and help people was a secondary motivator. One suggested that it was "a bonus" (S11), while others offered that "Of course, it's nice to work at a company that's, you know, maybe doing something good for people in the medical field. But it wouldn't be, it wouldn't make or break a decision for me" (S4). For this cohort, the societal role was of lesser importance than choosing a career that interested them.

4.2.2.3 Intrinsic Interest

An innate interest in technology is presented in the prospectuses as a motivation for studying engineering. In these cases, an interest in technology itself, rather than its application, is a motivation. Often this is conveyed as "*an interest in learning how things work*" (U7). Those with this curiosity are encouraged to pursue an engineering career. "*If you look at those items and think 'I can make this work better', then electronic engineering is definitely worth considering as a career for you*" (U3). Similarly other material suggests that prospective students "*should have an interest in technology*" (TU2). This aligns with the perceptions of academic staff who believe that "a lot of people go into engineering to begin with ... because they're interested in technology" (A5). For another, "that interest in how the world works" and someone who asks "how does that work? Where does that happen? That's the engineer" (A11). By emphasising engineering as an intellectual puzzle, these marketing materials appeal to the *stimulation* and *self-direction* values of the Schwartz value system, and align engineering closely with the characteristics of investigative professions that involve problem-solving, critical thinking, and a deep interest in exploring complex issues. This intellectual challenge appears to have attracted a number of participants to engineering. They reported that "what appeals to [them] about engineering is learning the internals of how lots of different systems work" (S4) and that this curiosity "made me go into engineering, because engineering kind of helps me get a better understanding of the world" (S2). A number of students described some version of this technical curiosity as having been a feature of their childhood. They recounted that they were "always interested in engineering and just building stuff" (S10), and "I liked, like, messing around with electronics, like taking things apart, putting them back together" (S6).

For many students who chose engineering due to this technical interest, engineering, or at least what they understood to be engineering, was a hobby before they ever decided to study it at university. One participant suggested that a lot of those in engineering "tend to be in it because they are... complete nerds who love engineering, like their hobbies are all like fixing cars and that type of thing" (S4). Staff suggested that an interest in engineering often coincided with an enjoyment of "things like puzzles, Lego, that type of thing" (A7) which was echoed by a number of students who suggested "I've yet to meet someone in engineering who didn't enjoy Lego a lot growing up" (S9). Similarly, another clarified "I didn't just like build Lego, I'd build like Lego contraptions that would like, do things" (S6). This differentiation between simply following the instructions and designing their own "contraptions" may indicate a preference for the value of *self-direction*. Another participant expressed a similar end goal to their interest in

how things work stating that they want to understand “of how lots of different systems work... so that I can actually apply that knowledge to create my own solutions” (S4).

This hobby-level interest was described as both a positive and a negative by participants. On the one hand, it seems as though every participant expressed some form of this interest at a young age and took it as an indicator that they should study engineering and encouraged a feeling that “just innately engineering is something fun” (S4). However, some staff felt that this was partly responsible for setting false expectations about the level of rigour and detail required in engineering. For instance, one participant discussed how “everybody’s an electronic engineer...because they all use an Arduino” but that “it’s a hobbyist thing as far as we’re concerned” (A11). They felt as though such easy access to surface level electronics makes the effort involved in a full electronic engineering degree appear less rewarding.

Despite this, the prospectuses use this idea of engineering as a hobby to attract students to their programmes. One highlights that as part of the programme “*students are required to Design, Build and Fly a model aircraft*” (U2), while another pointed to a competition in which students “*have the opportunity to become involved in the student competition to design and build a racecar*” (TU2). These are two examples of the prospectuses positioning hobbyist activities as part of an engineering education and encouraging students to pursue their recreational interests as a possible career path.

The other major instance of the marketing material appealing to students with an innate interest in engineering is in the programme content which students will study. This is discussed more thoroughly in the following sections.

4.2.3 What Will You Learn?

4.2.3.1 Fundamentals First

The engineering programmes offered in Irish universities are designed with a fundamentals-first approach. This is evident in the prospectus text and was confirmed by staff interview participants. Words like “*foundation*” (U4 & U2), “*core*” (TU1), and “*grounded*” (TU2 & U4) are used throughout the prospectuses to describe material the students will learn. In some cases, this language is specifically referring to the early years of the degree, where a bottom-up approach to teaching the subject is taken. In these cases, the contents of the first and second years of the degree are referred to as the “*fundamentals*” (U4, TU2, U1 & U2). In others it is more broadly applied to the programme in general. This is consistent with the programme structure described by academic staff who stated that “you have to learn the basics first” (A6) and believe “that if you don’t understand the fundamentals, you don’t necessarily understand the processes which are built on top of fundamentals” (A1).

However, it was acknowledged that this approach is less appealing to students. Staff reported a perception that students were more interested in the applications of technology rather than the underlying principles. One participant described that when “talking to school kids...the thing I wave in front of them... is the applications.” (A7). Others confirmed that “It’s very hard sometimes to sell the nitty gritty” (A11). There is evidence of an existing perception among second level students, that engineering is a rigid and inflexible discipline and that this was a reason for students choosing to not study engineering (Holmegaard et. al. 2010). The fundamentals-first approach taken in engineering education, and its presence in the marketing materials may contribute to this.

There is an element of tension here between the desire to attract students to an engineering programme, while also providing an honest overview of the degree and profession. When discussing the programme content, and what they consider to be the strengths of the degree on offer, many participants refer to the fundamentals. A commonly cited reason for this approach is the rate of change of technology. Rather than chasing “every new fad and every new technology” (A9), the programmes are designed to focus on the principles which underpin them as although “the technology is changing... the concepts and the fundamentals are still there” (A11). While this was described as the preferred approach, it was acknowledged that it is not necessarily appealing to students. When taken to an extreme, one lecturer suggested “if we want to get bums on seats [they would create] a degree in ChatGPT” (A11).

In contrast to this, there is also an effort in the prospectuses to present engineering as modern and to relate it to current technologies. Academic staff did acknowledge that they “try to capture ...the zeitgeist of the time” (A1) in the marketing material and that they include “a couple of teasers... and say, this is what you could be doing” (A11). This somewhat understates the extent to which current technology and new developments are included in the prospectus text. General statements such as “*trying out the latest in new technology?*” (U4), “*next-generation technology*” (U6) and “the latest innovative engineering advances” (U7) are included alongside more specific technologies. One such technological concept, “the internet of things” was mentioned as the kind of trendy concept which captured the public's attention. Specifically, they referred to it as “a big hoo haa”(A11). This technology featured in the text of four programme prospectuses across two universities.

The result of this is a dissonance between the programme content and other messaging in the prospectus. While in one place the text tells students that they might have the opportunity to “*design and build an entry for ‘Robot Wars’*” (U4), the curriculum is designed with the philosophy that “you can't make a robot until you understand what a resistor is” (A11).

This dissonance results in opposing values being appealed to. Focussing on relatively fixed and unchanging scientific principles would appear to appeal to the higher order value of *conservation*. Specifically, language such as “grounded” and “foundational” appeal to the value of *security*, as does the message that an engineer who understands the fundamentals will be able to adapt to technological developments. In contrast to this, the portrayal of the profession as dynamic and adaptive is in line with the higher order values of *openness-to-change*, with one prospectus stating that “*as an engineer, you will need to be adaptable both to the rapid development of new ideas and technology and to the shifting requirements of industry and society*” (U4)

4.2.3.2 Technical Focus

Where programme content is discussed in the prospectus, subjects described as “fundamental” (or “core”, “foundational” etc), are entirely technical. Positioning these subjects as the core of engineering pushes non-technical subjects to the periphery. They appear less important to the degree, and by extension, the profession. The modules listed, and the topics described as being at the core of engineering are largely those which deal with mathematics and natural sciences. Many focus on very specific sub-branch of physics, such as “Thermodynamics”, “Fluid Mechanics” or “Mechanics of Solids”. Technically-focused modules such as these make up the vast bulk of the programme content for engineering programs. A typical programme subject list might read as follows: “*Subjects covered include everything from Algebra and Geometry, Digital Electronics, Electrical Science and Microprocessor Fundamentals to Computer-Aided Design, Web Technologies and Databases, Software*

Design and Quality, Computer Architecture and Computer Systems and Wireless and Mobile Networks" (TU2). Previous authors have identified the belief among engineers that complex social problems can be reduced to a core technical issue and solved as such (Hacker 1981; Faulkner 2000, 2007; Cech 2013). These documents reinforce this techno-social divide implicitly, through the strong emphasis on technical subjects, and explicitly through statements such as *"the fundamental skill-set of an engineer... is the capacity to apply mathematical analysis to design problems"* (U4).

Across the 66 programme prospectuses included in this study, 32 listed no modules with a focus that is not technical or scientific in nature. Of the programmes that do list modules or subject areas with non-technically focused titles, the most common subject covered was professional engineering and/or management skills. Thirty-one programmes included at least one of these subjects, and in 14 of these cases it was included only as a first-year topic and was the only instance of a non-technical subject listed in the programme. Eighteen modules focusing on "business" or "entrepreneurship" appeared, while a further 14 mentioned "creativity". Notably there were only six programmes which included more than one non-technical subject in the same academic year, and no program included three or more non-technical subjects. Staff believed that the modules listed in the prospectus play an important role in attracting students to apply for a programme. One member of the marketing staff went so far as to say, "I think the most important thing is to have the modules listed" and "if they see a module that's of interest to them, they're more likely to consider that course" (M1). With module lists being so heavily focused on technical and scientific content, to the near exclusion of all else, this could have a major impact on the students who will be interested in pursuing these programmes.

The focus on technical elements of the profession is reinforced in the images selected for these programmes. Many prospectuses show no images of people, instead choosing to show inanimate objects. In cases where there are people included, many are students examining a piece of technology, or perhaps operating a machine. Not only that, but the objects are often incomplete or taken out of context. The aim seems to be to create an aesthetic of technology. In only one photo across the nine documents did a programme show an image of people benefiting from technology. A selection of these images is shown in Figure 4.2. The potentially misleading nature of these images was brought up by one academic staff member when asked if there were aspects of the prospectus that they were unhappy with. Describing a conversation with a colleague they reported that "someone made the point that the main image on the front of our prospectus from mechanical engineering, the level eight programme, was a set of gears. We actually started laughing when he made the point" (A12). The image in question is included as part of Figure 4.2. However, it was noted that the issue that they had with these images were due to the false impressions that it gave of the type of work that a mechanical engineer does rather than the depersonalising message it conveyed. "It creates a perception that's just wrong because again, people think of you're a mechanic, you know, you're fixing a gearbox or whatever" (A12). As has been discussed in the literature this is a common misconception about engineering and was reported by both staff and student participants.



Figure 4.2: Sample Images Collected in Engineering Programme Prospectuses

4.2.3.3 Non-Engineering Learning

According to the subjects listed in the engineering degree prospectuses, there are limited opportunities for students to study subjects from other disciplines. Beyond the strictly technical, the other major approach is from the business aspect of the profession. This was included in 18 modules across the various institutions. “*You’ll come to understand the design process from concept through to market, and study business as well as design and technology modules*” (TU2).

As was discussed above many engineers now find themselves working in management roles. Conlon (2008) discusses the pressure on graduates to adapt to the needs of an evolving industry. The ever-increasing focus on productivity, driven by modern management methods, causes engineers to treat business concerns as major factors in engineering decisions (see Meiksins, Smith, and Berner, 1996). This was evidenced here, where engineers are described as “*problem-solvers who want to make things work more efficiently, quickly, and less expensively*” (TU1). Similarly, staff members described business and economic skills as “an important skill set for mechanical engineers - knowledge of the issues of economics, of finance and of management as well” (A1).

An engineering degree is considered by some to be a pathway to a career in other areas of business, finance or economics. The inclusion of modules with titles associated with these areas may encourage some students to pursue this route. While it may encourage some students to choose to study engineering, it may be a less effective strategy in the context of an alleged global shortage of engineers¹ (Engineers Ireland, 2023b).

Business activities and management would typically fall into the *enterprising* work environment. Those who work in these kinds of environments have been shown to have a different set of value priorities. These include a positive correlation to *achievement* and *power* and a negative correlation to *universalism*.

A number of programme prospectuses refer to interpersonal, presentation and teamwork skills. These skills are something which staff reported students struggling with at times with statements such as “there’s never any, any question or issue around technical competency. It’s those kinds of soft skills...they weren’t great at putting themselves forward when they were making presentations” (A11). Students also acknowledged that “maybe just advocacy and networking and that sort of stuff” was not a “very common skill in our course” (S1). According to staff this is mostly a historical issue and the inclusion of these skills in so many degree programmes now appears to be an attempt to address this. “Our students actually do quite well at that now” (A7).

The emphasis on teamwork and communication skills in engineering education recruitment material may have two impacts on values. First, for those who recognize the importance of these skills for employability, it represents a *utility* value. These skills are desirable in industry and enhance employability (Conlon, 2008; Murphy, Christensen and Conlon, 2022). Participants reported feedback from companies hosting engineering interns that supports this.

¹ There is some debate as to whether this shortage is real, or an effort by industry to drive down wages by increasing competition for jobs (Bracey, 2008; Salzman, 2013; Harris, 2014; Smith, 2017). However, it was the view of many participants in this study that “there’s a shortage of engineers” (A15), that “we’re not producing enough of them across the country” (A2), and that “there’s not enough electronic engineers in the world for the work that’s there” (A11).

Highlighting professional and social skills in the prospectus shows prospective students that the degree programme addresses industry needs, thereby improving employability.

Secondly, the use of language relating to communication and teamwork highlights the collaborative aspects of engineering which may broaden the appeal for certain applicants. The stereotypical image of an engineer has historically been of an antisocial individual with poor communication skills or as one participant put it, "the usual engineer in the cave tipping away... that cliché of anti-socialness" (A11). Emphasising teamwork and communication as part of engineering may serve to redress this public perception. This may in turn affect the kinds of people who may choose to enrol in an engineering degree, and who might otherwise be deterred by the anti-social stereotype.

4.2.3.4 Cultural Literacy

Elective modules often represent the only opportunity for engineering students to formally study content from other academic areas. Only one institution includes this within the engineering section of their prospectus. Some others do offer an elective, but it doesn't appear anywhere in the engineering section. Instead, it is included elsewhere in the book.

"Similarly, if you are studying Engineering but you like languages and want to study a little Spanish, you could choose your electives in Spanish" (U1).

Within the pages of the engineering section, the only modules mentioned are specialisations within the engineering discipline. In contrast, other departments like the Health Sciences and Humanities frequently integrate subjects from a broader range of fields into their degrees. Law, for instance, is consistently offered with a language option, which includes cultural content from the chosen country, or with subjects that encourage reflection on the profession such as philosophy or sociology. It could be argued that the inclusion of international cultural content being included is a strictly pragmatic or utilitarian decision, and that this is simply a requirement for working in these countries. However, it's notable that many engineering prospectuses also suggest that graduates may choose to work internationally. *"Worldwide recognition"* (U7) is used as a major selling point of individual engineering degrees with multiple institutions highlighting the international employability of their graduates with statements like, *"Irish engineers are recognised in Europe...USA, UK, Canada, Australia, New Zealand, Hong Kong & South Africa"* (TU1). Staff members were aware that this is a factor for some students. "It's a degree that you can travel with, and I think ... students value that" (A2). One participant addressed the issue of "a cultural gap" (A15) in the context of international engineering work. Based on personal experience working internationally, this participant described working cultures which were "less argumentative" and in which "people won't question what older people are doing...because your seniors are always right" (A15) and how this can directly impact engineering work. They believed that to work internationally in engineering "you're going to [need to] have an awareness of working with different groups and different citizens across the world" (A15). Despite this clear recognition that international work is a realistic possibility for engineering graduates, there is no evidence of any course content which supports this cultural enrichment directly. Instead, the course content presented to potential students focuses almost entirely on technical and scientific content.

4.2.4 Is Engineering for Me?

4.2.4.1 Do you love maths?

It almost goes without saying that “*a strong mathematical ability*” (U5) is included in the prospectuses as an important, or even “*essential*” (U5), skill for those in engineering education. One document described it as “*the universal language of engineering*” (U7). Maths, physics, and depending on the specific programme, chemistry and biology are listed among the most desirable aptitudes for a student. For most of the engineering degrees included in this study, the only specific entry requirement is a “*H4 in Mathematics*” (U1), and a “*H6 in a Laboratory Science*” (U1). The “H4” here means a student must receive at least 60% at the higher level of the final state exams in Irish second level education. There are certain exceptions through which students can access an NFQ Level 8 (Honours Bachelors) programme after first completing a Level 7 (Ordinary Bachelors) degree, which may not have the same maths entry requirement. Similar pathways exist in a number of institutions which offer degrees at various levels. A 2015 study found that a significant proportion of students enrolled in a Level 7 course specifically because they had not met the maths requirement and intended to transfer to Level 8 upon completion (Murphy, Chance and Conlon, 2015). A participant explained that “if students meet 70% in maths in their final year of their Level 7, plus they get an average GPA of 50%, they can go on and do the final two years of the Level 8 programme” (A14). So, while their overall academic achievement is taken into account, “maths is the only specific requirement” (A14) considered during the application. In this case, it was explained that the accrediting body for engineering degrees, Engineers Ireland, was responsible for setting this threshold.

In secondary education in Ireland, higher-level maths is broadly considered to be a difficult subject. In 2022 36% of students sat the higher-level paper in the state exams. This has fallen by 4% in 2023 but is still an increase of 13% since 2019 and may be artificially high due to adjustments made to grading in the wake of the Covid-19 pandemic which saw students receive predicted grades. In 2012 only 12% of students sat the higher-level paper which prompted bonus points to be offered to students who sat the higher-level exam. This has a limiting effect on the number of students who have the option to choose engineering and has prompted concern from Engineers Ireland (Engineers Ireland, 2023c). An interview participant pointed out that “there's a shortage of engineers. And [...] you could also argue that there's an issue with maths. There's an issue with the education that we have at an earlier stage” (A15).

The importance of students' feelings towards their ability in maths in their decision to choose engineering was acknowledged by staff members who suggested that a common thought process is “I'm good at maths, I'm good at physics ... and that's generally why they choose engineering” (A13). This is the message that a number of students received while choosing their degree programme. One such student was of the opinion that “a lot of engineers get told that that's what they should do because they're good at... maths” (S6). Staff participants defended the importance of mathematical ability at the recruitment stage and maintained that a “mathematical background is vital... I think that's a skill they do need. And I think if they come in with that, pretty much everything else, I think you can expose them to” (A2). However, research into the inclusion of social concerns into engineering education in the UK suggests that a focus on mathematics and other STEM subjects may be having an unwanted filtering effect. Their participants “suggested that “we're choosing the wrong people to be engineers” and that it was “easier to educate a broad-minded person about calculus” than to “educate a narrow-minded person about social inclusion” (Xavier, Wint and Orbaek White, 2022).

Although this research is based on the UK system, where students specialise earlier, it may still be relevant to the Irish system as, even though Irish secondary students are required to study more subjects their counterparts in the UK, maths and science are still the only required subjects for pursuing an engineering degree. This increases the perception that these subjects represent the core of engineering, and that the social sciences and humanities are irrelevant.

More than just an aptitude, some staff suggested that students would actually need to have "some sort of *grá* [love] for numbers" (A8). It was their belief that "if you didn't like maths... you'd really struggle, even if you were good at it or you understood it... you'd struggle to go through 4 or 5 years of a program... without liking it" (A2). In one case this message was told by a student to a member of the marketing staff who reported "a current student, they said to me, it's not that you have to be the best in your class at maths... it's you would want to really like and love maths... And I thought that was actually a quite a nice way of explaining it" (M2). This same message was told to one participant at an information event for engineering held in his school. During the event the question was asked, "did you need to love maths to be an engineer? And they said, 'yep'. So at that point I decided, 'well, I'm definitely not doing that for my college degree', because I hated secondary school level maths" (S11). This participant has since found himself in a successful engineering career and has only now returned to education to pursue an engineering masters. They have found that "in engineering practice... you do not need to love maths" (S11). Several participants expressed the view that "maths is just something that [they] have to do in order to be able to do the rest of [engineering]" (S6).

Some staff believed that the level of maths required is overstated. "There's all this stuff that engineering is all about maths... the irony of it is it's not really all about maths because... the level of maths that we actually use is relatively intermediate I think for most things" (A4). Another course director said that their programme had "dropped the honours maths stipulation to get into the Level 8 because we were finding it hard to get students" (A11). This degree is offered in a technological university within the same city as a larger university and so they found themselves in direct competition for students. The number of students enrolling has increased since this requirement was removed, even though it has meant that the programme is no longer accredited by Engineers Ireland. However, the programme director believes that this has had relatively little effect on the quality of graduates citing their "100% employment rate" (A11). Participants believed that "there are probably talented kids that could have been great engineers but don't go into it" (S11) as a result of the maths requirement and that instead "you get those people who did it because they were good at maths or physics, but actually didn't really have any interest in how things work, or maybe weren't actually that mechanically minded." (S11). The focus on maths potentially obscures the relevance of skills and aptitudes such as creativity (discussed further below). While maths is a creative discipline, the school experience of maths in Ireland does not appear to convey this (Schoenfeld, 1989; Prendergast *et al.*, 2018). Another described a peer for whom "the engineering is secondary, the maths is what he actually loves about it" (S6).

Other participants sought to minimise the effect that the maths requirement has on student intake. "I think for those that want to be engineers, for the most part understand that, you know, it's mathematical based... And I don't think [the level of maths] is off-putting to someone who really wants to be an engineer, I suppose is the best way to put it" (A8). Another offered a similar opinion, basing their claim on a relatively recent increase in the maths requirement to enter their Level 8 engineering degree. "What we found is that pretty much the same calibre of student that initially met the 60%... made the jump. Whatever height you put the jump at, if

a student wants it, they will attain it" (A14). However, it's worth considering whether this perspective might be influenced by an element of survivorship bias, as it primarily reflects the experiences of those who succeeded in meeting the increased requirements.

Having mathematical ability acting as a filter to incoming students affects the skill sets which students arrive into university with. Staff participants noticed a trend among students who struggle with open ended, loosely defined problems. They discussed how "they don't necessarily like not having *the* correct solution" (S6) and "that students possibly just want an answer. They just want to get the thing done" (A15). This participant believed that this could be attributed directly to the students' second level education. "They've come out of the Leaving Cert. And there's always a nice, simple equation that you plug a few numbers into, and they want to plug those numbers into the equation" (A15). This echoes findings from Xavier et. al. (Xavier, Wint and Orbaek White, 2022) who found that students struggled to engage with ambiguity and uncertainty in their work.

4.2.4.2 Are you logical?

Engineers as logical people, and engineering as a logical process is mentioned throughout the prospectuses. It is described in terms of a repeatable process, something akin to the scientific method. In these instances, it is described as one of "*the skills needed to be a good... engineer*" (U4) On the other hand, "*A logical mind*" is also described as "*an important quality*" (U7), which gives the impression that it is an inherent trait in a candidate. Similarly, staff counted "a logical brain" (A14) among the most desirable traits for an incoming student.

The prioritisation of logic like this, supports the arguments made by others (Hacker, 1981; Faulkner, 2000; Riley, 2008; Cech, 2014a) that engineers see their profession as one that deals purely in factual, rational and scientific terms, rather than the less concrete or definitive types of knowledge which are present in other disciplines.

4.2.4.3 Are you creative?

There are numerous mentions of engineers as creative people in the prospectus documents, and frequently "creative" or "creativity" is used alongside "problem-solving". In some cases an institution will use the word to describe its graduates, and claims to instil creativity in students, while in others, creativity is seen as a trait which incoming students should possess. As mentioned above, 14 programmes include a module which includes "creativity" in the title. Staff stressed that "for engineers you always need to have a strong creative side" (A5). Students generally agreed stating "I think you can't really be a good engineer without having creativity" (S2).

Arieli & Sagiv (2020) identified a series of papers which show a pattern of correlation between creativity and values related to *openness-to-change*. These included specific positive correlations to *self-direction* and *stimulation*. The corresponding negative correlations between creativity and the *conservation* values of *security*, *tradition* and *conformity* have also been shown to be significant (Rice, 2006; Dollinger, Burke and Gump, 2007; Kasof et al., 2007; Sousa and Coelho, 2011). This is consistent with other work which has shown prioritising *Self-direction* to be among the highest priority values for engineers and investigative professions in general (Knafo & Sagiv, Arsenijević, Bulatović, & Bulatović, 2012).

The correlation between creativity and the values of *self-enhancement* and *self-transcendence* has been investigated though the results are more varied (Sousa & Coelho 2011). One student believed that "there's also a huge overlap of people in engineering who also have very interesting creative outlets though, as in they do really brilliant art or sewing or

painting, and they tend to be a bit... less grade focused" (S4). This would appear to contradict some literature which has found that creative people are often motivated by *achievement* (Mumford 2000; Sousa & Coelho, 2011). On the other hand, Sousa & Coelho (2011) found a positive correlation between creativity and the higher order values of *self-enhancement*. They suggested that a creative person is willing to commit time and effort to develop and practice new skills (Mumford, 2000).

4.2.4.4 Women in engineering

Women are an underrepresented group in engineering (Fouad and Singh 2018; Frueh 2014; Glass et al. 2013) and their sense of identity as engineers is likely to be more fragile than that of their male counterparts (Faulkner 2007). Irish universities are "actively trying to recruit more female students into the engineering cohort" (M1). Among the images included in these documents, female students are over-represented, relative to the actual proportion generally registered in engineering programmes (for example, approximately 30% of current engineering students at University College Dublin are female). This is consistent with efforts to increase the number of women in engineering by increasing the visibility of female engineers and "get across that there's a...better gender balance within engineering than people normally think" (M1). Staff believed that one of the primary concerns of female students was that they would be "in a class where they're the only girl in their class" (M1). The slogan "if you can't see it you can't be it" (M2) was referenced by another staff member. To increase visibility the strategies involved "targeting specifically girls' schools for promotional events" (A6), including visits from female engineering professors and students. In the case of any kind of information request from an all-girls school, staff "make them a priority" (M1). There are also efforts made to achieve a gender balance in recruitment and information events. One institution runs "a week-long event called Engineering Your Future... and we've really good conversion rates from [that] as well and we'll make sure when we take those 60 students in, that we have a [gender] split of 50, 50 as far as, as much as possible" (M2).

One institution's prospectus includes details of a scholarship which is awarded to a female student each year. The scholarship is awarded to the "female candidate who demonstrates the highest overall grade in her first-year university exams in engineering" (U6). The possibility of earning a scholarship based on academic performance may appeal to someone who places importance on *achievement*, while the financial reward may offset some of the perceived cost of pursuing an engineering degree (Eccles 2005; Matusovich 2013). However, it has been observed that students with low *attainment* beliefs, meaning that they do not easily identify with belonging in a group, generally have lower competence beliefs (Matusovich et al., 2008; Matusovich et al., 2009b, 2009a). The common feeling of "imposter syndrome" (S12) among female students reported by participants coincided with them "not having confidence in their abilities" (S12). In a field where female students generally have a more fragile sense of identity as an engineer, the possibility that they may earn this scholarship may appear less attainable and therefore offer less of an incentive than it might to a male student.

This scholarship was included in a specific "*Women in Engineering*" section and came with the tagline "*Become a Trailblazer*" (U6). While the inclusion of female students in imagery and testimonials serves to normalise the idea of women in engineering, this example presents a different approach. The use of the word "trailblazer" highlights that female students will be in the minority but frames this as a positive. This word has daring and rebellious connotations and challenges the prospective students to be at the forefront of change. This type of messaging appeals to values in the *openness-to-change* region of the Schwartz value system,

in particular *self-direction* and *stimulation*, while actively working against the *conservation* values of *tradition* and *conformity*.

This pioneering, risk-taking image is tempered somewhat in the text, which discusses the university's "*proud tradition*" (U6) producing female engineers and the general demand for qualified engineers in the workplace. As discussed above, highlighting "*well-paid opportunities*" and the "*unprecedented demand for talent*" speaks to the utility of an engineering degree and to the personal value of *security*. These points appeal to the utility of pursuing an engineering degree. As discussed by Matusovich (2018) having a weaker sense of identification with a discipline, means that a student will require significantly higher utility values in order to persist.

Canney (2013) determined that female students were more likely to have higher levels of social responsibility, and others have found that women are more likely to cite the good they can do for others when discussing their choice and persistence in an engineering career (Bielefeldt & Canney 2018; Buse, Bilimoria, and Perelli 2013; Bystydzienski and Brown 2012; Hewlett et al. 2008; Meyers and Mertz 2011; Niles et al., 2020; Skatova et al. 2014). Similarly, there was a perception among participants in this study, both male and female, that female students would be drawn to the opportunity to help others in an engineering career, than their male peers. In the context of biomedical engineering consistently having the highest proportion of female students compared to other engineering programmes, one student suggested "that human benefit that [they're] anticipating at the end is something that appeals more to women", and that perhaps as a result of "the more traditional gender roles that are imparted upon women ... in our society... there's a more nurturing tendency there" (S11). A female biomedical engineering professor also thought that the motivation was "to do... your societal good" (A7). The belief expressed was that this is the primary motivator and acts as "a carrier. Then the engineering comes in behind it" (A7)

However, a survey of female Irish secondary school students found that a "good work-life balance" and a "high salary" were rated as the two most important work-related values while "Contributing to the world we live in" was ranked 4th (I Wish 2023). It appears that this particular prospectus section has decided to appeal directly to the highest rated values of the prospective students.

4.3 Survey Results

This section will examine the value profiles of new entrants to the engineering programmes at one Irish university. Presented here are the results of a survey conducted among first-year students in the College of Engineering and Architecture at University College Dublin (UCD), from November 2021 to January 2022. This set of results for these students will be referred to as "Eng1" throughout this discussion. This is the largest engineering department in the Republic of Ireland, offering approximately 330-340 places to students in the first-year general entry program annually (M2). Examining the value profiles and social engagement scores of these students provides a snapshot of the values which are being recruited into engineering education. Students enrolled in the Schools of Nursing and Law at UCD were also sampled during this time. The value profiles of the nursing and law students in the first year of their degrees, as well as the data retrieved from the ESS results for 2021 (ESS ERIC, 2022) for Irish 18- and 19-year-olds provide a point of comparison for the results from the engineering students. These groups will be referred to as "Nurse 1", "Law 1", and "ESS 1" respectively. Engineering Students

4.3.1.1 Personal Value Profile

The mean value profile of 1st year engineering students can be seen in Figure 4.3 along with the mean scores for each value. These are the within-individual centred scores, calculated by subtracting an individual's mean response to all survey questions from each of their individual value scores, and then adding 3.5 to re-centre the values on the original 1-6 scale. This is recommended in order to highlight the relative importance of values rather than the absolute value (Schwartz, 2016; Sandy *et al.*, 2017; Rudnev, Magun and Schwartz, 2018).

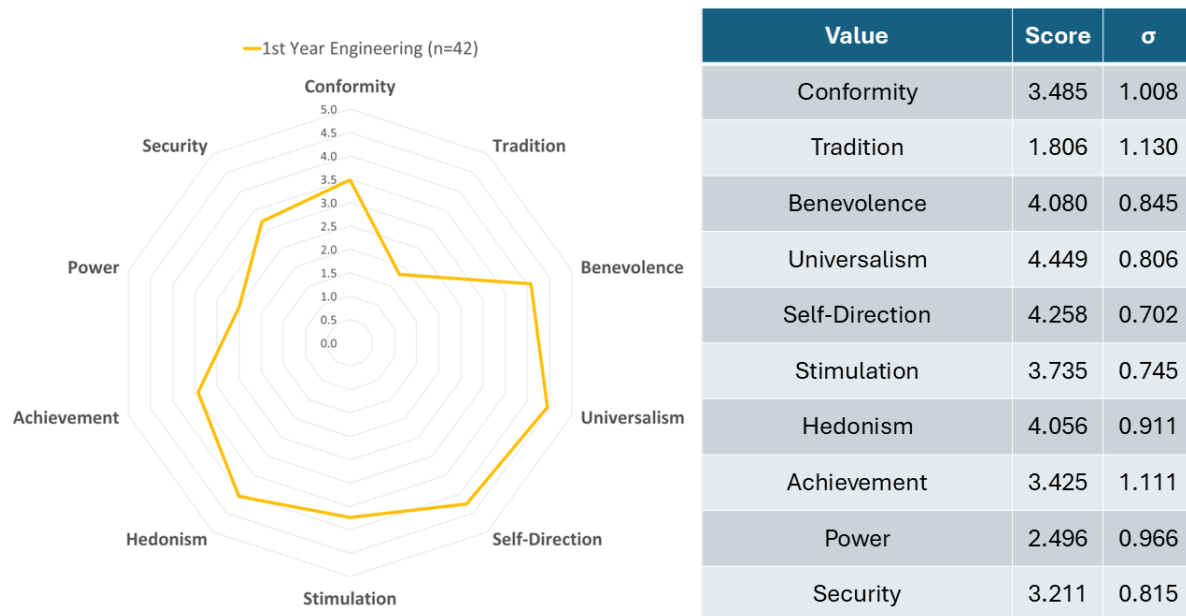


Figure 4.3: 1st Year Engineering Students Mean Schwartz Values

The higher order value priorities of each individual were also calculated by taking an average of the individual values which contribute to a given higher order value. These too used the centred scores. These values were then used to plot each individual along the dual axes of *self-enhancement/self-transcendence* and *openness-to-change/conservation*. This was done by subtracting an individual's *self-enhancement* score from their *self-transcendence* score and their *conservation* score from their *openness-to-change* score. The resulting scatter-plot can be seen in Figure 4.4.

The results are largely grouped in the *openness-to-change/self-transcendence* quadrant of the plot. Of the 42 first-year engineering students surveyed, 29 fall within this quadrant. Nine first-year engineering students scored more highly for *self-enhancement* than *self-transcendence*, while four favoured *conservation* over *openness-to-change*. None of this group of students favoured both *conservation* and *self-enhancement*, meaning the bottom left quadrant of Figure 4.4 is empty.

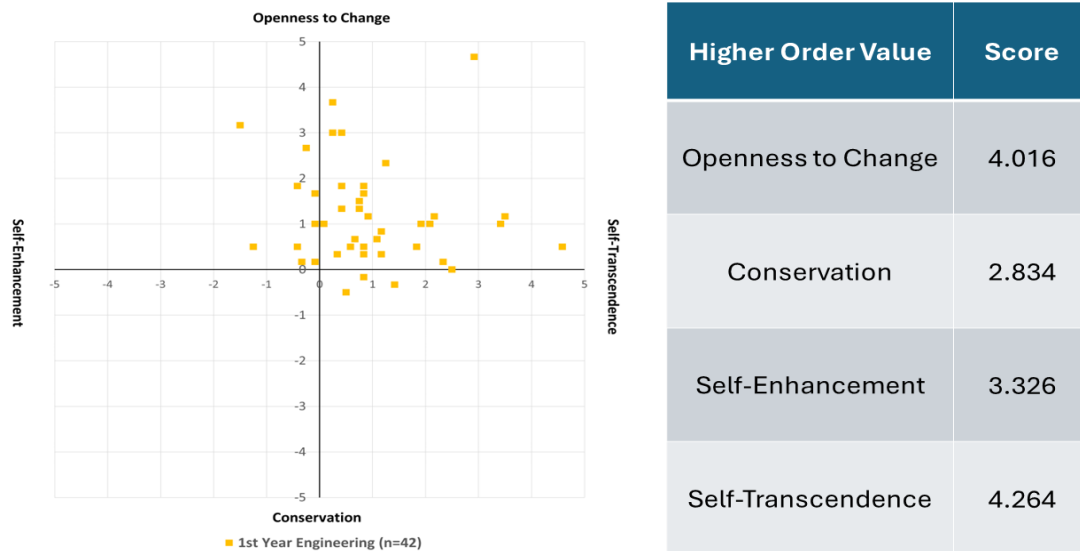


Figure 4.4: 1st Year Engineering Students Higher Order Value Priorities

4.3.1.2 Social Engagement Metrics

The response of first-year engineering students to the social engagement survey is discussed here. Figure 4.5 shows the mean scores of students in their first year an engineering degree for each of the ten items measured by the survey as well as the three calculated scores. These calculated scores, referred to here as “programme focus mean”, “career mean” and “personal social consciousness” are calculated by taking the mean response from each participant to the individual questions which make up that portion of the survey.

It is important to note that while all measures are shown in the same graph here, the items in the first section, relating to programme focus, are scored out of four, while all other survey items were scored out of five. This is in line with the original work by Erin Cech (2010, 2014) from which this survey was derived.

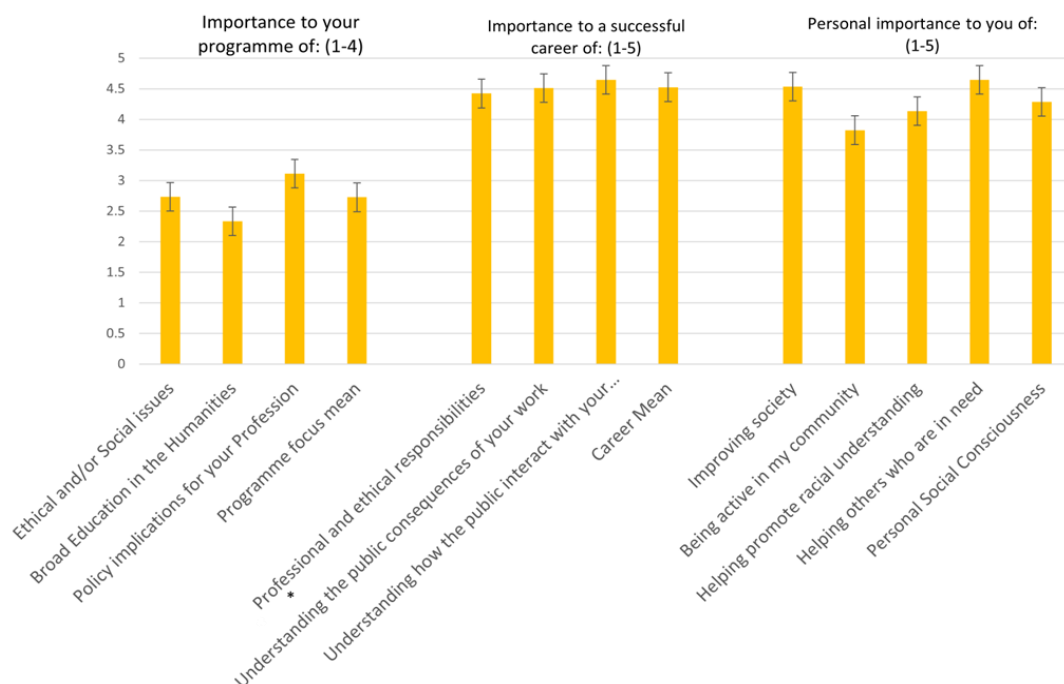


Figure 4.5: 1st Year Engineering Students Social Engagement Metrics

4.3.2 Gender Differences

Within the first-year engineering student cohort, the value scores of participants were examined for differences between male and female participants. Existing literature points to a number of differences between male and female students with respect to their personal values and their attitudes towards social and ethical problems, as well as their motivations for choosing engineering (Bielefeldt & Canney 2018; Buse, Bilimoria, and Perelli 2013; Bystydzienski and Brown 2012; Hewlett et al. 2008; Meyers and Mertz 2011; Niles et al., 2020; Lucena, 2013; Skatova et al. 2014). The value profiles of male and female engineering students were compared to assess the role of gender in the mean value profiles of the sample.

1 st Year (All)	She/Her	He/Him
Universalism	Universalism	Self-Direction
Self-Direction	Self-Direction	Universalism
Benevolence	Hedonism	Hedonism
Hedonism	Benevolence	Benevolence
Stimulation	Achievement	Stimulation
Conformity	Stimulation	Conformity
Achievement	Conformity	Achievement
Security	Security	Security
Power	Power	Power
Tradition	Tradition	Tradition

Figure 4.6: Mean Value Priorities of 1st year Engineering by Gender

The mean Schwartz value scores of male and female first-year engineering students were compared. Figure 4.6 shows the ordinal value rankings of each group. It was found that the mean female engineering student prioritised *achievement* more highly than their male counterparts. For female students it was ranked 5th while male students ranked it in seventh, behind *conformity* and *stimulation*. The other notable difference is that *universalism* is the most highly rated value among female first-year engineering students, with *self-direction* being ranked in second place. These two value priorities were inverted among their male peers.

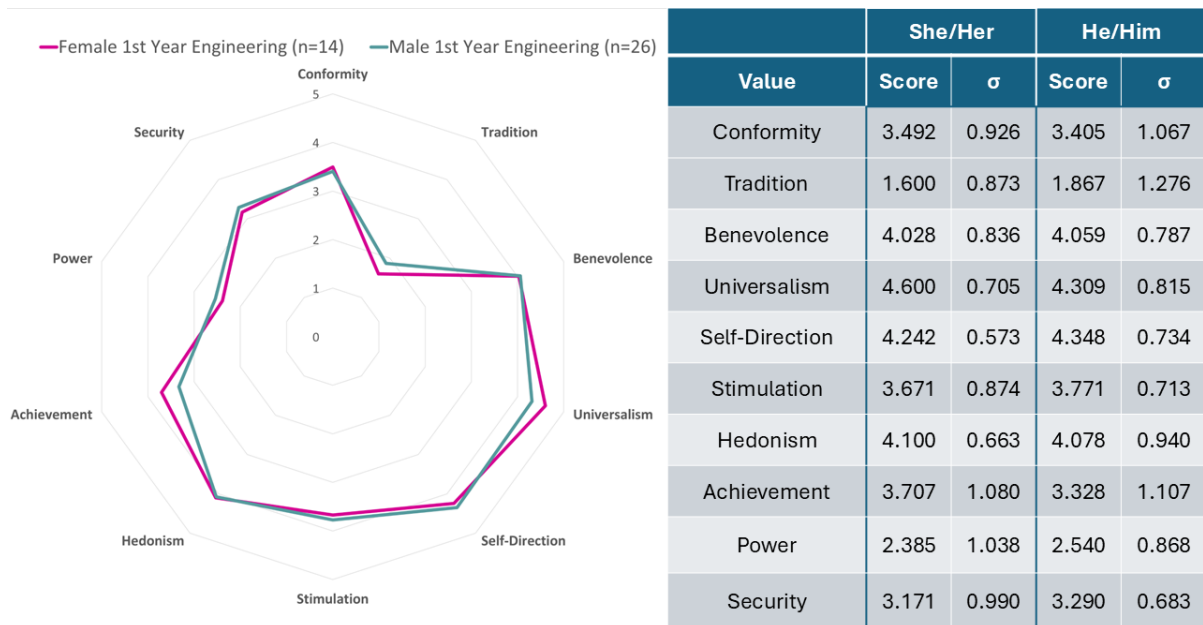


Figure 4.7: 1st Year Students Mean Schwartz Values by Discipline

While these differences exist in the ordinal rankings, the mean value profile of each group is largely similar. Figure 4.7 shows a comparison of these mean value profiles. When the numerical scores are examined the differences in mean value scores between male and female engineering students appear insignificant. The largest detected difference between both groups was in the scores for *achievement*, however this score also had a large variance among both the male and female cohorts ($M_{\text{Male}}=3.33$, $SD_{\text{Male}}=1.11$; $M_{\text{female}}=3.71$, $SD_{\text{female}}=1.08$). An independent t-test determined that this difference is not significant, and the effect size is small ($t_{\text{achievement}}(38)=1.04$, $p>0.05$, $d=0.345$).

The difference in mean scores for *universalism* and *self-direction* were similarly deemed to be minor. T-tests were carried out to compare the value scores of male and female engineering students in the first year their degree program. The results of these tests can be seen in Table 4.1. In none of these tests did the calculated t value exceed the t_{cv} . The differences in mean scores for all 10 of the personal values in the Schwartz value system between male and female students were determined to be insignificant.

Table 4.1: Schwartz value t-test: Male and Female Engineering Students

	Conformity	Tradition	Benevolence	Universalism	Self-Direction	Stimulation	Hedonism	Achievement	Power	Security
Mean (Male)	3.41	1.87	4.06	4.31	4.35	3.77	4.08	3.33	2.54	3.29
SD (Male)	1.07	1.28	0.79	0.82	0.73	0.71	0.94	1.11	0.87	0.68
Mean (Female)	3.49	1.60	4.03	4.60	4.24	3.67	4.10	3.71	2.39	3.17
SD (Female)	0.93	0.87	0.84	0.70	0.57	0.87	0.66	1.08	1.04	0.99
DoF	38	38	38	38	38	38	38	38	38	38
α	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
t_{cv}	2.048	2.048	2.048	2.048	2.048	2.048	2.048	2.048	2.048	2.048
t	-0.257	0.699	0.116	-1.124	0.465	0.390	-0.075	-1.039	0.502	0.448
Cohen's d	0.09	0.24	0.04	0.38	0.16	0.13	0.03	0.35	0.16	0.14

As relative importance of values is as important as the absolute scores, the differences which are evident in the ordinal rankings were specifically examined, namely the relative positions of *self-direction* and *universalism*, and *achievement*, *stimulation* and *conformity*. To assess these, a “difference score” was calculated by subtracting each individual's *universalism* score from their *self-direction* score. A t-test was then carried out to determine if there was a significant difference between the mean difference score for male and female 1st year engineering students. This process was then repeated for each of *achievement & stimulation*, and *achievement & conformity*. The results can be seen in Table 4.2. In none of these tests did the t value exceed the critical value, and so no significant differences were found.

Table 4.2: Value Difference Scores among 1st Year Engineering Students by Gender

	Self Direction - Universalism	Achievement - Stimulation	Achievement-Conformity
Mean Male 1st year Engineer	0.03846	-0.44231	-0.07692
SD (Male 1 st year Engineer)	0.706018	1.416523	1.622913
Mean Female 1 st year engineering	-0.35714	0.03571	0.21429
SD (female 1 st year engineer)	0.841897	1.322356	1.450654
DoF	38	38	38
α	0.05	0.05	0.05
t_{cv}	2.048	2.048	2.048
t	1.580	-1.041	-0.561
Cohen's d	-0.495015732	0.352921013	0.192820563

Similarly, only very minor differences were recorded in the social engagement metrics recorded by male and female first-year engineering students. Figure 4.8 shows the mean score for each of the ten items measured by the survey as well as the three calculated scores. In terms of programme focus, the mean response from female students was marginally higher for the perceived programme focus on “ethical and social issues” and “a broad education in the humanities”, while male students rated “policy implications for your profession” slightly higher on average. The results in the second category, “importance to a successful career” are similarly ambiguous with no difference in responses being beyond the expected error. In the final category, “personal importance of”, female students scored more highly in each of the individual measures. However, the mean personal social consciousness difference still appears small.

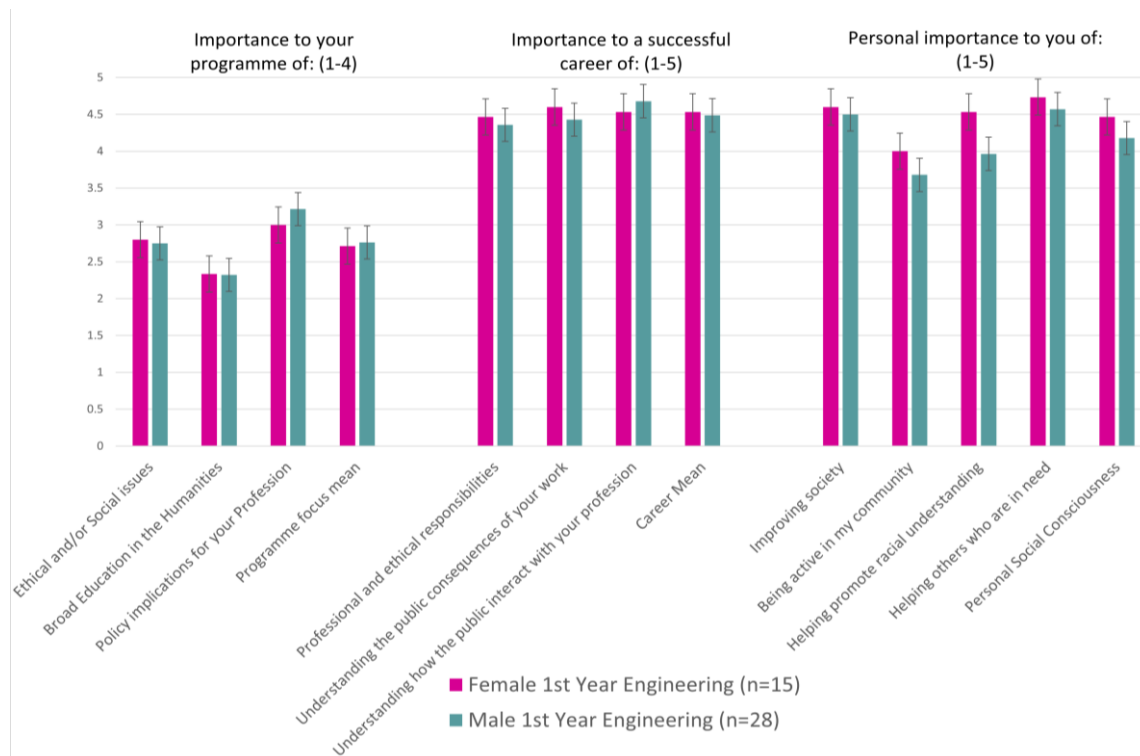


Figure 4.8: Social Engagement Metrics: 1st year engineering students by gender

An independent t-test of the mean responses to each of the thirteen metrics measured here, among male and female first-year engineering students revealed no significant differences. The calculations for these can be seen in Table 4.3. While none of the differences were significant, a medium effect size was detected for personal social consciousness. The medium and small effect sizes for three of the four contributing metrics to this may indicate that a larger sample size could detect a difference here.

In the following sections new entrants to nursing and law programmes are used as a point of comparison to give some context to the values and social engagement scores of engineering students. These degree programmes have significantly larger proportions of female students. However, as no significant difference was detected between male and female engineering students, for any of the measures being tested, gender can be eliminated as a confounding factor in this study going forward.

Table 4.3: Social Engagement Scores among 1st Year Engineering Students by Gender t-tests

	Importance to your program of:				Importance to a successful career of:				Personal importance to you of:				
	ethical and/or social issues	edu. in hum. & soc. sci.	policy implications	Program Mean	Prof. & ethical responsibility	public consequence	public interaction	Career Mean	Improving society	active in community	promote racial understanding	Helping those in need	Personal Mean
Mean Male	2.750	2.321	3.214	2.762	4.357	4.429	4.679	4.488	4.500	3.679	3.964	4.571	4.179
SD (Male)	0.887	0.905	0.917	0.666	0.678	0.790	0.670	0.517	0.745	1.020	1.105	0.573	0.623
Mean Female	2.800	2.333	3.000	2.711	4.467	4.600	4.533	4.533	4.600	4.000	4.533	4.733	4.467
SD (Female)	0.775	0.816	0.756	0.576	0.640	0.828	0.640	0.485	0.632	0.845	0.640	0.458	0.410
DoF	41	41	41	41	41	41	41	41	41	41	41	41	41
α	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
t_{cv}	2.021	2.021	2.021	2.021	2.021	2.021	2.021	2.021	2.021	2.021	2.021	2.021	2.021
t	0.184	0.042	-0.774	-0.249	0.514	0.667	-0.688	0.279	0.441	1.042	1.831	0.944	1.609
Cohen's d	0.059	0.014	-0.248	-0.080	0.165	0.213	-0.220	0.089	0.141	0.333	0.586	0.302	0.515

* t value exceeds t_{cv}

4.3.3 External Comparisons

4.3.3.1 Personal Value Profiles

The mean value profiles of students enrolled in their first year study in the schools of nursing and law at UCD were assessed. These results, along with the results of Irish eighteen and nineteen year olds from the ESS, were added to a comparative polar plot and can be seen in Figure 4.9. These figures again use the within-individual centred scores.

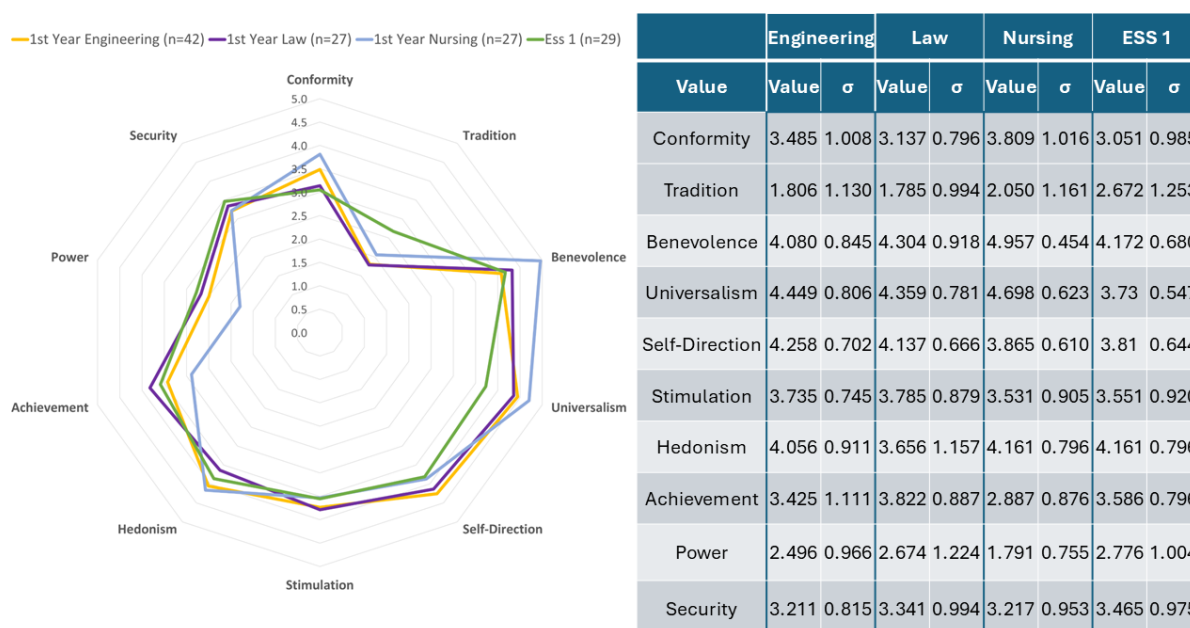


Figure 4.9: 1st Year Students Mean Schwartz Values by Discipline

Independent t-tests were carried out comparing the mean scorers of first-year engineering students for each value to those in the Law 1, Nurse 1 and Ess1 groups. Table 4.4 shows the results of the comparison with the ESS1 cohort. The results here show that the Eng1 group prioritised the value of *universalism* significantly more highly than those in the ESS1 cohort, with a large effect size ($t_{\text{universalism}(69)} = 4.181$, $p > 0.05$, $d = 1.044$). The same is true in relation to *self-direction*, but with a medium effect size ($t_{\text{self-direction}(69)} = 2.733$, $p > 0.05$, $d = 0.665$). Eng1 students also scored significantly lower than the ESS1 group for *tradition* ($t_{\text{tradition}(69)} = -3.036$, $p > 0.05$, $d = 0.726$).

Table 4.4: Schwartz value t-test: 1st Year Engineering Students and ESS1

	Conformity	Tradition	Benevolence	Universalism	Self-Direction	Stimulation	Hedonism	Achievement	Power	Security
Mean Engineer	3.485	1.806	4.080	4.449	4.258	3.735	4.056	3.425	2.496	3.211
SD (Engineering)	1.008	1.130	0.845	0.806	0.702	0.745	0.911	1.111	0.966	0.815
Mean (ESS1)	3.051	2.672	4.172	3.730	3.810	3.551	3.862	3.586	2.776	3.465
SD (ESS1)	0.985	1.253	0.680	0.547	0.644	0.920	0.758	0.796	1.004	0.975
DoF	69	69	69	69	69	69	69	69	69	69
α	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
t_{cv}	2	2	2	2	2	2	2	2	2	2
t	1.796	-3.036*	-0.489	4.181*	2.733*	0.924	0.943	-0.670	-1.178	-1.194
Cohen's d	0.435	-0.726	-0.120	1.044	0.665	0.219	0.232	-0.167	-0.283	-0.283

* t value exceeds t_{cv}

Table 4.5 shows the results of the comparison with law students. No significant difference was detected between any of the mean values of engineering and law first-year students.

Table 4.5: Schwartz Value t-test: 1st Year Engineering and Law Students

	Conformity	Tradition	Benevolence	Universalism	Self-Direction	Stimulation	Hedonism	Achievement	Power	Security
Mean Engineer	3.485	1.806	4.080	4.449	4.258	3.735	4.056	3.425	2.496	3.211
SD (Engineering)	1.008	1.130	0.845	0.806	0.702	0.745	0.911	1.111	0.966	0.815
Mean (Law)	3.135	1.783	4.302	4.357	4.135	3.783	3.672	3.820	2.672	3.339
SD (Law)	0.797	0.996	0.917	0.781	0.664	0.879	1.158	0.888	1.225	0.994
DoF	67	67	67	67	67	67	67	67	67	67
α	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
t_{cv}	2	2	2	2	2	2	2	2	2	2
t	1.520	0.085	-1.030	0.465	0.726	-0.247	1.534	-1.555	-0.664	-0.585
Cohen's d	0.375	0.021	-0.254	0.115	0.179	-0.061	0.378	-0.384	-0.164	-0.144

Table 4.6 shows the results of independent t-tests comparing the mean values of first-year engineering students with those of their peers studying nursing. A number of significant differences were found here. The largest of these was in the relative benevolence values where the engineering students sampled scored significantly lower than their nursing counterparts with a large effect size ($t_{\text{benevolence}}(67) = -4.947$, $p > 0.05$, $d = 1.293$). For the values of *power*, *achievement* and *self-direction* engineering students scored significantly higher than nursing students. The largest difference here was detected in *power* where $t_{\text{power}}(67) = 3.214$, $p > 0.05$, $d = 0.814$. This test also revealed a large effect size. Medium effect sizes were detected for the scores in *self-direction* and *achievement* with $t_{\text{self-direction}}(67) = 2.389$, $p > 0.05$, $d = 0.598$ and $t_{\text{achievement}}(67) = 2.125$, $p > 0.05$, $d = 0.538$.

Table 4.6: Schwartz Value t-test: 1st Year Engineering and Nursing Students

	Conformity	Tradition	Benevolence	Universalism	Self-Direction	Stimulation	Hedonism	Achievement	Power	Security
Mean Engineer	3.485	1.806	4.080	4.449	4.258	3.735	4.056	3.425	2.496	3.211
SD (Engineering)	1.008	1.130	0.845	0.806	0.702	0.745	0.911	1.111	0.966	0.815
Mean (Nurse)	3.809	2.050	4.957	4.698	3.865	3.531	4.161	2.887	1.791	3.217
SD (Nurse)	1.016	1.161	0.454	0.623	0.610	0.905	0.796	0.876	0.755	0.953
DoF	67	67	67	67	67	67	67	67	67	67
α	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
t_{cv}	2	2	2	2	2	2	2	2	2	2
t	-1.302	-0.866	-4.947*	-1.365	2.389*	1.015	-0.491	2.125*	3.214*	-0.028
Cohen's d	0.321	0.213	1.293	0.346	0.598	0.245	0.123	0.538	0.814	0.123

* t value exceeds t_{cv}

The ordinal rankings of these values were also examined according to the mean score each value received within each group. Figure 4.10 shows the results of this ranking. There are some commonalities across the groups. For instance, *power* and *tradition* are ranked in the last two positions by each group, albeit the order is inverted among nursing students. At the other end of the scale, *universalism*, *self-direction* and *benevolence* are ranked as a relatively high priority by all participants, though again the order varies.

Based on these lists, a number of pairs of values were identified as being prioritised differently by different groups. To determine if the relative importance of these values was significantly different between groups, the difference score for each pair was calculated, by subtracting the second value listed from the first, and an independent t-test was conducted to compare the mean difference scores within each of the groups. A negative mean difference here indicates that the second listed value is more highly prioritised for a given group. The t-tests were carried out such that a positive t value indicates that the mean difference score is higher among Eng1 students than the compared group. A negative t value indicates that the mean difference score for Eng1 students is smaller. The pairs chosen for further analysis were as follows: *self-direction* & *benevolence*, *universalism* & *benevolence*, *benevolence* & *hedonism*, *hedonism* & *achievement* and *achievement* & *conformity*. Table 4.7 shows the results of these tests.

Engineering	Nursing	Law	ESS 1
Universalism	Benevolence	Universalism	Benevolence
Self-Direction	Universalism	Benevolence	Hedonism
Benevolence	Hedonism	Self-Direction	Self-Direction
Hedonism	Conformity	Achievement	Universalism
Stimulation	Self-Direction	Stimulation	Achievement
Conformity	Stimulation	Hedonism	Stimulation
Achievement	Security	Security	Security
Security	Achievement	Conformity	Conformity
Power	Tradition	Power	Power
Tradition	Power	Tradition	Tradition

Figure 4.10: Mean Value Priorities of 1st Year Students & ESS 1 according to survey data

Table 4.7: Value Difference Scores among 1st Year Students by Discipline

Value Pair	Self Direction - Benevolence			Universalism - Benevolence			Benevolence - Hedonism			Achievement - Conformity			Hedonism - Achievement		
Mean diff. (Engineer)	0.179			0.369			0.024			-0.060			0.631		
SD (Engineer)	1.087			0.789			1.343			1.586			1.510		
	Nurse 1	Law 1	ESS 1	Nurse 1	Law 1	ESS 1	Nurse 1	Law 1	ESS 1	Nurse 1	Law 1	ESS 1	Nurse 1	Law 1	ESS 1
Mean diff. (other)	-1.093	-0.185	-0.362	-0.259	0.037	-0.443	0.796	0.685	0.310	-0.926	0.685	0.534	1.278	-0.185	0.276
SD (other)	0.694	1.030	0.885	0.468	0.970	0.749	0.963	1.346	0.749	1.597	1.272	1.316	1.682	0.944	1.074
DoF	67	67	69	67	67	69	67	67	69	67	67	69	67	67	69
α	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
t_{cv}	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
t	5.404*	1.385	2.218*	3.732*	1.558	4.202*	-2.588*	-1.966	-1.041	2.209*	-2.051*	-1.660	-1.987	2.095*	1.089
Cohen's d	1.394	0.344	0.545	0.969	0.375	1.011	-0.661	-0.492	-0.263	0.544	-0.518	-0.408	-0.514	0.511	0.271

* t value exceeds t_{cv}

Figure 4.10 shows that the engineering students are the only cohort to prioritise *self-direction* more highly than *benevolence*. The t-tests carried out indicated that the mean difference score between these two values for engineering students is significantly larger than that of Nurse1 students with a large effect size ($t(67) = 5.404$, $p > 0.05$, $d = 1.333$). The same is true of the comparison between Eng1 students and the ESS1 group ($t(69) = 5.404$, $p > 0.05$, $d = 0.545$). When compared to law students, engineering students did on average prioritise *self-direction* over *benevolence* more, though the difference in mean difference scores was not statistically significant, and the effect size was small ($t(67) = 1.385$, $p > 0.05$, $d = 0.0342$).

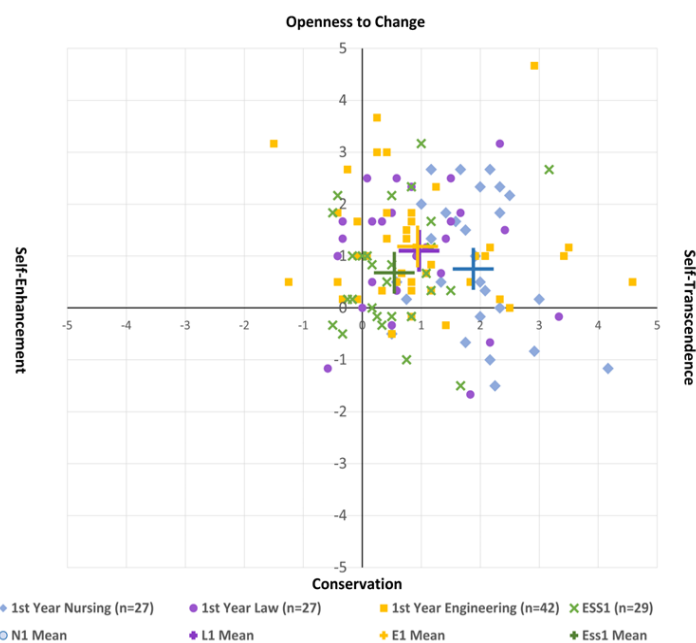
For the *universalism/benevolence* pairing, the same pattern was found. Engineering students prioritised *universalism* over *benevolence* by more than both of their peer groups and the ESS1 cohort, though the difference in mean difference score was only significant when compared to nursing students ($t(67) = 3.732$, $p > 0.05$, $d = 0.703$) and the ESS1 group ($t(69) = 4.202$, $p > 0.05$, $d = 1.011$).

Comparing the mean difference scores for *benevolence* and *hedonism* between Eng1 and Law1 students approached significance ($t(67) = -1.996$, $p > 0.05$, $d = 0.492$). While it did not exceed it, the effect size was medium, potentially indicating that among a larger sample, a significant difference may be found though in this case the null hypothesis could not be rejected. However, the mean difference score for the Eng1 group was significantly lower than for Nurse1 ($t(67) = -2.588$, $p > 0.05$, $d = 0.638$). These results indicate that nursing and law students prioritise *benevolence* over *hedonism* to a greater extent than engineering students, with a significant difference only in the case of nursing students.

When examining the *achievement/conformity* pairing, significant differences were found with both Law1 students ($t(67) = -2.051$, $p > 0.05$, $d = 0.506$) and the Nurse1 group ($t(67) = 2.209$, $p > 0.05$, $d = 0.545$). While both are significant the differences are in opposing directions. In this case the mean Eng1 score for both of these values are close to the centre of the scale with a relatively large standard deviation. No significant difference was found between the mean difference scores of Eng1 students and the ESS1 cohort.

In the case of the *hedonism/achievement*-tests, the mean difference score of Eng1 students again fell between that of the Nurse1 and Law1 groups. In this case the comparison with Nurse1 students found that the mean difference score of Eng1 students for these two values was lower than that of Nurse1 students. The t value approached, but did not exceed the critical value ($t(67) = -1.987$, $p > 0.05$, $d = 0.490$). This again had a medium effect size and so a larger sample size may have found significance here. Eng1 students rated *hedonism* significantly higher than *achievement* relative to law students with a medium effect size ($t(67) = 2.095$, $p > 0.05$, $d = 0.517$). No significant difference was found between the Eng1 and ESS1 groups for this value pairing.

4.3.3.2 Higher Order Values Between Disciplines



Engineering	Openness to Change	Conservation
Self-Transcendence	29 (69%)	4 (9.5%)
Self-Enhancement	9 (21.4%)	0
Law	Openness to Change	Conservation
Self-Transcendence	18 (66.7%)	5 (18.5%)
Self-Enhancement	3 (11.1%)	1 (3.7%)
Nursing	Openness to Change	Conservation
Self-Transcendence	19 (70.4%)	8 (29.6%)
Self-Enhancement	0	0
ESS 1	Openness to Change	Conservation
Self-Transcendence	14 (48.3%)	8 (27.6%)
Self-Enhancement	5 (17.2%)	2 (6.9%)

Figure 4.11: 1st Year Students Higher Order Value Priorities

The higher order value priorities for each participant in their first year of each discipline were calculated by, again, taking the average of each of the contributing individual values. These were then plotted on a pair of axes by subtracting *conservation* from *openness-to-change* and *self-transcendence* from *self-enhancement*. The results of this can be seen in figure Figure 4.11. We again see that the majority of the results across all disciplines are grouped in the *openness-to-change/self-transcendence* quadrant. 66.7% of law, 69% of engineering and 70.4% of nursing students were placed in this quadrant. The ESS1 cohort also had the largest proportion of its members in this quadrant, though at 48.3% it was considerably below the other groups. Despite the larger sample size, engineering students had the lowest number of participants who favoured *conservation* over *openness-to-change*, with only four students (9.5%) rating *conservation* more highly. This is compared to six (22.2%) law students, eight (29.6%) nursing students and 10 (34.5%) of the ESS cohort.

Table 4.8 shows the results of independent t-tests which were conducted on the mean axial scores, to compare Eng1 students to each of the other groups separately. No significant difference was detected between Eng1 students and Law1 students. When compared to Nurse1 students, Eng1 students scored significantly lower on the *self-enhancement/self-transcendence* scale ($t_{\text{enhance/transcend}}(67) = -3.513$, $p > 0.05$, $d = 0.908$).

Eng1 students scored the highest of any group on the *openness-to-change/conservation* scale, though the differences were not significant. Relative to the ESS1 group, the difference approached significance and had a large effect size ($t_{\text{openness/conservation}(67)}=1.862$, $p>0.05$, $d=0.450$). It is possible that a larger study may detect significance here.

Table 4.8: Higher-Order Value Difference Scores between Eng1 Students and Other Groups

	Openness to Change/Conservation			Self-Enhancement/Self-Transcendence		
Mean Eng1	1.183			0.938		
SD (Eng1)	1.121			1.242		
	Nurse1	Law1	Ess1	Nurse1	Law1	Ess1
Mean	0.827	1.099	0.543	1.883	0.963	0.543
SD	1.300	1.183	0.790	0.791	1.021	0.790
DoF	67	67	69	67	67	69
α	0.05	0.05	0.05	0.05	0.05	0.05
t_{cv}	2	2	2	2	2	2
t	1.207	0.297	1.862	-3.513*	-0.085	1.514
Cohen's d	0.293	0.073	0.450	0.908	-0.022	0.380

* t value exceeds t_{cv}

4.3.3.3 Social Engagement Metrics

Figure 4.12 shows the response of first-year students to each of the social engagement metrics assessed by the survey as well as the three calculated scores, separated by field of study. Independent t-tests were conducted to detect any potential differences between the mean scores of Eng1 students with respect to students in the other disciplines.

1st year engineering students scored significantly lower than their counterparts in law and nursing in terms of the focus which they believed that their degree programme places on social engagement issues. When compared to nursing students, engineering students rated the focus of their programme lower in each of the three survey items, which in turn resulted in a lower mean score.

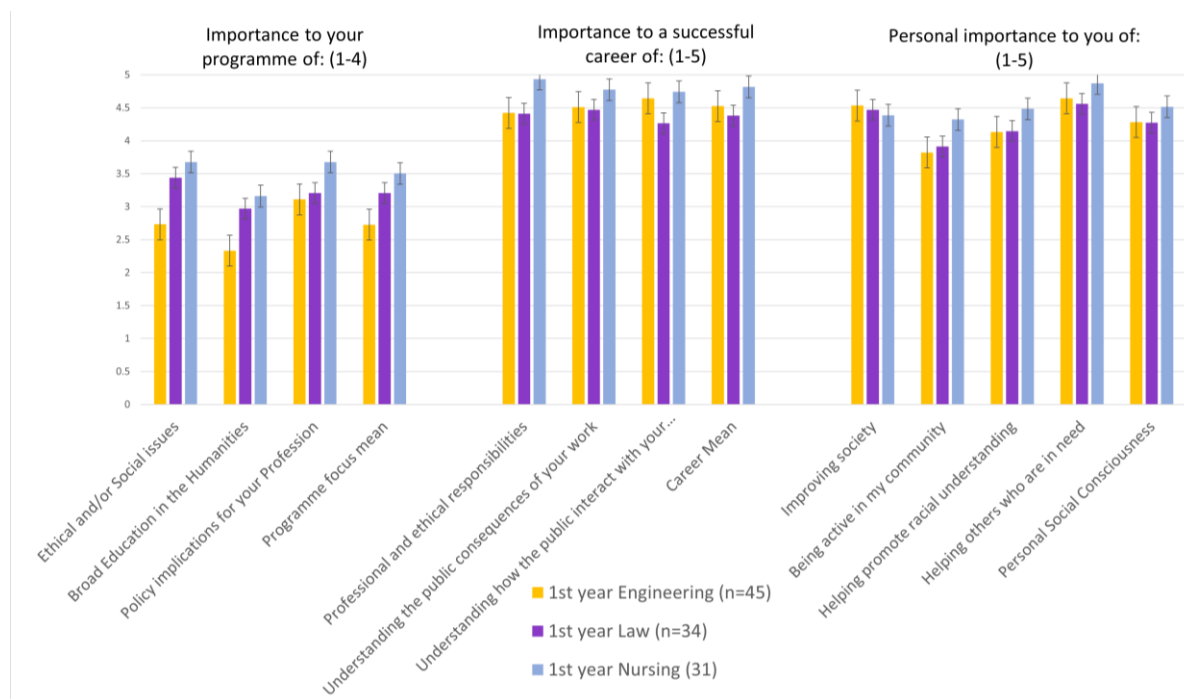


Figure 4.12: Social Engagement Metrics: 1st Year Students by Discipline

The same is true compared to law students, with the exception that the difference with regards to “policy implications for your profession” was not significant. The results of these tests can be seen in Table 4.9 below.

Table 4.9: Programmatic Focus: t-tests among 1st Year Students

Importance to your program of:								
	Nursing					Law		
	ethical and/or social issues	edu. in hum. & soc. sci.	policy implications	Program Mean		ethical and/or social issues	edu. in hum. & soc. sci.	policy implications
Mean Engineer	2.733	2.333	3.111	2.726	Mean Engineer	2.733	2.333	3.111
SD (Engineer)	0.863	0.905	0.910	0.683	SD (Engineer)	0.863	0.905	0.910
Mean (Nurse)	3.677	3.161	3.677	3.505	Mean (Law)	3.441	2.971	3.206
SD (Nurse)	0.475	0.779	0.599	0.393	SD (Law)	0.705	0.937	0.880
DoF	74	74	74	74	DoF	77	77	77
α	0.05	0.05	0.05	0.05	α	0.05	0.05	0.05
t_{cv}	1.994	1.994	1.994	1.994	t_{cv}	1.994	1.994	1.994
t	-5.531*	-4.145*	-3.037*	-5.729*	t	-3.898*	-3.053*	-0.465
Cohen's d	1.388	0.981	0.735	1.398	Cohen's d	-0.837	-0.661	-0.112

The other sections of this survey revealed fewer significant differences. In section two, Eng1 students scored significantly lower than the Nurse1 group with respect to how important they believe the professional and ethical responsibilities of their profession are to a successful career ($t(74) = -4.143$, $p > 0.05$, $d = 0.618$). Eng1 students also scored below their nursing peers for the other questions in section two, though the difference was not found to be significant.

As a result, the overall means for this section did differ significantly ($t(74) = -2.755$ $p > 0.05$, $d = 0.392$) though this is largely attributable to a single question.

Engineering students rated the importance of all of the public engagement metrics more highly than their peers studying law, though only the importance of understanding the public interaction with the profession was significantly higher ($t(77) = 2.016$ $p > 0.05$, $d = 0.404$). The results can be seen in Table 4.10.

Table 4.10: Public Engagement: *t*-tests among 1st Year Students

Importance to a successful career of:									
	Nursing					Law			
	Prof. & ethical responsibility	public consequence	public interaction	Career Mean		Prof. & ethical responsibility	public consequence	public interaction	Career Mean
Mean Engineer	4.422	4.511	4.644	4.526	Mean Engineer	4.422	4.511	4.644	4.526
SD (Engineer)	0.657	0.787	0.645	0.500	SD (Engineer)	0.657	0.787	0.645	0.500
Mean (Nurse)	4.935	4.774	4.742	4.817	Mean (Law)	4.412	4.471	4.265	4.382
SD (Nurse)	0.250	0.617	0.575	0.374	SD (Law)	1.019	1.080	1.024	0.936
DoF	74	74	74	74	DoF	77	77	77	77
α	0.05	0.05	0.05	0.05	α	0.05	0.05	0.05	0.05
t_{cv}	1.994	1.994	1.994	1.994	t_{cv}	1.994	1.994	1.994	1.994
t	-4.143*	-1.559	-0.676	-2.755*	t	0.055	0.193	2.016*	0.878
Cohen's d	1.032	0.372	0.160	0.659	Cohen's d	0.013	0.047	0.404	0.193

Only one significant difference was found within the personal social consciousness metrics. engineering students rated “being active in my community” as significantly less important than nursing students did, with a medium effect size ($t(74) = -2.354$ $p > 0.05$, $d = 0.588$). Notably, “improving society” was the only metric across these questions for which engineering students scored more highly, on average, than nursing students.

The results of the comparison with law students were mixed, with engineering students scoring more highly for “improving society” and “helping those in need”, though none of the differences were statistically significant, and all effect sizes were very small. Table 4.11 displays these results.

Table 4.11: Personal Social Consciousness: t-tests among 1st Year Students

Personal importance to you of:											
	Nursing						Law				
	Improving society	active in community	promote racial understanding	Helping those in need	Personal Mean		Improving society	active in community	promote racial understanding	Helping those in need	Personal Mean
Mean Engineer	4.533	3.822	4.133	4.644	4.283	Mean Engineer	4.533	3.822	4.133	4.644	4.283
SD (Engineer)	0.694	0.960	1.036	0.529	0.558	SD (Engineer)	0.694	0.960	1.036	0.529	0.558
Mean (Nurse)	4.387	4.323	4.484	4.871	4.516	Mean (Law)	4.471	3.912	4.147	4.559	4.272
SD (Nurse)	1.054	0.832	0.811	0.718	0.698	SD (Law)	0.788	1.026	1.132	0.746	0.734
DoF	74	74	74	74	74	DoF	77	77	77	77	77
α	0.05	0.05	0.05	0.05	0.05	α	0.05	0.05	0.05	0.05	0.05
t _{cv}	1.994	1.994	1.994	1.994	1.994	t _{cv}	1.994	1.994	1.994	1.994	1.994
t	0.730	-2.354*	-1.579	-1.584	-1.612	t	0.375	-0.398	-0.056	0.597	0.078
Cohen's d	0.164	0.558	0.377	0.360	0.369	Cohen's d	0.064	-0.084	-0.012	0.106	0.014

4.4 Survey Discussion

As discussed above, engineering is variously portrayed and perceived as both an investigative and realistic profession, and those working in each of these vocational areas have been shown to prioritise different personal values. Investigative professions have been shown to prioritise *self-direction*, *universalism* and *achievement*, while de-emphasising *conformity*, *tradition*, *hedonism*, and *security*. Realistic professions have been shown to correlate negatively with *self-direction* but prioritise *hedonism* and *tradition*. Finally, *benevolence*, *universalism*, *conformity* and *tradition* have been shown to be prioritised by those in social professions. This latter group has been shown to de-emphasise *self-direction*. The Law1 cohort in this study are an example of an investigative profession while the Nurse1 group belong in the social category. The ESS1 group represents an average Irish 18 to 19-year-old. By examining the value profile of engineering students in relation to these we can better understand the value priorities of those who choose to study engineering.

The profile of first-year engineering students which emerged from this data appears to fit with some, though not all of the trends one would expect to see for someone in an investigative profession. *Universalism* and *self-direction* are indeed the two highest scoring values among the Eng1 group, and both were rated as significantly more important by engineering students than by the ESS1 cohort. All three of the student groups included here represent professions which we would expect to prioritise *universalism*, and all three scored higher for this value than the ESS1 cohort. Similarly, we can see that Eng1 and Law1 students rated *self-direction* higher than the ESS1 cohort.

Examining the lower value priorities, we can see some evidence of the expected value priorities of an investigative profession. *Tradition* and *security* are rated as in the bottom three positions, along with *power*, by Eng1 students. This score for *tradition* is in line with the scores of those in the other investigative profession here, law, and while all groups rated *tradition* in a low position, the score given to *tradition* by Eng1 students was considerably lower than the average score of the ESS1 group. On the other hand, this score was not significantly different

from that of nursing students, who belong to a group which might have been expected to prioritise *tradition*. Similarly *security* was rated lower, though not significantly so, by Eng1 students than by any other group. *Security* is a value which has been shown to correlate positively with age and so it is possible that this low rating is a feature of the age profile of participants rather than their vocational interest.

The values of *achievement*, *conformity* and *hedonism* are three cases where we see the profile of Eng1 students differ from the expected priorities of an investigative profession. The engineering students included in this sample rated both *hedonism* and *conformity* above *achievement*. Based on previous literature an investigative professional would be expected to prioritise *achievement* and de-emphasise *conformity* and *hedonism*. When we compare the relative position of these scores among Eng1 students with those of Law1 students we can see that the difference is significant. Law1 students appear to place significantly more importance on *achievement* relative to *conformity* and *hedonism* than their engineering peers. The Eng1 relative scores for these values are instead closer to those of the ESS1 group.

It is interesting to note that the value of *stimulation* did not form part of any of the trends to emerge from the data. It was rated as a mid-level value by all four cohorts, and the score among Eng1 students did not differ significantly from any other group. With problem-solving forming such a significant portion of the engineering identity in both the public understanding and the marketing material it might have been expected that the value of *stimulation*, which is associated with language such as "seeking challenges" (Schwartz, 1992) would have been a priority for those who choose to pursue an engineering degree.

It's possible that this interest in problem-solving manifests elsewhere in the value structure of engineering students. As discussed above, an intrinsic interest in technology was a motivation for many engineering students. Multiple sources described having engineering adjacent hobbies like Lego, electronics, or simple robotics. While others mentioned an interest in puzzles as a good indicator of a potential future engineer. First-year engineering students did not de-emphasise *hedonism* as would have been expected for an investigative profession. It is possible that pursuing an engineering degree is seen by these students as a means of pursuing their hobbies further, and as such is motivated in part by their *hedonism* values.

Elsewhere within the marketing materials and interview transcripts, multiple sources described the role of engineering as being for the public good and that by solving problems engineering benefits humankind. Of the three student groups included in this study, engineering students rated the personal importance to them of improving society the highest on average, though the difference was not significant. The highest value priority for Eng1 students was *universalism*, which they rated as significantly higher than the ESS1 group. Based on this, it does appear that the engineering students sampled here appear to value "social justice" (Schwartz and Boehnke, 2004) and "protecting the welfare of all people and nature" (Schwartz, 1992), and so the interest in problem-solving may be based in the benefits that these solutions can provide humanity.

Within the prospectus documents engineering solutions are described with a degree of distance. As discussed above, there is a sense that engineering should and does extract the technical challenge from a societal problem, and by solving this can improve conditions for all. This is consistent with the literature which describes a depoliticisation of engineering (Cech 2013; Seron et al. 2011 ; Faulkner 2000; Haraway 1988). The results presented here appear to show some evidence of this effect. By examining the difference score between *universalism*

and *benevolence*, it can be seen that Eng1 students rate *benevolence* significantly lower relative to *universalism* than both their nursing peers, and the ESS1 cohort. A-larger-than-average difference score here is consistent with a culture that praises solving problems for the benefit of society while maintaining a scientific detachment from the social factors which might otherwise bias scientific work.

As was suggested above, the focus on technical subjects in engineering education may contribute to the social engagement of engineering students described in the literature (Cech, 2010, 2013). Eng1 students in this study rated the importance to their chosen programme of ethical and/or social issues and of a broad education in the humanities significantly lower than their peers studying nursing and law. Even as they begin their degrees, those studying engineering perceive the narrow focus of their programme.

There is little evidence in the value profiles to suggest that engineering students are choosing their degree based on the utility of career opportunities such as job *security* or potential salary. As has been discussed already, the value of *security* was rated lower, though not significantly so, by Eng1 students than by any other group. *Achievement* and *power* are two values which might motivate a high salary. Neither of these were prioritised by engineering students in this study. One interviewee reported his classmates discussing their potential future earnings as a motivation for their career, meaning that there is evidence that this is a factor for engineering students, but it does not appear to have been reflected in their value profiles.

Creativity is a trait which was highlighted as an important skill and trait for engineers in the prospectuses. It has been shown to correlate positively with *self-direction* and the higher order value of *openness-to-change* (Kasof *et al.*, 2007; Arieli, Sagiv and Roccas, 2020). The Eng1 cohort here rated *self-direction* as their second highest value priority and rated it significantly higher than the ESS1 and Nurse1 groups on average. Eng1 students also had the highest proportion of individuals who favour *openness-to-change* over *conservation* at 90.4%. This is compared to 65.5% of the ESS1 group.

Eng1 students scored significantly lower than Nurse1 students for the personal importance of being active in their community. This may support the perception that engineers are unsociable individuals. However as nursing is considered a social profession, and the difference between engineering and law students was not significant it is difficult to draw any definitive conclusion from this.

The primary finding from the value differences between male and female engineering students was the lack of any significant difference in their average value profile. There were no significant differences in any values or any social engagement metric between the male and female students. While female engineering students rated *universalism* higher, in the ordinal rankings, than their male peers who prioritised *self-direction*, the numerical differences were not statistically significant. The largest difference was between the respective scores for *achievement*, which female students rated higher, and *tradition*, which they rated lower. Looking at the higher order values, 93% female first-year engineering students rated *openness-to-change* above *conservation*, while the remaining student scored them both equally. The female students in this study have chosen to enter a historically male-dominated field, which may explain their *openness-to-change* and the low placement of the *tradition* value.

Throughout most of the prospectus documents an attempt is made to normalise women in engineering by increasing female representation in the images used, and by increasing the

visibility of female engineers to young women. On the other hand, the one document which made an overt appeal to female students frames it as a challenge and encourages them to break from the norm and choose engineering. While *tradition* was scored significantly below average for engineering students when compared to the ESS1 cohort, the mean score for Eng1 students in *conformity* was marginally above average. This is true of both the male and female engineering students. This may suggest that these normalising efforts are having some effect, in that female students with slightly above average *conformity* scores are choosing to enter a male dominated field. Conversely, the values of *self-direction* and *stimulation* are prioritised more highly by these students, suggesting that given the choice of choosing to pursue a challenge that interests them and try something new or sticking to a norm or convention these students are likely to choose the former.

Above all, the value profile of both male and female students who entered engineering were consistent across all metrics. While it has been reported elsewhere that female students are more likely to cite the ability to help others as a reason for choosing to study engineering (Bielefeldt & Canney 2018; Buse, Bilimoria, and Perelli 2013; Bystydzienski and Brown 2012; Hewlett et al. 2008; Meyers and Mertz, 2011; Niles et al., 2020; Lucena, 2013; Skatova et al. 2014), this does not appear to have manifested in the personal values of the students in this sample. There was no significant difference detected between male and female engineering students for the values of *universalism* or *benevolence*, the higher order value of *self-transcendence* or the personal importance to them of helping those in need and improving society. It appears then that those female students who choose to study engineering have broadly the same personal values as their male counterparts, which raises questions as to why the perception of different motivations has persisted.

Similarly, the majority of metrics which refer to personal values and attitudes did not differ significantly between engineering students and those in the other investigative profession, law, despite the Law1 cohort consisting primarily of female students. The major differences found here were in relation to thoughts about their degree programme or aspects of their future career. The only exceptions to this were the relative placement of the value of *achievement* with respect to *conformity* and *hedonism*. This suggests that for these students, the choice of degree, or at least vocational area, is a larger factor in their personal value profile than gender.

4.5 Conclusions

The purpose of the analysis presented in this chapter was to gain an understanding of the values and motivations being appealed to in prospective engineering students, and the perception of the profession presented to them at the recruitment phase. In the university's marketing materials, engineering is fundamentally defined in relation to problem-solving, a theme consistently highlighted in course prospectuses and by interviewees. This portrayal positions problem-solving as an intrinsic quality of engineers and a primary motivation for students pursuing engineering degrees.

The dual emphasis on practical application and scientific theory creates a dissonance between public perceptions and the reality of the profession and further perpetuates confusion about the categorisation of engineering as a *realistic* or an *investigative* profession according to the Holland Typology. An emphasis on practical action contributes to misconceptions among prospective students, who may expect a hands-on education but encounter a more theory-intensive curriculum. The prospectuses may also not do enough to clarify the already blurred definition between an engineer and a technician or tradesperson. Simultaneously the portrayal

of engineering as a purely scientific task misrepresents the societal impact of engineering. While engineering is marketed as addressing significant social issues, it is also shown to maintain a position of scientific detachment. This reinforces the technical/social divide discussed previously.

From a values perspective, this causes some interesting conflicts. The value of *self-direction* has been consistently rated highly among those in *investigative* fields and devalued by those in *realistic* careers, while the opposite is true of the conservative values of *hedonism* and *tradition*. The third vocational area which receives attention in these documents is the *enterprising* group. This is largely through business and management opportunities presented as career opportunities and certain included subjects. This again has its own set of value correlations including prioritising *power* and *achievement*, and devaluing *universalism* and *benevolence*. The findings of this study suggest that those entering engineering education most closely match the value priorities previously observed among *investigative* professionals. The relative prioritizations of *achievement*, *conformity* and *hedonism* among engineering students did not match the pattern observed in first-year law students, which more closely fit with trends from previous literature. In later chapters I will examine whether this difference persists, by examining the value profiles of engineering students at more advanced stages of their professional socialisation process.

The prospectuses analysed appear to be designed to appeal to a wide variety of candidates. The answer to the question of why a student should choose to study engineering appears to have three major aspects to it.

Career opportunities are presented as perhaps the most valuable commodity that these degrees can offer a graduate and was used by staff to demonstrate the success of their program. It is very much an appeal to *security*, or the *utility* values described by Eccles (Eccles, 2005; Wigfield and Eccles, 1992). This may be important, as many now view an education as an investment, though these values have been shown to matter most to engineering students who have less intrinsic interest in the subject and who don't identify personally with their image of the profession. As *security* values were not prioritised by the engineering students in this study, this appeal may be directed towards the parents of the students who also play a role when choosing a degree. Placing so much emphasis on this employability also reinforces the idea of engineering as part of the corporate structure.

Another major motivation to consider is the way that the role of the profession is portrayed. In numerous places there are claims that the engineering profession is a force for good in the world. Many of these programmes claim that their discipline is one which can offer graduates the opportunity to solve society's problems, and in doing so appeal to values of *universalism* and *benevolence*, though crucially not in equal measure. However, in the framing of these problems we see some of the issues previously discussed by those in the E4SJ movement. The role we see presented is that engineers are to solve society's problems, without needing to develop the ability to understand these problems. Or rather that they only need to understand them through a technological lens. There is surely a role for engineering and technology to play in tackling some of society's biggest challenges, but doing so will likely require a broader range of actors and skill sets (Conlon, 2008, 2019; Murphy, 2015; Jamison, 2013; Baille & Levine 2013; Cech, 2014; Colby, 2008; Nair, 1997). The prospectus documents do not acknowledge this as we continue to see the heavy focus on technical and scientific subjects in the programme content of these degrees, and the very limited inclusion of subjects beyond this.

The final major motivator would be an intrinsic interest in technology and problem-solving. This is evident in the significant focus on the technical learning students will undergo. Students are encouraged to pursue engineering out of a genuine curiosity and passion for the field. Students with a natural inclination towards understanding how things work are attracted to engineering by the intellectual challenge. The higher-than-expected placement of the *hedonism* value by engineering students may be a motivating factor for this choice. This implies a sense of neutrality, not in the sense that the student feels they should keep their values separate from the work, but rather that they are motivated by the technical challenge alone regardless of the wider context of the work.

Mathematical ability is considered one of the primary indicators and criteria for entry into engineering. Requiring a high level of aptitude for maths to enter engineering education has a number of possible effects. It may contribute to the "perception that people have that engineering is maths" (S11). This definition ignores the other critical skills which an engineer needs, at least instils the idea that they are less important. Having maths as the primary required skill may suggest that it is somehow less teachable than other skills. It also represents a barrier to some students who may have other talents and aptitudes which would make them a successful engineer. The employment success of graduates from an electronic engineering degree which does not have this requirement, discussed above, may speak to this point.

Engineers are increasingly recognized as creative problem-solvers, with creativity being emphasised here in the recruitment material. It is highlighted both as a desirable trait for incoming students and a skill that will be taught. Staff members stress the importance of creativity for engineers, viewing it as essential for success in the field. Results in this study were consistent with research by Arieli & Sagiv (2020) who found a positive correlation between creativity and values such as *openness-to-change*, and *self-direction*, while also noting negative correlations with values like *security*, and *tradition*, though the positive correlation to *stimulation* and negative correlation to *conformity* reported previously was not evident here. Prioritising *self-direction* has been identified as important for engineers and investigative professionals and was rated as an important value by engineering students in this study. Some students note that engineers often engage in creative pursuits outside of their field, which would be consistent among a group with higher levels of *self-direction*.

The values and attitudes of engineering students, male and female, are generally consistent with those of other investigative professions like law, but there are some unique differences. Notably, engineering students place less emphasis on *achievement* relative to *conformity* and *hedonism*. These distinctions raise important considerations about the engineering value profile and how it may evolve through the professional socialisation process. These may form part of a unique engineering value structure. Alternatively, it may be a symptom of an incomplete socialisation process. Chapter 6 will explore whether these differences persist by examining the value profiles of engineering students at more advanced stages of their education and professional development.

Chapter 5: The Ideal Engineer

The purpose of this thesis is to explore and understand the professional socialisation of engineering students during their formal education from a values perspective. In the previous chapter, the values of individuals choosing to study engineering were examined, along with the values expressed by universities during the recruitment of engineering students. That chapter explored how the profession is portrayed to students before they begin their engineering education. In this chapter, the focus shifts to understanding how the engineering profession is depicted to students during their education. The academic staff in university engineering departments are tasked with preparing their students for future careers as engineers, and this chapter investigates the end result they are striving to achieve. Specifically, it asks how those involved in engineering education envision the ideal engineering graduate. This chapter will therefore address Research Question 3: What are the ideal values of an engineer according to those involved in Irish engineering education?

As part of understanding the socialisation which occurs during engineering education it is important to understand what educators are trying to achieve. It has been identified that engineering academics base decisions regarding their curriculum on their vision for and perceptions of engineering practice and what makes a “good” engineer (Quinlan, 2002; Murphy, O'Donnell and Jamesons, 2019; Murphy, Christensen and Conlon, 2022). Participants in this research expressed similar thoughts. When designing a degree programme participants in this study described starting with an image of their future graduates and then “reverse engineering something to fit that” (A12). “From the outset we were looking to see, what would a student graduating with this degree programme look like and how they sound and what would be their application? And then from there, when we knew what the end product should look like, we started to fill in the pieces to make that happen over the four years.” (A15). Understanding this imagined graduate is key to understanding the objectives of engineering education.

The content that an educator chooses to teach is seen, by students, as an endorsement of its relevance to the engineering profession, and thus informs their understanding of what is considered a good engineer. It should be noted that there are limitations to this. It has been found that the extent to which a would-be-mentor or teacher resembles the student's preconceptions of a member of the profession affects the willingness of the student to accept a socialising influence (Cohen, 1981; Cornelissen and Van Wyk 2008). Jamison (2014) has suggested that there is a responsibility on engineering educators to form this image of the engineering profession as a hybrid technical and social discipline. Murphy et. al (2019) suggested that the skills and competencies learned during an engineering degree affect the development of a professional identity.

Previous authors have criticised engineering education as having a narrow technical focus, and excluding non-technical skills and forms of knowledge. Some have argued that this has created a techno-social dualism (Hacker, 1981; Faulkner 2000), in which scientific, positivist epistemologies are valued above all other forms of knowledge (Kramer, 2022; Blue, Levine, and Nieusma, 2014; Herkert, 2000). It has been suggested that this narrow definition of what constitutes valid engineering knowledge and decision making criteria is responsible for a culture of disengagement in engineering (Cech, 2014a; Cech and Sherick, 2015b), and obstructs the profession from effectively integrating social justice, and responsibility values

into the engineering mindset (Riley, 2008; Riley and Lambrinidou, 2015; Kramer, 2022; Murphy, Christensen and Conlon, 2022; Xavier, Wint and Orbaek White, 2022). Some success has been achieved in integrating individual aspects of professional responsibility, such as human safety, environmental protection and sustainability, into the engineering identity, though results in terms of a wider social responsibility or social justice have been mixed (Bielefeldt, 2018; Martin and Conlon, 2023; Martin and Polmear, 2022; van de Poel, 2001; Murphy, Christensen, and Conlon 2022; Canney, Bielefeldt, and Russu, 2015; Bielefeldt 2021). Others have suggested that the social organisation required to instigate a cultural shift towards socially responsible engineering is actively hindered by the depoliticisation within the engineering profession (Riley and Lambrinidou, 2015). It has also been observed that the skills taught during engineering education can affect the ability of students to consider multiple perspectives when assessing a problem (Kabo and Baillie, 2009). The skills that an engineering student learns during their education shapes how they can see the world, and by extension the role they will expect the profession to play in it (Riley and Lambrinidou, 2015; Leydens and Lucena, 2018).

This chapter investigates both the implicit and explicit values and norms in engineering education, using a thematic analysis of semi-structured interviews. Thematic analysis has been demonstrated as an effective means of exploring values within an organisation (Wæraas 2022; Buckley et al. 2024; Wright, Zammuto, and Liesch, 2017), while this style of interview has also been used in investigating various aspects of the culture within engineering education (Murphy, O'Donnell, and Jamesons 2019; Martin and Polmear 2022; Xavier, Wint, and Orbaek White, 2022).

The findings in this chapter are based on an analysis of 28 semi-structured interviews conducted across several Irish universities. Of the 28 participants, 13 were currently enrolled engineering students and 15 were engineering academic staff. Staff with a role as programme director (or equivalent title) of an engineering undergraduate programme were initially selected, with snowball sampling then being used as initial participants recommended colleagues or engineering modules which they deemed relevant to the topics being discussed. Students were recruited via student-run organisations such as engineering student societies and Women in STEM groups. These interviews were recorded, transcribed and then analysed in NVivo 12, using the 6-phase process outlined by Braun and Clarke (2006).

Implicit values are, by nature, embedded in action and norms of practice (Espedal et al. 2022), and are more suited to qualitative investigation (Brigstocke et al. 2017; Espedal et al. 2022) where richer descriptions can capture the lived experience of these values. Norms are often defined as the ways an individual should, or is expected to, behave (Merton, 1938). These can be difficult to perceive until such time as they are called into question (Mulkay, 1976) and as such investigating the expected behaviour of this abstract “ideal engineer” allows these to be more freely discussed. Interviews, followed by a thematic analysis, are a preferred method of investigation of how implicit values manifest within an organisation (Wright, Zammuto, and Liesch, 2017; Askeland 2014; Wæraas, 2022). Examining the descriptions of the ideal engineering graduate by academic staff, and how they define success in terms of student learning outcomes can inform which aspects of socialisation are considered important by engineering educators. This chapter examines what aspects of the ideal graduate are discussed, which are highlighted as important and which aspects are neglected.

To assess explicit values, interview participants were also directly asked about their beliefs and objectives with regards to the professional socialisation of engineering students. They

were asked to discuss which of the elements of socialisation (role, skills and values) were within the remit of engineering education as well as how, and to what extent this was achieved. In each interview, the direct approach described here took place only after participants had been allowed the opportunity to discuss their objectives in their own terms. They were also asked to rate the ten values from the Schwartz Value System according to how they would like to see them prioritised by an engineering graduate, and to discuss how these value priorities are applicable to engineering.

Explicit values can be assessed both qualitatively and quantitatively (Schwartz, 2006; Espedal *et al.*, 2022; Løvaas, 2022). As this chapter is dealing with the values of the ideal engineer, rather than of actual participants, qualitative methods are used. Quantitative assessment of engineering students' values can be found in Chapters 4 and 6 of this thesis.

In this chapter the descriptions of the ideal engineer are compiled and examined to capture a picture of how engineering educators see the ideal graduate in terms of their role, their skills and their values, as well as what constitutes good engineering practice. Skills are addressed first, with a description of the technical skills that participants deemed important for an engineer, as well as the relative importance of other skills included in the curriculum². Following this, the qualities that participants believe describe 'good engineering work' are discussed. This is informative as it highlights the norms that participants believe an engineer should abide by and by what criteria an engineer's work should be assessed. Next, the role that students and staff believe the ideal engineer should play, are considered. This includes the contexts in which engineers work, as well as some of the major tasks they are expected to carry out. It also addresses the question of whether participants describe the profession as striving for social benefit or operating in a value-neutral manner. Finally, the value profile of the ideal engineer is discussed. This includes the ordinal rankings of the 10 values of the Schwartz value system (1992), as well as participant perspectives on how these values are applicable to the ideal engineer.

5.1 Skills Ideal

When asked about the ideal engineer, and the outcomes that staff wanted to achieve, the interview participants primarily focused on the skills which a graduate engineer should have. It was stated by staff participants that "I think our duty is to make sure that we've got really, technically excellent engineers so that they can then have the best set of skills to apply to these problems" (A7). We again see problem-solving referred to here. Some participants referred to it as its own skill, however others described it as a set of skills. For the purpose of this thesis problem-solving is being considered as a role for engineers. It is an activity which they carry out, "using the knowledge and skills which they've been educated in" (A1).

Students also expressed that it was skills which made them "feel like an engineer" (A2). Rather than the theory-heavy first-year core classes, one student reported that it was their electives in which they learned some "hands on skills" (A2) which they found satisfying. Being able to say "now I know how to build this robot and how to programme an Arduino, or now I know how the laser cutter works....We had really, really good labs that they showed us how the CNC

² This chapter does refer to curriculum content when discussing the skills deemed important for the ideal engineer. A more comprehensive discussion of the process of designing engineering curricula and the forces which affect this can be found in chapter 6.

machine works and how welding works and the laser cutters and the 3D printers work" (S2) is what made them feel like they were becoming an engineer.

A theme which emerged from these interviews was a clear divide between the core technical engineering skills, and all other non-technical skills which an engineer might need. This divide has been identified in the literature, and in Chapter 4 of this thesis, and once again emerged here.

5.1.1 Technical Skills

Technical skills were the most frequently mentioned topic when discussing the skills a good engineer would need. They are also the skills which receive the lion's share of attention over the course of a degree programme. One participant estimated that "we would deliver 70% technical skills and 30% soft skills" (A2). These technical skills were often called "the fundamentals" (A3). As was discussed in Chapter 4, staff discussed "grounding" students' skill sets in "core engineering" skills. Multiple participants expressed that "having a very strong knowledge of the fundamentals is really essential" (A1). When asked what the most valuable thing an engineering student takes away from their programme is, one participant responded "I think it's probably an understanding of the fundamentals of all aspects of mechanical engineering" (A1).

These fundamentals typically included maths and physics across all engineering disciplines with varying amounts of biology and chemistry as required by specific branches. "There's a core kind of common core of engineering subject matter" (A8), which is "built on the fundamentals of physics, the fundamentals of material science" (A1). This is reinforced from the beginning of an engineering education with these being the first subjects which students study. "The first-year syllabus is pretty similar to the first-year syllabus of most engineering programmes. Anywhere you go there's an introduction to computing. There's a number of maths modules. There's a physics module, a chemistry module, one on mechanics, one on electricity. Um, what else? One on experimental methods, one on materials, one on engineering drawing" (A9). Within the bounds of an engineering degree, achieving competence in those subjects is considered most important. "Once [a student] has been through the rigour [and] can do all of the hard, sort of rigorous mathematics and physics and design and solid modelling and all of that. We get all of those tools together, and [they're] competent in that part, then we've done our job" (A8).

Participants believed that "a mathematical background is vital" (A2), and that "the biggest thing, for all the engineering problems, is to have the, you know, the sort of technical and scientific knowledge in order to do that, then that they're experts in their own domain" (A7). These technical and mathematical skills are prioritised above all else for an engineer. They are prioritised in terms of class time spent learning them as well as the order in which students typically receive these classes. While other skills were included as important for an engineer, they were often accompanied with the caveat that they could only be studied "once you've developed the basic... core technical and maths skills." (A5).

5.1.2 "Soft" Skills

As well as the technical topics, there are a range of other skills which are considered part of the ideal engineering graduate's skill set. These are mostly those skills which have in the past been called "soft skills". As has been discussed in the literature, this name has received some criticism for giving the impression that these skills are less relevant, important or valid than the

“hard science” which engineering education has tended to focus on (Martin and Polmear, 2022; Murphy, Christensen and Conlon, 2022). This is consistent with previous research which found that specifically ethics related content was described as an “ancillary” or “supporting” skill. A participant in that study suggested that referring to these as “soft skills” or “professional skills” reinforces the narrative that they are not engineering skills (Martin and Polmear, 2022). More recently the term “transversal skills” (A8) has increased in use for describing this range of skills which are applicable across a range of disciplines.

However, despite the focus being heavily on technical skills, there were a number of specific transversal skills which were highlighted as relevant to engineers. A common trait was the relevance that these skills had to the role of an engineer as an employee in a corporate setting. “I know from speaking to employers, how important the likes of communication skills and the soft skills are” (A13). Among those skills which participants included as part of the ideal engineering graduate’s toolkit are communication skills, teamwork and cooperation, critical thinking and reasoning, understanding or empathy, and creativity.

5.1.2.1 Communication and Teamwork

Communication skills were described as critical for engineering graduates. After the technical skills discussed above, communication was frequently the first skill discussed by participants, often in the same breath as teamwork. Together these interpersonal skills were described as “essential” (A2), “crucial” (A12) and “much more important than their academic skills, you know, in some of the roles they’re going into” (A13).

The reasoning for this was related to the kinds of jobs available to engineering graduates. “Engineers by and large will always work as part of teams because the engineering endeavours are usually part of teamwork” (A1). As is the nature of transversal skills, this is applicably true for a wide range of fields, but participants felt that this was particularly true of engineering, stating that “very few people would operate as individuals in the world of work in engineering, I think you’re operating as part of a team” (A2) and “within the engineering profession... no person exists as an island” (A1). As another participant pointed out, “no matter how good your technical skills are, [...] if you don’t communicate and aren’t able to be working with others, it’s very, very difficult to go out and really make a difference” (A15).

As well as being important in terms of finding employment and dealing effectively with colleagues, the ability to communicate with those outside the profession was also highlighted. The ideal engineering graduate should “be able to communicate with a range of different people of different backgrounds, whether that be technical or non-technical” (A2) and in a range of modes “whether it’s verbal or visual or written, you know, a number of different kinds of communication and are very important for engineers” (A2).

Students primarily understood the importance of these skills through the lens of employment, with a number offering warnings like, “some of the smartest people I know struggle to get a job because they didn’t have the interview skills. They might have had an honours in every module all the way through... but didn’t develop more social skills” (S4). However only one student mentioned communication with non-engineers, and even that was discussed in terms of “being in a team with people who might not be engineers” (S4).

5.1.2.2 Leadership and Confidence

Related to teamwork skills, many participants spoke about the importance of an engineer being able to lead a group. Engineering educators believed that a good engineer should have “the ability to integrate within teams, to work with teams and possibly to have some sort of

leadership role" (A1). This is born partly from the belief that "a lot of engineering students will be aiming towards management" (A5), but also that "even if they don't see themselves as a manager, as an engineer, you're going to end up doing some level of management, whether it's a small little team or something" (A5). According to these participants, the role of an engineer will inevitably involve some degree of management and so skills relating to project management and leadership are important to develop in students including "knowledge of the issues of economics, of finance and of management" (A1). One participant who teaches a module on Engineering Management stated that "Management, I would say, is largely about people skills" (A5). This includes the aforementioned communication and interpersonal skills, but also a certain amount of self-confidence and comfort with responsibility. "They also have to be strong-minded...they're probably going to be making important decisions that have significant consequences" (A12), and so a good engineer should be comfortable with this. For students, the confidence aspect of leadership was emphasised. A participant first suggested that "you have to be confident in your abilities. You can't really be second guessing yourself all the time, because people are definitely relying on you to make correct decisions" (S12), to which they then added "Confidence in your abilities. Not overconfidence. That's worse" (S12). This same participant then highlighted a gender aspect to this suggesting that "A lot of mainly women in engineering particularly... would suffer from imposter syndrome and not having confidence in their abilities" (S12).

5.1.2.3 Creativity

The ideal engineering graduate is also creative. Multiple staff and students believed that "you can't really be a good engineer without having creativity" (S2). Creativity was mostly discussed in relation to design. As a profession that is tasked with solving problems it makes sense that the best graduates would be those who are "creative in coming up with design solutions" (A1). As well as in the idea-/solution-generation stage, a very specific application of creativity was described which involved creativity in interpreting challenges or design briefs. Someone who would spend time "trying to see what you can get out of the brief and how far can you push the boundaries" (A2) was one of the signs of a good engineer according to one participant. Another explained it by saying "you don't want to constrain your solution space in any way" (A1). "Engineers always need to have a strong creative side... to analyse whatever problem you come across in detail and... not necessarily just stick to some traditional solution" (A5).

5.1.2.4 Investigation and Understanding

Creativity in interpreting a brief leads to the next important transversal skill. An ability to investigate and understand a problem in depth and detail is something that a number of participants discussed. It was discussed almost as a form of patience where an engineer will "define the problem first and foremost" (A11), rather than rushing straight into designing. "An understanding of context is vital to good design practice" (A9), and is what allows engineering to tackle the "disease rather than the symptom" (A7). As one participant put it, "anybody can go along and find a solution to a particular issue that they're having at a particular time, whereas I think engineers are a bit more systematic about it. And I think the sign of a real engineer is that they can sit down and really understand the root cause of the problem before they actually find and start coming up with solutions" (A15). This is also an issue identified as something which students can struggle with. "Students much prefer to get in and start to jump to conclusions" (A15), and "they tend to focus in on a solution too fast" (A6). As such staff encourage students to value the understanding and investigation aspect of the design process as a necessary skill for a good engineer.

5.1.2.5 Critical Thinking

Another related skill for the ideal engineering graduate was “ability to think critically” (A8). It was suggested that an engineer should approach every problem with a certain amount of scepticism “and to perhaps not accept everything at face value” (A1). This questioning was seen as a path to progress and development by participants. It was suggested that asking “‘Why is such a thing being done in that way?’ is often a very relevant perspective or question which sometimes might result in a change of how the process is done” (A1). Another participant added that their “philosophy is that ...there won't be any improvement if you just take as gospel everything that you're told, like looking back on history, if people believed everything they learned in school, we wouldn't have any new scientific advancements” (A6). This is again related to the two previous skills of creativity and understanding. Applying this critical thought and questioning the assumptions within the problem space is a necessary step for a good engineer to fully tackle an engineering challenge. Students felt the same, reporting “we're definitely very encouraged to question anything that we see” (S12), while another believed that one of the most important parts of engineering problem-solving “is developing that logical, critical thought” (S11).

5.1.2.6 Marginalisation of “Soft” Skills

When they were mentioned at all, skills related to ethical reasoning or the ability to understand social issues were typically lumped in alongside the transversal skills discussed above. For instance, a participant mentioned that over the past decade or so their programme had increased content relating to “the likes of ethics and what have you, communications, all these softer skills” (A4). Even when asked about the ethical content of the degree, and how ethics are applicable to engineering, the scope was often confined to research ethics and basic integrity. One participant highlighted that they are “coming from sort of an ethics background a little bit as well, because I'm involved with research ethics” (A7), while another believed that the most relevant aspects were “honesty and integrity in the workplace....stealing IP or things like that” (A6) and that “there's definitely stuff about, like, you know, teamwork and everything” (A6) involved. Murphy, Christensen, and Conlon (2022) highlighted how participants in their study also pointed to a similarly broad range of subjects when looking to identify where social justice is included in engineering programmes. Other previous work has found that staff feel that they lack the necessary expertise and vocabulary related to social justice and ethical considerations in engineering (Martin and Polmear, 2022; Xavier, Wint, and Orbaek White, 2022) This may be factoring here as technically expert, traditionally educated engineering academics are unfamiliar with the nuances of non-technical subjects.

The result seems to be that skills related to ethics and social justice are doubly devalued. Firstly, they are lumped in with a set of transversal skills that are seen as less important for engineers. For example, when discussing the inclusion of non-technical skills and content, one participant referred to them collectively as “things that you wouldn't start with...you want to get fundamentals in there first. Things you'll be putting in later” (A3). This echoes a finding by Martin and Polmear (2022) in which an Irish educator described the attitude to ethics as “you have to know to build the bloody bridge first before getting into ethics. So, you have to know your mathematics, your geometry and your trigonometry and all that good stuff.” Secondly, the other skills grouped under this category, like communication and creativity, are very clearly related to employability and as a result appear to be given far more priority. Within the “soft” skills, the interview participants dedicated most of their attention to the transversal skills at the expense of those related to ethics or social justice.

5.2 What constitutes “good” engineering?

5.2.1 Effective and Useful

Quite often the first trait mentioned with regards to what constitutes a good engineering solution was “obviously it has to be effective. It has to do what it's meant to do” (A3). Similarly both students and staff agreed that the main indicator of bad engineering is “if it's technically faulty, that's the obvious one” (S1). So, a good engineering solution should achieve its objectives. This leads directly to the next most common trait of good engineering which participants described.

Engineering solutions should be useful. They should be “useful to society” (A6). Multiple participants pointed out “that we have enough solutions walking around looking for a problem” (A15), and that “as engineers, a lot of times the temptation can be to answer questions that nobody is asking” (S2). The implication here is that because “a lot of people who go into engineering to begin with are doing it because they're interested in technology” (A5), there is a temptation to fixate on developing and experimenting with the technology rather than being problem-focused. Staff reported a common mistake made by students being to produce “a very well-developed technical solution, but they may not necessarily be taking the actual user needs or whatever into account” (A5). For many participants this was incorporated into their definition of engineering by saying something like “applying science to do useful things for the world” (A3), so while “Science might give the breakthrough, engineering uses that technology to do something useful with it” (A6).

This point was illustrated by a participant telling a story of a pair of physics students who transferred to engineering in order to find a role which is more applied. “It was science, physics they were doing, and theoretical physics. They didn't see an application for it. They didn't see... it was just too up there. They wanted to apply their knowledge to real-life problems, which is what they consider to be engineering” (A4). A combination of the problem-based approach and heavy focus on industrial applications of engineering education reinforce this notion that good engineering should be useful. One participant expressed this as “some things are a very good technical solution, but they're solving the wrong problem” (A5) while another described good engineering as “the most advanced application of a technology or engineering to solve a problem. The most advanced application, which is not necessarily the application of the most advanced technology” (A7).

5.2.2 Systematic approach

As well as “problem-solving in general” (A7), participants specified that the ways in which engineers solve problems is an important part of good engineering practice. Broadly speaking the ideal engineer is supposed to “apply the scientific techniques to solving [these] problems” (A2). As well as “the application of science and technology” (A8) to these problems, it is the scientific approach to understanding the problem which participants described as being key to successful engineering. An engineer should use “analytic techniques” (A2) to understand the problem, suggesting that when “confronted with a problem, [they should] break it down into its components. Examine the components. Examine the details. Look for other factors that might be affecting it. I think that is kind of fairly well built into most engineers” (A5). This desire to find and solve the core issue is a key part of what defines good engineering practice according to multiple participants. As one described it, “anybody can go along and find a solution to a particular issue that they're having at a particular time, whereas I think engineers are a bit

more systematic about it. And I think the sign of a real engineer is that they can sit down and really understand the root cause of the problem before they actually find and start coming up with solutions" (A15). Another described the engineering approach as taking a complex challenge and trying to "boil it down to something that is very kind of objective, and to bring it back to the science" (A7).

5.2.3 Objectivity

The importance of objectivity as a core tenet of engineering practice is something which was stressed by a number of participants. Staff reported that one of the approaches that they encourage in their students is "we teach them to be objective in what they do" (A7). It appears that the intended purpose of objectivity is to prevent any kind of corruption or selfishness on the part of the engineer. It was suggested that objectivity "helps to overcome any social pressure to make a decision, for example...the kind of social basis like you want someone to like you or to do what's best for yourself" (A5). In this sense it appears to align quite closely with the Mertonian scientific norm of disinterestedness. This too is intended to prevent an individual from misusing or misinterpreting, intentionally or otherwise, scientific work for their own benefit. Instead, they should be an impartial adjudicator of empirical scientific observations.

It remains to be seen how suitable objectivity is as a norm to apply to engineering. There are questions as to whether it is even possible to achieve objectivity in this type of situation, as well as whether or not it is an appropriate end goal. Part of scientific investigation often involves isolating the subject of the study from its environment. A good scientific study is situated in a laboratory setting. This "instrumental rationality" (Buch and Bucciarelli, 2015) is appropriate as science is concerned with investigating a particular phenomenon and determining causal links, and so a deductive process of systematically removing factors can be a successful strategy. Staff participants in this study described the ideal engineering approach to tackling major societal problems as to "identify those things in a very objective way so they can boil down to something that is... is very kind of objective. Or we can, you know, bring it back down to the science and the engineering" (A7). This approach has come in for criticism in the literature as others have found fault with the assumption among engineers that complex social problems can be reduced to a technical issue and solved with a technical solution (Hacker, 1981; Faulkner, 2000,2007; Cech, 2013). It has even been argued that scientists and engineers assume this objectivity or "view from nowhere" (Nagel, 1989), or what Donna Haraway (1988) described as "the god trick", when identifying which problems constitute "the main big problems that society faces" (A7).

Even within the context of science it has been shown that the Mertonian norms can be and often are disregarded to the benefit of scientific work. It has even led to the development of counternorms, norms which directly oppose the original norms, but which have all been observed as part of good scientific practice (Mitroff, 1974). In the case of disinterestedness, the counternorm "self-interestedness" has been shown to motivate scientists as they compete for funding and recognition (Anderson et. al., 2010). It seems unlikely that engineering, which is much more "commercially driven" (A6), and has greater direct societal impact, could or should achieve a level of disinterestedness or objectivity comparable to that of science.

The result of scientific practice is certified knowledge (Merton, 1973). In engineering this is not necessarily the case. The fruits of engineering work are artefacts in the world. They exist surrounded by a full social context. These artefacts shape and are shaped by these contexts.

Understanding these contexts may require forms of knowledge which are not neatly captured by empirical scientific inquiry. This issue was in fact highlighted by a participant in this research who warned that “you probably can, you know, in a way go too far and lose the social thing entirely or lose it too much by taking a very analytical approach because it tends to reduce things to numbers” (A5). To attempt to apply scientific objectivity to engineering activities then risks ignoring the important social factors which are involved, while engineers, with their predominantly technical skill set may be ill-equipped to identify, understand or predict these outcomes.

This disconnect between technical engineering content and the social context in which it exists has been discussed in earlier chapters. In Chapter 4, a number of examples were found in the university prospectuses of this scientific detachment causing strange anomalies in the vocabulary used as the texts went out of their way to avoid introducing human or social elements to engineering discussions. In previous work, this has been discussed in terms of a feeling that introducing these “soft” issues would somehow pollute the purity of engineering science (Faulkner, 2000, 2007; Riley and Lambrinidou, 2015; Slaton, 2015) or, as it was described elsewhere, “dilute the engineering call” (Xavier, Wint, and Orbaek White, 2022).

A similar phenomenon was observed in these interviews. At times when participants discussed the social or political implications of engineering work, they appeared to suggest that integrating these aspects into engineering education was somehow abstract or unserious. For instance, one participant, while discussing the role of the profession remarked “It’s no use having [an engineer] who can talk, you know, very loftily about societal good and health care benefits...” (A7) while the idea of considering values such as *universalism* as part of an engineering decision was described as “a little bit airy-fairy” (A11). At times these interviews dealt with more abstract concepts and aspirational goals for engineering, but in this particular context “health care benefits” appears to be a relatively concrete metric and a low bar for the word “lofty”. Similarly, a civil engineering lecturer implied that they might be straying from the technical realm of engineering when they remarked “It might sound like a fuzzy word that engineers really kind of don’t use, but it creates a more liveable environment” (A10). Again, creating a “liveable environment” appears to be a very reasonable aspect of a civil engineer’s role and so it seems notable that the participant felt the need to explain themselves.

5.2.4 Efficiency

Another hallmark of a good engineering solution is a focus on efficiency. There is an old adage which says “Any idiot can build a bridge that stands, but it takes an engineer to build a bridge that barely stands”. This philosophy was echoed by a number of participants when describing the attributes of a good engineering solution. “Obviously it has to be effective. It has to do what it’s meant to do. It has to be efficient. And so, it does it at a reasonable cost and using reasonable amounts of energy” (A3). Others added that “it’s trying to get that balancing act” (A13) between the various engineering criteria being considered. A good engineer finds “elegant but economic kinds of solutions and is economical not just by not monetary standards but by use of materials and so on” (A2). Similarly, a good engineering solution achieves its goal and “does it at a reasonable cost and using reasonable amounts of energy or whatever. It depends what the problem is, what efficiency means” (A3).

5.2.5 Environmentally Sustainable

Environmental sustainability is one of the major problems which participants suggested are within the realm of engineering, and which an engineer should be looking to address in their work. It formed one of the metrics by which engineering educators judged engineering work as good or positive. An engineer should be trying “to make a difference from the point of view of the environment and sustainability. In an idealistic world they'd say, ‘you know, actually I can have quite an impact if I do civil engineering’, because the projects are generally quite large and the impact of those can be quite considerable” (A2). Sustainability was a common feature of descriptions of good engineering, which should tackle problems “hopefully in an innovative and sustainable manner.” (A14), while a bad engineering solution “doesn't take sustainability... into account” (A2). An example of this was presented by one participant from the discipline of civil engineering who pointed out that, “Engineers have an important role whereby their particular designs could, on one hand, facilitate car driving, or their designs could facilitate sustainable travel. I would argue that that's higher order engineering design and it absolutely addresses climate action issues and, and ethical issues” (A10).

However, the importance of sustainability was sometimes considered secondary to other criteria. One staff member, who is involved in teaching a degree with a focus on sustainability reported “you know, and some of the time we all want to say, ‘well, it's not about the money’. It's about that some of the time. In fact, in most of my findings, it's always about the money” (A11).

5.2.6 Ethical

The other metric by which engineering educators suggested engineering work could be assessed for social benefit or merit was in respect to ethics. Participants referred to the code of conduct which a good engineer should adhere to. In this case they were specifically referring to the code outlined by Engineers Ireland . One participant included this in his initial definition of engineering by saying that “Engineering is the deliberate use of intellect and resources to produce solutions to problems in an ethical way” (A9). This code of conduct was described as governing the behaviour of engineers in the profession emphasising that a good engineer “should behave professionally, they should behave in an ethical way or consistent with ethical norms and ethical frameworks” (A7). When asked how good ethical behaviour manifests in a graduate engineer one participant explained that “ethics can cover a whole variety of forms, from academic integrity to, you know, robust interpretation and processing of statistical data to questions about implications for design to informed consent for personal information” (A9). A good engineer should be “aware of the code of conduct and ethics” (A14) and apply them to all aspects of their work.

5.3 The Role of the Engineer

The section discusses the role that the ideal engineering graduate would play in society. This includes an overview of the tasks assigned to engineers as well as the context in which they work and to what ends. The section begins with a discussion of two of the defining roles of the engineering profession as described by the interview participants: problem-solving and technological development. The third aspect of the engineer's role which is discussed is the role that engineers play as employees. Finally, this section concludes with a discussion of the societal role of the engineer in terms of how and if the profession works to the benefit of society, as well as how this is portrayed in engineering education.

5.3.1 Problem-solvers

In Chapter 4 of this thesis, it was identified that problem-solving is perhaps the most ubiquitous role for an engineer according to the recruitment material. It makes sense then that it featured heavily again here. Every participant referred to problem-solving and/or providing solutions as part of their definition of what constitutes good engineering and the role of the ideal engineer. Each participant, both students and staff, in some way, expressed that “fundamentally a lot of engineering is about problem-solving” (A1). When asked about the daily activities of an engineer, once again “just solving a lot of problems” (S1) was a popular response.

Some participants were more specific with their definition suggesting that the role of the engineer is “to solve a particular problem that has been defined and that will make a difference, and doing so with a limitation of resources” (A15). Regardless of the specific field of engineering “It's always solutions-based. You define the problem first, find out what the potential solutions are and then determine the path to those solutions” (A11). Problem-solving is described as being so fundamentally part of engineering, that only engineers are capable of solving problems. One participant suggested that as a society “we need the profession to solve the problems. It will not be possible to solve the problems without engineers” (A15).

5.3.2 Innovators

The other main role of engineers which was discussed by interviewees is that which engineers play in the progress and development of technology. By extension this technological advancement was linked to the development and even evolution of society. The profession was given a significant amount of credit by participants for “the great, let's say, progress that's been made in the last 25 years, 50 years, 75, 100 years. Engineering has been at the centre of them and it continues to be at the centre. So, I would say engineering is central and core to the evolution of humankind. So, it's really critical, really central, and it's really made a huge contribution” (A1). Among the advancements discussed were things with huge societal benefits like medical advancements. For instance, “almost all advances in medicine in recent times haven't necessarily been down to doctors who are very reluctant to adopt new technology and new medicines, but down to scientists and engineers” (A6). The ideal engineer has a role to play in fuelling this development as they work “to promote innovation” (A12).

This focus on innovation and development was so firmly ingrained in one student participant, that when the work environment of an internship did not live up to that expectation, their conclusion was that “that didn't feel very representative” (S1) of engineering in general. This placement “was in an infrastructural engineering department within a large pharma company. So, there was a focus on just kind of keeping the buildings running, keeping the lights on, making sure there's clean water and electricity everywhere” (S1). Despite this being the only professional engineering experience of this student, their perception of the profession as one of innovation and change rather than maintenance and repetition outweighed what they witnessed for themselves. They still maintained that “the whole point is breaking with the traditions, coming up with new stuff” (S1) rather than “doing the same things over and over again” (S1).

Problem-solving and innovation were combined in some of the participants' responses. For instance, one staff participant quoted the expression “if there's no problem, [engineers] create our own problems to solve anyway” (A11). This speaks to this constant fuelling of development which participants included in the role of a good engineer. “As a profession I think it's centred around driving evolution, like whether it's, you know, technological evolution, like ultimately

things are always trying to be better or made easier for people” (A12). By persistently trying to improve and optimise technology and systems, engineers view every inefficiency as a problem to be solved. Their role is “creating things, perfecting things, improving different things...just to optimise them for the better of everyone who uses them in the world” (S12). They ask “‘Wouldn't it be great if...?’ and that starts off a new revolution or innovation” (A11).

5.3.3 Employees

While discussing the skills needed by an engineer (see section 5.2), participants suggested that engineers need “a broad spectrum, I guess, of skills that are required, um, you know, for societal use, really I guess in industry use” (A12). In that sense, part of the ideal engineering graduate is someone who is “career ready” (A12) and who is able “to meet the needs of the industry” (A14). This usefulness is directly linked to the role of engineers in industry and as employees with staff suggesting, in terms of their graduates, that “a primary aim... would be for the students to be employable” (A3).

In one case, a participant discussed designing a new engineering programme by first deciding what their ideal graduate would be like. This was specifically in relation to a Mechanical and Sustainability Engineering degree programme which was being established. The participant said that their imagined student “would be very well grounded in in energy related work [...] would have a really solid base in everything to do with energy conversion, you know, thermal energy transfer, all of that area and, but would be able to apply their trade in almost every area of industry.” (A8). This programme had specific sustainability goals, but also ensuring that this was presented in a way that was useful to industry was a key factor.

This is a recurring theme throughout this thesis. In Chapter 4 it was shown that during the recruitment stage, a significant amount of focus is placed on the employment options for engineers. In Chapter 6 the various influences on the content of an engineering degree will be discussed in detail. A significant factor in programme design is input from industrial partners. As teaching staff members explained “we're constantly trying to serve the needs of industry, and to be... I won't say competitive, but, you know, we're obviously trying to achieve the best for our students, so we want them to have the best opportunity” (A12). The “best for our students” here is to equip them with the skills necessary to find employment in the field. Students offered similar descriptions, describing successful outcomes from their programme by saying “everyone lands on their feet. Everyone got an engineering job of some description” (S4). With this in mind, it is clearly communicated that the role of the engineer as presented during engineering education is as an employee.

5.3.4 Value-neutral or Societal Good?

As discussed in Chapter 4, there are a range of conflicting views as to the role of the engineering profession, and whether it does and should actively pursue societal benefit, or whether the engineer should consider the application of technology to be beyond the scope of their responsibility. In this section the various views held by interview participants is discussed, specifically in terms of how the role of the profession is portrayed in Irish engineering education.

Many of the responses to the question “what is engineering?” included language like “the application of science to real world problems. Um, to try to improve the lives, I suppose, of people” (A4) or “to do something useful” (A6) with technology. They also believed that “the engineer's role in society... is to improve technologies... for the benefit of society” (A6). It was

proposed that a good engineering mindset should be concerned with “how your engineering contributions will help society and help humanity” (A1) and that these were specific objectives for a graduate engineer. “The protection and welfare of humanity and nature is vitally important. And I think we need to be producing engineers who are aware of that and have an appreciation for that” (A2).

A common theme expressed throughout was that while engineering as a profession should contribute to the common good, this was not an area on which engineering education was currently focusing. One participant believed that “we probably should be doing more...[to] raise these softer issues” (A4). Similarly, a final year student reported that “we never did anything in my degree on how you should consider the impact of what you do on society or the world, although there was a bit on the impact on the environment” (S4).

While some participants felt that more should be done to raise these issues, others felt that it wasn't their place to influence what constitutes a social benefit in engineering work. For instance, one participant felt that “it would be my own preference, I guess, to see things a lot more directed in more sustainable directions. But I'm not going to go in and say, ‘you have to do it this way’” (A5). The social impacts of engineering are described by staff as beyond the scope of engineering education on multiple occasions: as “softer issues” (A4), as “personal preference” (A5), and as “ideals” (A8). As such they are presented as unscientific and beyond the scope of engineering education. Students believed that what constitutes a societal good is “probably more of a moral line... which is so different from person to person... like some people will think something's fine and some people will think it's totally out of line” (S12) while another added “I think your kind of personal political leaning is probably a very big factor in that too” (S11). When asked about these aspects of engineering work one participant replied, “I think as educators, our job is to stay away from that” (A7). Instead, the view that engineers should be technical experts only was expressed by a number of participants. As one participant explained, “the way I look at it, I think our duty is to make sure that we've got really, technically excellent engineers so that they can then have the best set of skills to apply to these problems” (A7).

The choice of where a graduate chooses to work was the primary avenue through which participants described how an engineer could attempt to direct the impact of their work from a societal perspective. Participants reported that “it really does depend on the role and organisation that you're working within” (A1). The examples repeatedly mentioned during these interviews were the choice of going to work in biomedical engineering vs the weapons industry, or fossil fuels vs renewable energy. While staff admitted having preferences as to the kinds of work that they would like to see their graduates carry out, they again did not feel that they should influence this choice. As one participant explained “if students will go off and work for arms manufacturers or oil companies or something there's nothing wrong with that ... Well, there is, from my point of view. But that's not my place to judge that or to make those decisions or anything like that” (A7).

The perception is that within an organisation, an individual has limited scope for controlling how their work will be directed. Some believed that that was an issue of corporate culture, and that “culture is always leadership driven” (A9). In that context an individual has limited scope for influence. Even in the context of major ethical breaches participants felt that an individual engineer has limited choice. “Overall, it's probably pretty tough if someone ended up in that position.... At the end of the day, what can you do? You can leave a job or report them and if you report the company you're working for to someone somewhere, you might have been

better off just leaving the job, to be honest. There's some support, but it's still quite a tricky position" (A5).

Participants largely agreed that it is personal choice, based on multiple factors, including personal values which affect where a graduate will go to work. It was suggested by staff that "the value set that that individual has could easily dictate which company they go and work for" (A15), with students agreeing that "we're all we're all going to choose what we work on depending on our personal values or personal convictions" (S2). When asked about the motivations of their peers one participant replied "I don't think many people who I studied with would work for like a fossil fuel company or would work for.... actually there's one guy I know who works for a company that makes weapons, but the rest of them want to do something, has a net positive impact. So people want to do renewables and a lot of people do biomedical stuff because they want to do something that lets them sleep at night" (S4). However, it was also acknowledged that for others the objective is "just having a safe and stable job. And unfortunately, these morally dubious jobs are a lot of times the ones that pay really well" (S1). Another student discussed the specific engineering landscape in Ireland and how they believed that interacts with an engineer's motivations for choosing a particular career path. "It's a tough question. I would say engineers are probably more likely to go where the money is. I'm not so sure there's that strong appeal to the more noble stuff. I mean, I think it's a bonus, but if you look at Ireland, for example, we have medical device companies and we can say, 'oh, it's great. It's all very noble', but they actually do tend to pay better than the competition in the country. So it's not like people are doing it out of the goodness of their heart. It's also the better financial option for them" (S11). In other words, we have a situation where a branch of engineering which is often considered a good, noble, or socially beneficial choice is also one of the most pragmatic career choices.

Engineering educators do have personal views on what constitutes a public benefit and the direction that they would like to see the profession going. They also believe that the choice of where an engineer chooses to work is one of the most significant choices that an individual can make in terms of how their work will impact society. However, they do not believe that their role should involve influencing that choice. This is also the experience of students who feel that that choice "is completely personal. I don't think that it's instilled or kind of forced on you" (S4). This is consistent with the skills-focused view of staff which suggests that "when engineers leave their course, I suppose they should know about technologies, they'll know about how they can be applied and then what they do with that is up to them" (A6).

During discussions about whether engineering should be working specifically for the public benefit, a number of participants believed that engineering as a profession could sidestep that issue in many cases. They thought that the responsibility lay with forces outside of engineering which ultimately made the steering decisions which dictates the direction of engineering work. In terms of the social consequences of engineering work they felt that "an engineer on a day-to-day basis, mightn't actually be in the position to actually make those changes or make a decision that would have those impacts" (A14). A significant theme in these interviews was the role of engineers as employees (discussed above) and as such participants felt that engineers lacked the ability to influence the social impacts of their organisation. They believed that "for engineers, those roles are quite specific and niche. I think for your average engineer there's a disconnect" (S11) and that a barrier to engineering having a positive impact in society "is the kind of corporate decisions being made or kind of seeking profit and things like that, as opposed to someone who's actually designing the thing and making the thing" (S9). They were

of the opinion that “the impact that you as a, you know, an engineer can make is a drop in the ocean” (A14) and that the responsibility for shaping the direction and public impact of engineering work “is probably aimed more at people in power” (A14). This is a particular form of abdication of responsibility which has been discussed elsewhere (Conlon, 2008; Riley, 2008; Baillie and Levine, 2013). Here engineering as a profession absolves itself of the responsibility for the consequences of engineering work by playing the part of a loyal servant who acts in service of another master.

This argument is offset somewhat by the fact that many engineers enter management positions. One participant cited a statistic which states engineers are “more likely to be CEO within an organisation than any other profession” (A14). Management as a career path is something which is included in many engineering degree programmes, including a number of specialised “engineering with management” (A9) degrees, leading one participant to explain, “if we accept the idea that lots of engineers go on to become managers of not just engineering companies, but various types of companies, then how we teach, how we train those engineers obviously is going to have some influence on how they run and manage all sorts of companies in the future” (A5). However, even in these powerful positions, some participants still believed that engineers as managers could be constrained by other forces. “Yes, they’ll be making decisions, but for the best for the company. Whether that’s also best for humanity and welfare of people and so on and so forth. That might not necessarily be the same thing” (A14).

Within these roles, some participants saw scope for an engineer to work towards “objectives other than profit... that is becoming more of an objective for businesses and should be more of an objective for management as well.... Obviously the need for profit, but ... balancing it against environment or social considerations” (A5). There was a degree of scepticism about this being born from some desire of the profession to benefit the public though. “I guess because more sustainable product development is probably going to save money. Well, maybe it is from an ethical point of view.... But I would suspect it’s more grounded in a kind of industrial benefit in some way” (S11). There was some consensus among participants that environmental sustainability is a major societal issue which engineers have a role to play in tackling (there was far less discussion of the role that engineers play in causing sustainability-related issues). However, it was again highlighted that this goal wasn’t necessarily decided upon by engineers based on particular moral or value judgements. “It’s important to note that the engineering profession didn’t decide that the environment is important and that we’ve got to look after it. Society did. And that’s been driven down at us by mainstream media” (A15). A similar position was expressed by another participant who suggested that “I think what we have to do is reflect exactly whatever the current status quo, you know, whatever the current guidelines are, the current thinking is, or the best science is, or whatever correct government policy is in that space” (A7), though in this case it was said with regards to how engineering educators should approach topics like sustainability or engineering topics that have major social implications.

Other participants accepted that the engineering profession was often constrained or directed by external policy, be that corporate or political/regulatory, but also acknowledged the responsibility that the profession has in terms of shaping this policy. “As an academic... you’re essentially trying to shape policy. You know that is the end goal with the research. You know you’re trying to shape policy” (A8). Another responded to the question of whether engineers should be trying to influence decision makers with regards to technological policy direction by saying “Yes, they have to be. They’re the only ones who should be really. They certainly should

be more than they are" (A11). Multiple participants believed that as experts in the field of technology, engineers are uniquely able to understand, and advise on issues around engineering work, saying "we have all of that technical knowledge behind it. We probably might understand better than others what the negative consequences of making a decision might be. And so we probably have a lot of responsibility to at least argue those things. But yeah, at the end of the day, you're often not the one making the final decision" (A5). This echoes ideas expressed by Verbeek (2006), among others (Zimmerman, 1995; van de Poel, 2001), as they outline that technical knowledge is required to fully understand the full range of solutions, as well as the potential consequences of each.

As was highlighted, quite often those in power do not have this technical knowledge. For instance, multiple participants asked, "how many engineers are there in the Dáil (Irish Parliament)? That's an issue. It's a big issue, I think, to be honest with you" (A11), and "How many engineers are politicians? I don't know of any politician, certainly in this country, that is an engineer" (A14). Instead, the role of engineers, be it as direct consultants or through academic publication, is advisory. "They must get advice from somebody. But again, advising isn't decision making. You know what I mean? The decision maker ultimately is the politician. Maybe they need more engineers in the door to say at the decision-making level, to say, I think, as you say, 'we'll put the thumb on the scale there a second'" (A11). Another participant considered whether other countries, who they believed had more effective planning and governing, were more successful because "maybe they have more engineers in positions of responsibility" (A15).

It is interesting to see the opinion expressed that not enough engineers are in positions of power, when considered alongside all of the major societal roles that engineers do play, from major "large-scale infrastructure projects" (A2) to "almost all advances in medicine in recent times" (A6), to the high proportion of engineers in management positions. These are all aspects of engineering that get praised, and yet when discussing the capacity for the profession to steer its own output towards public benefit, participants were more likely to describe the profession as being controlled by external factors. The attitude described was one which suggests that engineers are most comfortable when given a "discrete little problem that needs to be solved, and that's got a very kind of defined start and end" (S11), and beyond those constraints "that becomes probably, a management decision then or a corporate social responsibility decision ... so there's probably a passing-off of responsibility... but to be honest, it's not something that's discussed [in the engineering classroom]" (A11).

A number of participants felt that the work of engineering by its nature contributes to a public good. They described the core of the profession as "trying to provide solutions to tackle, you know, the big problems, the big global problems" (A8), and by extension "if these are the main, the big problems that society faces...[solving them] will make it a better world as such" (A7). Delving a little deeper into this problem-solving role of engineers, participants were asked about the nature of the problems which engineers should be solving and how they are identified. Responses often included phrases like "a need is identified" (A4) or "I suppose society in general [identifies the problem]" (A6) and of course, "I suppose a lot of them are commercially driven" (A6). When engineers are presented with a problem "they like it to be set out in a nice brief" (S11), with predefined goals. The role of the engineer, as discussed by participants here, is to "solve a particular problem that has been defined that will make a difference, and doing so with a limitation of resources" (A15). The various analytical and scientific methods of investigation and technical problem-solving and innovation are then

channelled into tackling that brief. While they are encouraged to “push it to its boundaries and to try to see what [they] can get out of the brief and how far [they] can push the boundaries” (A2), their role was not to set or outline these briefs. This is consistent with previous criticism of problem-definition in engineering education, when it was pointed out that “it is significant that every problem that undergraduates encounter begins with the word ‘given’” (Downey & Lucena, 2018).

Staff asserted that “when we think of engineering, we’re always thinking about how we can better the lives of humanity” (A1), and highlighted “good examples of how technology can be used to benefit society” (A6). However, the role of the engineer as an employee is highlighted, both as a strength of the degree, but also as a constraint. For the participants, engineers can occupy senior positions within a corporate structure but their preference for working within narrowly defined briefs and to externally determined objectives limits the effectiveness of engineering in pursuing a public good. Unless engineers are willing and able to engage in defining the problems that they will solve, it does not seem justified for the profession to claim that it serves the public good. The reality is more likely to be that it can serve the public good, just as it can do the public harm. Given the framing of engineers as diligent employees in industry, it seems likely that engineering would only serve the public good to the extent that the latter aligns with private corporate interests, and would only refuse to do harm when legal frameworks prevent it. It was expressed that, “I hope that our graduates wouldn’t take that type of approach, but I don’t think it’s my job to educate them on that or to be involved in that” (A7). For reasons grounded in objectivity and depoliticisation, even when university staff believe that the role of the profession is to benefit society, they do not feel that their role is to instil that in their students.

5.4 The Ideal Values of Engineering

As has been discussed in this thesis, values are beliefs about desirable end goals, which affect decision-making (Schwartz, 1992) and so are an important lens through which to examine this description of the ideal engineer. The values of a profession are a significant part of the culture of that profession and influence the objectives which it will work towards. In section 5.4.5 above, it was suggested by participants that personal values are a factor in an engineer’s choice of where to work and by extension, the impact that their work will have on society.

Despite the importance of values in professional socialisation, this was an aspect which participants reported not having considered extensively. Instead, general discussions and descriptions of the ideal engineering graduate contained very little in terms of explicit values. As explained above, the skills which an engineer would require dominated the conversation, while participants did not discuss values until explicitly prompted to do so. What follows is based on the conversations which followed these prompts. There was also a significant lack of consensus as to the role that engineering education could or should play in influencing student values. While the staff members who were interviewed were all in agreement that providing students with the necessary skills to be an engineer is part of their objective, there was quite a lot of disagreement in terms of the educational objectives relating to values. A full spectrum of views were reported considering whether engineering education can, does and should influence the values of students and whether this happens intentionally or not.

5.4.1 Should Engineering Education Try to Influence Values?

When asked about their objectives with respect to shaping students' values, the opinions expressed by staff were often contradictory, even within responses from the same individual. At times participants would initially baulk at the idea of influencing student's values or beliefs. They appeared to be reluctant to be seen as trying to "tell someone what to think" (A8). However, as the interviews progressed, and specific ideas and situations were discussed more thoroughly, this stance softened somewhat. For instance, there are a number of aspects of socialisation which staff would refer to as professional skills or attitudes. In other cases, questioning revealed latent values and norms which were embedded in engineering education in the form of "mindsets" (S4) and "ways of thinking" (A4), and so were not considered by staff upon initial questioning. In some cases, this section contains seemingly conflicting statements from certain participants. The purpose of this is not to demonstrate some kind of hypocrisy but rather to show the various ways in which values, and societal issues are being considered within engineering education.

When faced with the question of whether engineering education should be trying to shape or influence the values of students, many academic staff were against the idea. The arguments made varied with some believing that influencing students' values wasn't something that engineering education should be doing while others suggested that it wasn't something that they could do. The arguments against attempting to shape the values of engineering students were grounded in ideas of depoliticisation and value-neutrality, while those who claimed that it is impossible believed that values are inherent traits of students or sought to minimise the influence that education can have on them.

One of the more firm negative positions taken by staff was that engineering education should not be trying to influence students' values. They believed that this is not within the scope of engineering education, and that they, as educators, should not be trying to engage in this area. Participants felt that they shouldn't be steering their students towards certain ideologies, or defining what represents a public good or bad. Multiple teaching staff said that they "try not to push values too much" (A5). Values and the "softer" (A4) social considerations were seen as "a personal choice" (A7), and staff felt uncomfortable exerting influence on this. "I don't think it's our job to promote particular value systems or particular, um, you know, to impose our own opinions on students as educators" (A7). This participant suggested that engineering education should stick to "our own domain" (A7), and that "our strength here is really in being really true to the science and the engineering" (A7). It's interesting to see the word "opinions" used here. This was said in the context of a discussion about the application of engineering knowledge and effort, and so it is notable that this was not considered relevant.

Staff who took this position often held very pragmatic views as to the purpose of education. They were of the belief that the major obligation of staff towards students was to equip them with the skills required by employers and "trying to get them career ready" (A12) and that "if I'm perfectly honest, you know, education for kind of personal development or education for education's sake is [...] for the arts" (A6).

Another position taken by some staff members was that personal values are not something which engineering education could influence. Values and related traits were described as inherent traits of the student, and not something that could be shaped by them as educators. As one member of the teaching staff said in relation to personal value profiles, "I'm inclined to

think that you're kind of born like that" (A4). Another said that "I suppose you need a certain kind of mindset" (A11), and also that "you need to have this from day one" (A11).

It was also said that values are "built into the students when they arrive. We could tweak them a little bit, but we can't change them completely" (A3). This hints at a separate, but related argument, in which staff believed that values could be affected and shaped, but that in the context of the wider world, engineering education would not have a significant enough impact. They believed that there were too many competing influences and so for engineering education to attempt to direct a student's values towards a particular goal would be futile. "I don't think you can decouple the education system from the context in which it operates. So the views and values of people are formed by so many complex interactions" (A9). This participant was open to the idea that there were values that they would like to see in their graduating students, but did believe that "what happens within the control volume of the educational system is only one small part. Education is part of the development of a person" (A9). A similar opinion was expressed by a student who, in response to a question about whether they thought that engineering education had changed their values, responded "it's very hard to decouple, what specifically is like from the education, what is from like just being on campus. I think being in college is very maturing, um, in a very good way" (S10).

"The person that emerges at the end of that education is a product of a number of things, and the general societal values and what they experience" (A9). While this is true and reflects what is found in some of the literature (Bourdieu & Wacquant, 1992; Calhoun, 2000; Schwartz, 1992), it ignores or minimises the enhanced influence that a closed societal group such as a profession has on those seeking to gain membership. Students in this situation are in the process of developing their professional identity and exploring the culture within the field. An educational institution represents a trusted source of information about the field and the profession and wields a disproportionate influence on the students' understanding of it (Bradley, 2013). In fact, as the discussions progressed, this same participant appeared to arrive at a similar conclusion themselves. "it's also strongly influenced by their journey through [the engineering profession] and inspiring figures, whether that's somebody they work for or work with or somebody they're taught by. And I guess as an educator, I'm not without bias. But I'm always struck by when famous people, high achievers in any field, talk about what influences them and it almost always comes back to a teacher. Somebody they were taught by at some point, can really have a very fundamental shift in terms of their values and how they operate and how they think about things" (A9).

It has also been argued elsewhere (Riley, 2008; Godfrey, Crick and Huang, 2014; Leydens *et al.*, 2018; Kramer, 2022) and was described by interview participants here, that part of an engineering education involves learning to think like an engineer. Multiple people have described an "engineering mindset" (A4), and a way of approaching the world as being part of becoming an engineer. Another explained that part of their role is "teaching people to think like engineers" (A15). This then affects the way in which individuals perceive and experience society and thus indirectly shapes the values they will develop based on those experiences.

Some staff members accepted that their degree programme could influence student values, but didn't feel that it was something which should influence their teaching. One participant answered the question of whether they believed that education shaped values by saying "yeah, to some extent, but not directly. I would say through experiences, maybe mostly and through I mean, you're not going to lecture people on this content on these values" (A6). This implicit values education is one of the more affirmative views expressed by participants here.

No participant suggested, in explicit terms, that shaping the values of students is an objective of their degree, however a few participants believed that engineering education did influence students in ways that hinted at underlying values. For instance, one participant used the phrase “you have to make people good global citizens” (S4), while another spoke about their colleague who is “very much on the idealistic side, and that's why she ended up being a lecturer in this field [sustainability engineering]. She wanted to effect change” (A8). Given that participants lacked specific training in values as a sociological or psychological concept, the variation in terminology is understandable. They were also referred to as “personal philosophies” (A11) by a participant, who came to the conclusion that unintentionally influencing values is inevitable because “if you're a mentor to students, you like them to kind of come out some way in your own mould as well” (A11).

Another staff member perfectly highlighted the issue of vocabulary around values by saying “I think the individual development of the person is a conscious part of curriculum design, whether those values are... you know, this is one way of notion of a value, one way of labelling it. I think values are present, but probably more implicitly than explicitly, I would say” (A9). This participant also believed that educators could influence the values of their students through academic rewards and grading. “If you get your curriculum and your assessment right, then the values that you're trying to promote are the ones that are incentivized through the student performance. So even if people are choosing because they want high salaries, they don't do as well as the people who are meeting the values you want” (A9).

5.4.2 Ideal Value Priorities

Here the personal value priorities of the ideal engineering graduate, according to those in engineering education, are discussed. As has been outlined above, a significant amount of the value content of engineering education is implicit and unintentional. Many participants did not include value-related topics in their descriptions of the ideal engineer of their own volition. In this section the results of direct questioning about the value priorities of the ideal engineering graduate are analysed, along with the values implicit in the skills and role of the engineer, as outlined in the previous sections.

The Schwartz value system is the dominant system used currently in psychology, however it is not something which engineering educators are generally familiar with. Similarly it was discussed in Chapter 2 that one of the major issues when discussing values is the huge array of definitions and categorisations which exist (Rohan, 2000). As a result, when discussing the values of the ideal engineering graduate the values listed by participants did not necessarily fit with the standardised definitions used by Schwartz and others. In some cases what participants listed would be better considered as norms or attitudes. In other cases, they represent specific values which fall under the more broadly applicable umbrella values created by Schwartz. For the purpose of this analysis, the Schwartz value which underpins these norms or attitudes was identified and discussed as such.

Participants were also specifically asked to rank the Schwartz values according to how they believed the ideal graduate should prioritise them. Participants were presented with a series of cards which featured the title of the value and a short definition. In the case of online interviews, this exercise was carried out using a shared document which featured the same information. The interviewer introduced this activity by giving a short explanation of the concept of values and how they affect decision making. Based on each individual's ranking,

each value was given a score from 1 to 10. The mean scores were calculated for students and staff. For staff, the mean values were calculated separately for university and technological university staff respectively, as well as the combined total group. The results of this are shown in Figure 5.1.

Combined Staff	University Staff	Tech. Uni. Staff	Students
Self-Direction	Universalism	Stimulation	Stimulation
Benevolence	Self-Direction	Self-Direction /Benevolence	Universalism
Universalism	Benevolence	Benevolence/ Self-Direction	Self-Direction
Stimulation	Stimulation	Universalism	Benevolence
Achievement	Achievement	Achievement	Security
Security	Security	Security	Achievement
Tradition	Power	Tradition	Tradition
Power	Tradition	Conformity	Hedonism
Conformity	Hedonism	Power	Conformity
Hedonism	Conformity	Hedonism	Power

Figure 5.1: Ordinal Value Rankings by Interview Participants

Comparing the value profiles suggested by each group we can see some general commonalities. All three sets of value priorities can be split into three tiers. In each case, *Achievement* and *security* were rated as the middle priorities, taking the fifth and sixth positions respectively. The same group of four values, namely *self-direction*, *benevolence*, *universalism* and *stimulation*, were rated as the highest value priorities for the ideal engineering students by all groups, while *tradition*, *power*, *conformity* and *hedonism* made up the bottom four values in each case.

Interestingly, university and technological university staff differed on what the top value priority should be. University staff favoured *universalism* and rated *stimulation* in 4th place, while for technological university staff the opposite was true. Both groups rated *self-direction* and *benevolence* in second and third place (the two were evenly matched in the case of the TU staff) meaning that for the combined total, *self-direction* topped the list with *benevolence* in second place. Students rated the same four values at the top of the list, with *stimulation* being ranked in first, followed by *universalism*, *self-direction* & *benevolence*.

5.4.2.1 Self-Direction

When taken as an average across all staff participants, *self-direction* was the most highly ranked value for the ideal graduate to prioritise. The primary justification for its high ranking was related to creativity and the freedom that an engineer needs to generate new ideas. As discussed above, creativity is a skill which is highly valued in engineers. A number of participants related this to *self-direction*. When asked how they felt *self-direction* applies to an engineer one participant replied “I think it's your freedom of expression in creating and exploring, and autonomy to make your own decisions. I think otherwise you're constrained and

you can't really fully do your job as an engineer" (A7). Students were similarly of the opinion that "you can't really be a good engineer without having creativity. Creativity has to play a part in it" (S2).

As a profession with problem-solving as part of its remit, participants suggested that engineers should value the opportunity to explore their own ideas and solutions. Having this freedom is considered necessary to create new ideas. "If you don't have *self-direction*, it stifles innovation" (A6). Another participant said that they "prefer to think that the good engineer would be one who would be able to think outside the box to use the cliché and come up with novel ideas and different ways of solving problems and not just turn the handle and do what everybody always does in this situation" (A3). Innovating was described as one of the major roles for engineers by participants across all groups and as such, seeing *self-direction* featuring highly on each list here appears consistent.

The other major manifestation of *self-direction* in the ideal engineer was in "bringing completed projects to the table. Not more questions about how to do something" (A12). Staff described the need for an engineer to be able to take on a complex project rather than being given a series of discrete tasks. Discussing it from the opposite perspective, one participant explained that "nothing kind of gets me more irritated than somebody who comes in and says, 'Now what should I do?'" (A4). Staff imagined the ideal engineering graduate as someone who is comfortable "taking the initiative to make decisions" (A5). When asked to think about some of the students who have stood out over the years, one participant recalled someone who "was particularly self-motivated, self-driven. He didn't care what got in the way. He was going to solve it" (A15). This was echoed by a student participant who has industry experience. They recalled the best interns in their workplace being the ones with "a can-do attitude. They just have a tendency to be more eager to...just throw themselves into a task that they have no prior knowledge of... and they'll come back with something that's usually pretty decent with minimal guidance" (S11). This is preferred to others with whom "you need to do an awful lot of hand holding" (S11). Another participant suggested that "you can't beat somebody who's enthusiastic, you know? They just jump out at you. They're really good students, you know, And they're the ones who are coming up with ideas or entering competitions" (A4).

5.4.2.2 Benevolence

As shown in Figure 5.1 *benevolence* was the second-highest ranked value by staff, on average when discussing the value structure of the ideal engineer. In discussions with participants, it was often linked to "collegiality" (A2) and "trying to help people solve problems" (A7). Team-working skills were included as an important skill for engineers, particularly given that engineers usually work as part of larger organisations. "I think people being kind to each other and having a healthy team dynamic is absolutely crucial. You don't want to get someone who can't work with others or who just has an incompatible personality or a bad attitude or something" (S11).

However, during the ranking process one student participant expressed that *benevolence*, which they took to mean "being nice to people" (S9) might be an important trait in general, but was not particularly relevant to engineering. To begin with they had placed it near the top of the list "with *universalism* and *self-direction*" (S9), but decided to change it. "I had *benevolence* up there. But now after saying it's more about being nice to people, to kind of put it in simpler terms, right? Maybe I would, maybe I'd swap those two... maybe move *benevolence* even further down" (S9). Another participant similarly expressed the view that "when it comes to the ideal engineer, I think the big picture is more important than being nice to those people in your

immediate surroundings" (S10). This was a common sentiment among those who rated *benevolence* below *universalism*.

Even some of those who did rank *benevolence* more highly than *universalism* did so with a justification which suggested universalistic intentions. Part of this was due to the perceived achievability of *universalism* as a goal. When discussing *universalism* one participant remarked "it's a bigger thing obviously, and it's maybe less controllable, whereas everyone can be kind to the people around them. And if everyone was like that, I think it would be a better place" (A4). Similarly another commented that they "prefer to take the small bites first. How do you eat an elephant? One bite at a time, whatever that thing is. So take the small bites and eventually get to the big bite. So maybe *benevolence* and *universalism* are hand in hand. If everyone does enough *benevolence*, maybe *universalism* will come from that" (A11). In this regard, participants were viewing *benevolence* as a pragmatic approach to *universalism*.

The high ranking for *benevolence* is consistent with an outlook that believes that the engineering profession plays a positive role in society and "improves the lives, I suppose, of people" (A4). Many believed that "engineering is problem-solving different issues that arise largely based in society to benefit society" (S12). They believed that this view is consistent with prioritising *benevolence*. However, the opposing view is supported by certain aspects of the engineering approach to problem-solving as described above. Scientific detachment, and an analytical approach which favours objectivity and efficiency, are less associated with a value with such caring connotations.

5.4.2.3 Universalism

University staff rated *universalism* as the top value priority that they would like to see in a graduate engineer. With a significant portion of participants discussing the role of engineers in terms of helping and improving things for society, it seems consistent that the ideal engineer would prioritise a value which supports the "welfare of humanity" (A15) and the belief that "that has to take precedence over everything, doesn't it?" (A15). In many cases, those who had rated *benevolence* lower, had prioritised *universalism*. Those in support of each raised similar points related to solving problems for the benefit of society. Those who favoured *universalism* suggested it was a more important value for an engineer, as their approach to problem-solving, and thus benefiting society, is "more systematic than personal" (S1). This reconciles more easily with the themes of objectivity and impartiality evident throughout engineering education than the value of *benevolence* had. As one participant suggested "I suppose because we do tend to analyse things as opposed... to just dealing with people socially more directly. That probably does help with *universalism*, to some extent at least" (A5).

The link between *universalism* and sustainability was also highlighted as an important learning for engineering graduates. Staff want to instil in their students that the "protection of welfare and humanity and nature is vitally important... We need to be producing engineers who are aware of that and have an appreciation for that" (A2). Another staff member suggested that there is a potentially utilitarian benefit to prioritising sustainability and, by extension, *universalism*. They cited a move towards "sustainable management thinking and objectives other than profit. That is becoming more of an objective for businesses and should be more of an objective for management" (A5).

Universalism was discussed in terms of the positive ways it "can better the lives of humanity" (A1), and also in terms of the potential negative effects that the ideal engineer would work to prevent. As one participant explained, "I put it number one, because the engineer has to be

able to stand up and say, hold on. Is this going to have a negative impact on what's going on around us in terms of the environment? Is it going to have a negative impact on other people?" (A15).

A number of those who had rated it lower believed that *universalism* did so because they thought that it sounded like "a very naive perspective" (S10), or "a little bit airy-fairy" (A11). They found it to be too idealistic for an engineering graduate to be pursuing these objectives. Some student participants suggested that while they would like an engineer to have selfless values such as *universalism* and *benevolence*, they weren't convinced that the engineering industry would be receptive to them, and that as a result they would be a less effective engineer. One student felt that "it's a pretty indifferent industry. We're not activists here, unfortunately" (S9), while another justified their ranking (they had ranked *universalism* in fourth place) by saying "until the industry as a whole finds a moral solution before a cheap solution, I couldn't possibly put *universalism* any higher" (S10). Another suggested that while their ideal engineering graduate would have *universalism* as their top priority, "the world will probably end up chewing them out. Um, which yes, it is true. My dad has warned me" (S10).

5.4.2.4 Stimulation

Stimulation is the final value which featured in the top group which the ideal engineer should prioritise, and was rated as most important by staff participants from technological universities and by student interviewees. Language including "pursuing novelty and change" as well as "challenge" are among the defining goals associated with this value (Schwartz, 1992). Participants saw this as relevant to an engineer. As discussed in Chapter 4, one of the recurring themes in engineering education marketing materials was the question of "how things work". An interest in investigating and understanding this are presented as a significant indicator that a student might be suited to engineering. This is evident again here as participants cited "curiosity and interest" (A14) as a significant trait that they would like to see promoted in their graduates. These traits are motivated by the value of *stimulation*, as well as *self-direction*. One participant suggested that "it's probably one of the most important things" (A5) for an engineering graduate. Curiosity was described as being important across all engineering disciplines. "No matter what the project topic, I would love to see evidence that they've gone away and that they've learned something. They've developed some kind of expertise in something they didn't previously know about" (A12). Students shared this opinion with one participant saying "one of the key... maybe *the* key trait is being interested and curious. So then *stimulation* would kind of play into that...that's kind of the key because... if you're interested in something and spend time on it and enjoy it, the technical knowledge will follow" (S1).

The importance of novelty and innovation in engineering also aligns with the value of *stimulation*. As explained by one participant, "when I'm talking to [secondary school students], I say 'if there's no problems available then engineers make their own ones to solve'. So, going back to that, there's no real need for a wireless phone. Back in the day the old phones were perfect, but someone said, 'geez, wouldn't it be great if...' And that's what you need to have as an engineer. 'Wouldn't it be great if' and that starts off a new revolution or innovation" (A11). Part of the role of engineers according to participants is fuelling innovation and developing new solutions. Seeking challenges and novelty and change were all seen as relevant to this innovation. "Seeking out those kinds of challenges and trying to figure out some solutions to them, I think would be a good quality for an engineer" (S4).

5.4.2.5 Achievement

Achievement was rated as a mid-level value on average by both groups of staff participants. Most described it as a useful or important value in terms of motivation, but did not feel that it should represent the primary objective of an engineer. They did not believe that the ideal graduate should “carry out [their] engineering activities purely focused on what [they] will achieve from it or what will come out of it from [their] personal perspective. So I would rank that much lower compared to how engineering contributions will help society and help humanity” (A1).

There was a subset of staff participants who rated *achievement* quite highly. Two participants, one from each type of educational institution, rated *achievement* as the most important value for a graduate engineer while another rated it in third place. All three of these participants were very explicit about employability of graduates being a key objective. They also favoured the values of *self-direction* and *stimulation*, rather than either *universalism* or *benevolence*. They justified their choices as the values which would make the best employees.

They related *achievement* to motivation and determination, the logic being that if someone gets a lot of personal satisfaction from *achievement* then they will pursue it enthusiastically. “If you were going to hire an engineer, you'd want somebody who wants to be successful who can actually...get things done and achieve things” (A3), is how one such participant explained their choice. The other was of the opinion that “a good engineer is someone who is driven, who wants to achieve and who's not, you know, shying away from jobs” (A13). Participants felt that, for an engineer, it is important “when you take on something that you see it through to the end and it's not a case that maybe halfway through that you find things aren't working out for you, so you lose interest and you drop it” (A1). This was described as “a certain work ethic” (A11), “a hunger” (A15) and “that kind of dog with a bone sort of thing” (A2). A willingness to take on a complex challenge and work through to a solution is something which was desired by virtually all staff participants in their ideal graduate. They described a good engineer as “somebody who is willing to put their hand up for a particular project or take on a particular project and is not afraid to take on challenges” (A13). Staff want their students and graduates to be driven and enthusiastic in their work and valuing *achievement* was seen by some as the value which most accurately reflected that.

Others were slightly cautious about the level of emphasis that a person should place on *achievement*. To one person it seemed “self-serving” (A5), while another warned about the dangers of too much competitiveness in a team. “You do want them to have a certain amount of ambition because that kind of makes them hungry. But, for example, if you had two grads on the team. You don't want one of them to try to upstage the other because they think it's gonna help them progress, right? You want them working together as much as possible and sharing information. But if one is out there trying to outshine the other, that's not really going to happen” (S11).

5.4.2.6 Security

Language relating to safety and security resonated with participants when they considered the placement of this value in the ideal graduate's hierarchy. They believed that an engineer needs “quite a strong awareness of health and safety” (A1). No participant rated this as the highest value, however one person rated it in second place. They saw the health and safety aspect, but also looked at the role of an engineer more broadly. “I mean, safety. Safety, definitely. Yes. That is one of my reasons for putting it up there. But I think that element of society, peace and harmony, you know, it's something that I think is important to what we do” (A2). This

participant was from the field of civil engineering and saw the relevance to the role of that discipline in shaping certain social interactions and structures. Another civil engineering staff member had a similar view suggesting that of all of the engineering disciplines, the safety and harmony of society is more relevant to that discipline than the others. "By the very definition of what civil engineering is, I just think it's probably stronger among us than, um, the other engineering disciplines" (A10). There is some evidence in support of this, whereby civil engineers were found to have a greater sense of social responsibility than mechanical engineering students, though less than environmental engineering students (Canney and Bielefeldt, 2015b)

For others, beyond the immediate health and safety aspects of their designs, the connection was less clear, with a number "finding it difficult to see what harmony and stability of society, what that would look like in a graduate engineer" (A6).

5.4.2.7 Tradition

Tradition is the first of the four bottom ranked values by both groups of staff participants and students. Two participants did rate it as the third and fourth most important value. In discussions these participants focused on the aspect relating to respect for culture and customs and related this primarily to working within multicultural and international groups. For an engineer "it is very important within companies nowadays that you do respect... other people that you're working with, or if you're working for a client or another organisation that you show respect to them, and you accept their customs and their ideas and traditions" (A13). They believed that the main way *tradition* is important to an engineer is "from the perspective that they need to be conscious of other people's traditions" (A2).

Another participant specifically discussed the direct relevance of *tradition* to engineering work, as opposed to the work environment. This participant believed that an engineer would be "very foolish to ignore *tradition*" (A9) and that "an understanding of context is vital to good design practice... and one of the dimensions of context is going to be the *tradition* of the people and the culture and the society that's around you" (A9). Similarly, a student participant commented that "if you're solving problems, you want to do it in a way that like that works for everybody, you know?" (S10)

Most participants accepted the interpersonal aspect of it, and acknowledged the relevance of understanding how and why things were done in the past. For instance "not reinventing the wheel" (A3) was mentioned multiple times. Not all students believed in this though as one believed that "for engineers, the whole point is breaking with the traditions, coming up with new stuff. Because if we keep doing the same things over and over again, that's just not a good engineer" (S1). This illustrates the conflict between the value of *tradition* and the goal of innovation and development. Participants justified placing *tradition* lower on the list by describing it as a restriction on an engineer's thinking, believing that "at one level, *tradition* sort of perhaps sets the boundaries" (A1).

The placement of *tradition* in the bottom group, but not at the bottom of the list reflects the compromise that participants reached between balancing a need for "understanding constraints and in the environment that you're working in from a cultural perspective" (A6) and the freedom and creativity associated with the higher ranked *self-direction* values. One participant summed this up as "I do think *tradition* is important, but it shouldn't be overarching. So, one should be aware of it but not be bound by it" (A1).

5.4.2.8 Power

Staff participants expressed that some degree of *power* is necessary in order to express other values such as *self-direction* and to engage in benevolent behaviour. Without some aspect of *power* or “agency” (A11) then staff felt that the “full realisation of *self-direction*, and *universalism*” (A9) among other values would be impossible and so the ideal engineer has to “have the ability to make those decisions for themselves” (A11). This sentiment was also expressed as “if you have *power*, you can make decisions. You're in a position to make those decisions that impact people” (A14). Students also believed that “*power* is a valuable quality to have” (S4), though they were quick to add “Not in a negative way, but just to be able to fight for something that you or a group wants or need. Having the *power* to do that is something that's valuable” (S4).

Another participant pushed this argument one step further, suggesting that some degree of pursuing *power* was a responsibility of engineers, they “have a responsibility to step forward, to make an impact. And that means having the *power*” (A9) and to avoid being “the barstool philosopher” (A9).

These values were specifically being ranked from the perspective of a graduate engineer. Decision-making and management on some scale are likely to form part of the work of most engineers over the course of their career, but participants were of the opinion that this isn't something that they would like to see graduates actively pursuing. It was expressed that “if you're attracted to *power*, you're attracted to hierarchy and, in a sense, you're probably attracted to the bad side of corporations” (S11). “Ultimately, as you progress, you probably do have more *power* over people and over situations, but I think it's something you grow into rather than something that's going to be important straight away” (A2). Engineers are likely to end up with some *power*, but it's not a goal that they should be prioritising over any of the higher rated values. Instead, it could facilitate the expression of other values. “If you have the right approach, you know, trying to ensure welfare of those around us and so on, and then if you also have the *power* to do something about it, okay, those together would make a pretty good engineer” (A4).

5.4.2.9 Conformity

The primary case presented against the prioritisation of *conformity* is again, because of how staff felt it opposed innovation and development. They felt that someone who prioritised *conformity* would not be suited to a profession which “is fundamentally a profession of change” (A9). Once more they contrasted *conformity* with the importance of creativity and the need to promote innovation and free thinking” (A12). With the importance of innovation and development to the field of engineering, staff felt that rather than “maintaining the status quo, I think that people should be trying to improve things” (A4).

The one caveat which gave participants pause for thought was the social aspect of *conformity* and the need for engineers to integrate into a workplace. They suggested that some degree of *conformity* can be helpful to avoid “rocking the boat too much” (A11) and that “on the other hand, to be successful in some organisations, you might have to conform quite a lot” (A3). Not innovating for the sake of innovation and “going along with the group decision or doing things because it's the way they've always been done in their business, is something that tends to be the low risk option” (A5) and so is less likely to cause a problem for an engineer at work.

5.4.2.10 Hedonism

Hedonism was the lowest rated value on average among staff participants and was also the value which eight of the fifteen staff participants rated as least important for the ideal graduate to prioritise. Among students it was slightly higher, though still in the bottom four. The case presented in favour of *hedonism* was related to “work-life balance” (A5). The point was made both from an individualistic perspective as well as a managerial one. The participant in question related this to teaching engineering management content and pointed out that as a manager an engineer can have a significant impact on a work environment. This directly impacts work outcomes as “if your staff are having a good time and probably tend to perform better and stick around and you'll have less turnover and things like that” (A5).

Most felt that this was a small consideration compared to other values which an engineer should prioritise. “So even though it might be important at an individual level, it's when you apply collectively, perhaps it may be or it's less altruistic compared to *benevolence* in *universalism* as defined here, too” (A1).

In a small number of cases, participants linked *hedonism* to those with a genuine love of engineering and suggested that for them it can be a useful value. “It's not that common. But if you have someone who really loves it, the output you get will be on a different level... Across the board, you've got a couple of rare cases where they just live and breathe it. And the stuff that they come out with is different level” (S11).

In general, though, when participants spoke about students enjoying a particular aspect of some piece of work, they were more likely to relate it to *stimulation* or a sense of *achievement* from having completed a project. *Hedonism* was perceived as being fully separate from any kind of productive work. As one staff member joked, “I think we leave that for the crowd doing speech and drama and stuff... people who enjoy their jobs” (A11).

5.5 Conclusions

This chapter answers Research Question 4: What are the ideal values of an engineer according to those involved in Irish engineering education? To answer this, various perspectives on the ideal engineer from within engineering education have been examined. These perspectives examined the ideal engineer in terms of the skills which they require, the nature of the role which they occupy and the ideal value priorities for an engineer. The criteria for what constitutes good engineering work were also discussed. Collectively these represent an aspirational characterisation of what the ideal engineering graduate should be, the norms they should adhere to, and something of a target for those in engineering education to work towards “producing”. The findings here bear a striking resemblance to a piece written by Joseph Herkert over twenty years ago:

“The prevailing engineering culture is readily recognised from both inside and out. Engineers are no-nonsense problem-solvers, guided by scientific rationality and an eye for invention. Efficiency and practicality are the buzzwords. Emotional bias and ungrounded action are anathemas. Give them a problem to solve, specify the boundary conditions, and let them go at it free of external influence (and responsibility). If problems should arise beyond the workbench or factory floor, these are better left to management or (heaven forbid) to politicians” (Herkert, 2001).

This was written in order to highlight the shortcomings in engineering ethics. Participants in this current study were asked to describe the ideal engineer and yet there are a remarkable number of similarities.

The role of the engineer as a problem-solver featured heavily in discussions here, and where Herkert uses the word “invention”, the current vernacular is “innovation. Specifically, engineers are technical problem-solvers. This is reflected in the skills included in the ideal engineer’s toolkit. While problem-solving and innovating are the activities which constitute the role of the ideal engineer, the context in which they work is very much that of an employee. The influence of this is evident across the various aspects of the ideal engineer discussed.

The skills required by an engineer were by far the most frequently discussed aspect of the ideal engineer which staff would discuss unprompted. The interview participants emphasised that the ideal engineer should possess strong technical skills, particularly in relation to the natural sciences and maths. These technical skills form the core of the curriculum and are the basis of the engineering identity presented here. Participants estimated that 70% of the focus is on technical skills, while transversal skills, such as communication, teamwork, leadership, creativity, critical thinking, and problem investigation, are often relegated to a secondary status. Although these transversal skills are acknowledged as important, particularly in the workplace, they maintain their reputation as “soft” and are frequently viewed as less critical and are only addressed after students have mastered the core technical competencies. This breakdown of skills is consistent with previous work on the makeup of engineering curricula (K. J. B. Anderson *et al.*, 2010; Murphy, O'Donnell and Jamesons, 2019; Murphy, Christensen and Conlon, 2022), as well as traditional understandings of engineering identities (Downey, Lucena and Mitcham, 2007; Schneider, 2010; El-Zein and Hedemann, 2013). This skillset has also previously cited as a contributing factor in the culture of disengagement (Cech, 2014a; Cech and Sherick, 2015b) in engineering education and the difficulties in integrating social justice values into the profession (Riley and Lambrinidou, 2015; Kramer, 2022; Murphy, Christensen and Conlon, 2022).

As well as scientific and technical knowledge, some of the norms of science, such as objective rationality and disinterestedness should be applied by this ideal engineer. It is suggested that this engineer should apply the same deconstructive logic and reduce problems down to bare scientific data, and that the inclusion of non-technical epistemologies constitute bias. Describing engineering as problem-focused while enforcing this scientific detachment severely limits the scope of decision-making criteria an engineer can include in their decision-making process, and potential pathways to social benefit. The role of the engineer as an employee is again relevant here as certain exceptions are made with regards to non-technical influence on engineering practice. Economics is considered a useful and welcome discipline for an engineer to engage with. It is seen as a “hard” science where other social sciences are considered “soft” (A4), “lofty” (A7), or “fuzzy” (A10), which illustrates what was meant when Herkert described engineers as “no-nonsense problem-solvers” (Herkert 2001).

It is interesting to see which aspects of engineering ideology and norms of practice should diverge from that of science and which should not. For instance, while engineers should maintain scientific objectivity and disinterestedness (Merton, 1973), engineering work should set out to achieve some useful ends other than discovery. Staff highlighted the importance of engineering work being effective and useful. Seeing this highlighted suggests some underlying inclination of engineers to pursue technical challenge for its own sake, something which prioritising the values of *self-direction* and *stimulation* would appear to support.

Viewing the suggested value priorities from a societal benefit perspective, the outlook appears promising. *Universalism* and *benevolence*, both of which fall within the higher order *self-transcendence* value, are associated with equality and the welfare of others (Schwartz, 2012), and were rated highly by all participant groups. They are joined in the top group by the *openness-to-change* values of *self-direction* and *stimulation*. *Openness-to-change* has previously been shown to correlate to more socially desirable engineering designs (Al Kakoun, Boy and Xavier, 2021).

Despite this, the depiction of the engineering role stopped short of openly supporting working towards a social benefit. While educators and students alike recognise the importance of contributing to societal well-being, they often view this as a personal choice rather than an inherent responsibility of the profession. Certainly, there is a requirement to minimise harm, hence the inclusion of the code of ethics and a concern for safety, but actively pursuing a social good was not seen as something which an engineer has a great deal of control over.

The ideal engineer, which is illustrative of the wider beliefs in engineering education, has a peculiar relationship with *power*. The industrial context in which engineering operates is frequently cited as the dominant factor in determining the social impact an engineering career can have. That impact is based on management decisions, rather than engineering. Yet it's also widely acknowledged that engineers occupy a significant proportion of management roles. Engineers are deliberately equipped with skills and knowledge to prepare them for this role, though in doing so they align with established business practices rather than challenging the constraints they once viewed as limitations.

Previous criticism of engineering has pointed to the lack of critical thinking in engineering as an obstacle for the profession in working towards social justice. Critical thinking did emerge as an important skill for the ideal engineer, though the context in which it was discussed suggests that it is closer to an analytical thinking style. An engineer should apply a degree of scepticism and verify the underlying assumptions within their brief, but ultimately stay within the brief. What is encouraged is critical thinking within engineering as opposed to critical thinking about engineering, which aligns with findings in the literature (Claris and, Riley 2012; Riley and Lambrinidou, 2015). Participants acknowledged the potential of the ideal engineer to serve the public good yet showed a reluctance to define what this public good might be. The same creativity and outside-the-box thinking which the ideal engineer applies to their work does not extend to addressing the context in which the profession operates.

This was also reflected in the proposed ideal value priorities for an engineer. Staff and students believe that the engineer should prioritise the *self-transcendence* values of *universalism* and *benevolence*, while the value of *power* is ranked towards the bottom of the list. This arrangement supports a conception of engineering which will work towards a benefit, but which is less inclined to take responsibility for defining what that benefit is. Similarly, despite choosing to prioritise *benevolence* and *universalism* within the ideal value structure, participants were sceptical about their utility within the context of engineering work describing these values as naive and idealistic.

It could be argued that the high ranking of *self-direction* opposes this. However, in describing the self-directed engineer, participants discussed them in terms of a motivated self-starter and a degree of autonomy, though always within the certain constraints. What is being described is an engineer who can be trusted to take on a complex work-package, and who will show initiative and creativity in overcoming challenges that they face along the way.

What has been established here is a depiction of the ideal engineering graduate from the perspective of students and staff in engineering education. This hypothetical graduate is described in terms of their skills and knowledge, their societal role and their personal values reflecting the aspirations and expectations within Irish engineering education. The following chapter examines the process by which an engineering degree programme is constructed, the content which is included and ultimately examines some of the effects that this has on the values of engineering students. Having already established a profile of the students entering engineering education in Chapter 4, these chapters collectively provide insight into the values promoted by the engineering education process.

Chapter 6: The Values in the Engineering Curriculum

The purpose of this thesis is to explore and understand the professional socialisation of engineering students during their formal education from a values perspective. In this chapter, the socialising effects of engineering education are explored. This is in response to Research Question 4: What are the values promoted by engineering education in Irish universities? In Chapter 4, the values of students as they begin their engineering education were examined. Chapter 5 investigated the values of the ideal engineering graduate according to engineering educators and students. The objective of this chapter is to examine the values promoted during engineering degree programmes and to assess whether these contribute to the desired professional identity established in Chapter 5. These values are investigated via three major avenues, namely staff interviews, student interviews, and a cross-sectional values survey.

A defining trait of professions is the inherent responsibility to society, and engineering should be no exception (Greenwood, 1957; Brint, 1994; Florman, 1996; Johnson, 2006). Greenwood (1957) argues that unlike regular business, which follows the philosophy of "the customer is always right," professions have the authority and responsibility to exercise independent judgement, based on their expertise. In engineering, the complexity of modern technical systems makes it difficult for the general public to oversee research and development, placing this responsibility on the profession (Greenwood, 1957; Herkert, 2000; Johnson, 2006; Verbeek, 2006). Riley suggests that by neglecting this responsibility, engineering fails to meet the standards of a true profession (Baillie and Levine 2013; Riley 2008).

The Engineers Ireland code of ethics recognises this societal responsibility, stating that members should act "in accordance with the public good" and that "a member's obligations to the client can never override their responsibility to the public good, and members of Engineers Ireland should not enter undertakings which compromise this responsibility" (Engineers Ireland, 2023a), with similar sentiments included in codes of ethics elsewhere (NSPE, 2019; ASCEE, 2020; EERG, 2022). If the engineering profession has a responsibility to look after the welfare of society, then engineering education has a responsibility to equip students with the full range of skills and knowledge required. The Irish professional body for engineers now includes an understanding of the role of the profession in society, and the societal impact of engineering among the requirements for programme accreditation (Engineers Ireland, 2021, see appendix D). As will be discussed in this chapter, this accreditation has a significant influence on the design of engineering degree programmes.

The history of the engineering profession is closely tied to the needs of private industry (Noble, 1979, 2011), and engineering has traditionally externalised its definitions of progress to others (Downey and Lucena, 2004). It has been observed that as industries become increasingly privatised, professionals' perceptions of their responsibilities and the broader societal role of their professions become more restricted, focusing primarily on the technical and intellectual aspects of their work (Brint, 1994).

The emphasis on technical skills and narrow epistemologies in engineering, along with the belief that these can achieve true objectivity, has drawn significant criticism (Haraway, 1988; Riley, 2008; Bell, 2011; Cech, 2014a; Riley and Lambrinidou, 2015; Seron *et al.*, 2018;

Kramer, 2022). Critics argue that when engineers strive for value-neutrality, the values of their employers often become embedded in their work (Leydens, Lucena and Riley, 2022). This limited focus, coupled with a narrow focus of critical thinking skills as discussed in the previous chapter, hinders engineers' ability to fully consider the social consequences of their work (Riley, 2008; Cech, 2014b; Cech and Sherick, 2015b; Riley and Lambrinidou, 2015). The skills and knowledge required to address social issues are often not the same as those demanded by industry (Conlon, 2008) which often has a responsibility to private interests. This chapter will examine whose interests are being represented within the engineering curriculum.

As discussed in Chapter 4, many university recruitment materials define engineering primarily through its application of science. This focus on scientific and positivist epistemologies is often viewed as legitimising a hierarchical structure within engineering (Herkert, 2000; Blue, Levine and Nieusma, 2014; Kramer, 2022). Such a structure contributes to the depoliticisation of engineering, promoting the view that it is a "purely technical space" devoid of socio-cultural complexities (Cech and Sherick, 2015). This perspective suggests that engineering education should concentrate solely on reducing complex problems to technical components, while viewing technology and engineering as value-neutral (Seron et al., 2018; Haraway, 1988; Riley, 2008; Miller, 2021; Cech and Sherick, 2015). This narrow focus on technical skills and scientific knowledge limits students' understanding and their ability to address social issues (Baillie and Levine, 2013; Riley, 2012; Claris and Riley, 2012; Buch and Bucciarelli, 2015). Although these technical skills are valuable, failing to appreciate the value of non-STEM disciplines is seen as a barrier to more socially engaged forms of engineering (Murphy, Christensen, and Conlon, 2022; Riley 2008; Kramer 2022; Murphy, Chance, and Conlon, 2015).

It has been suggested that greater integration between engineering and the humanities and social sciences (HSS) in universities could broaden the narrow view of engineering as purely technical, framing it as both a technical and social discipline (Christensen and Ernø-Kjølhed, 2012; Jamison, Kolmos and Holgaard, 2014; Buch, 2022; Christensen *et al.*, 2022; Trevelyan, 2022). Efforts to merge these disciplines have seen some success. For instance, Claris and Riley (2012) reported that introducing critical thinking skills into an engineering programme led to more reflexive thinking among students. Similarly, co-educating engineers with non-engineering students, using specific pedagogical methods, helped students assess unjust power structures in their work (Orbaek White, Xavier and Groves, 2020).

However, integrating socially-oriented content into engineering programmes has encountered resistance. A UK study found that educators are reluctant to "dilute the engineering call" or "sacrifice" technical content for "something that is not engineering" (Xavier, Wint and Orbaek White, 2022). Although recent accreditation criteria require the inclusion of engineering ethics, concerns remain about the effectiveness of this process and the adequacy of resulting educational content (Conlon et al., 2018; Martin and Polmear, 2022; Murphy, O'Donnell, and Jamesons, 2019).

This chapter will explore engineering staff perspectives on creating these programmes to understand the values embedded in curriculum design and students' experiences of these programmes.

Previous research on the socialisation of engineering students has found that students' beliefs and attitudes towards their engineering work evolve over the course of their degree programmes (Carberry, 2010b; Cech, 2010, 2014a; Bielefeldt and Canney, 2014; Canney and Bielefeldt, 2015b; Canney, Bielefeldt and Russu, 2015; Kramer, 2022). While these studies have detected changes in relation to specific beliefs and attitudes, it is not clear whether these changes affected the underlying personal values of the students. By assessing the value profiles of students this chapter will assess whether the personal values of students at the end of their engineering education differ from those at the beginning.

In Chapter 5, the values of the ideal engineer according to those in engineering education were discussed. The profiles described by staff and students were broadly similar. *Universalism, self-direction, benevolence, and stimulation* were rated highly by all groups. These value priorities are compatible with supporting social justice values such as equality and the welfare of others (Schwartz, 2012). In this chapter, the results of a cross-sectional values survey will be used to assess whether engineering education successfully promotes these value priorities in students.

This chapter will assess the implicit and explicit values which are promoted within engineering education using both qualitative and quantitative methods. Semi-structured interviews and thematic analysis are employed to qualitatively investigate these values. A total of 28 interviews were conducted with engineering students and academic staff across several Irish universities. The thematic analysis, guided by the 6-phase process outlined by Braun and Clarke (2006), allowed for a nuanced exploration of how these values are promoted, or neglected, within the educational system. This method has been shown to be particularly effective in exploring organisational values (Wæraas, 2022) and has been widely used in studies of engineering education (Orbaek White, Xavier and Groves, 2020; Martin and Polmear, 2022; Murphy, Christensen and Conlon, 2022; Xavier, Wint and Orbaek White, 2022). By comparing staff and student perspectives, the chapter seeks to determine whether the intended educational outcomes align with the actual experiences of students and the consequences with regards to their personal values.

This chapter begins by exploring how a degree programme is created and its content managed, discussing the various stakeholders involved, including academic stakeholders, industrial groups, and the professional body responsible for accrediting engineering degrees in Ireland. It then addresses the challenges participants face in designing a curriculum and integrating non-technical content. The chapter also examines the socialising effects on students, as described by participants, and analyses results from a cross-sectional survey of engineering students measuring personal values and social engagement. The survey results are used to compare the value profiles of students at the start and end of their degrees, and are compared with data from the European Social Survey (ESS) of similarly aged groups in Ireland. Collectively these methods can inform our understanding of the socialisation of engineering students, and the values promoted within engineering education.

6.1 Programme Design Process

The design of university degree programmes is a complex task with numerous stakeholders and a range of objectives. There are a number of groups with input into the content of an engineering degree programme, each with different levels of influence and responsibility.

There was some variation in terms of the titles assigned to the various individuals and groups, but participants from each university described a broadly similar process. The following sections outline some of the processes by which engineering degree programme content is decided upon and the roles and responsibilities of the various groups and individuals involved. These include various academic groups, both internal and external to the university, industry partners and employers of graduates and the professional body with responsibility for accrediting engineering degrees. As well as having multiple contributors, designing a programme has the added complexity of legacy. In virtually every case, engineering degree programmes have existed for a number of years and so rather than being designed from the ground up, they are developed and evolved over time.

6.1.1 Legacy

Very few participants described designing a programme from scratch. In most cases the degree had existed in some capacity for many years before the current programme director was appointed. Programme directors and the coordinators for specific modules described similar situations in which they “inherited [the role] from someone else, so there's a bit of legacy there” (A6). They described making changes incrementally. “Evolution rather than revolution” (A5) was how one participant described the approach. Having taken over a course which “has been going for a long time. 20 years at least” (A5) this participant felt that making significant changes immediately would be “drastic” (A6) despite having “a number of changes [they] would like to make” (A5). The process is complex, and depending on the scale of the change, involves collaboration from a number of parties. All of this contributes to staff concluding that “it is a kind of a clunky process. You know, it's not something that you can change quickly” (A13).

There is a sense of inertia to these programmes which resists major changes being made by a director. As there are multiple parties with input into the degree programme, making a change involves having to ensure that all parties will be satisfied with these changes. This process was likened to “a diplomatic exercise” (A4) by one programme director. The existing course material and structure has already passed scrutiny by these groups, and are already being taught, meaning there is an existing body of teaching materials and infrastructure in place. Making a change then creates work and risks upsetting stakeholders, meaning the possible benefits need to be deemed worth the effort and risk. In a situation with an established programme with a successful history, there is little impetus to drive change unless suggested by an external factor.

Many modules included in engineering programs are shared across multiple degree programmes which can increase the complexity in terms of making changes to course content. This is common in engineering as there is a lot of overlapping content between disciplines. For instance, in the “mechanical programme there's a significant component of electronic and electrical engineering” (A1), and a mechanical engineering lecturer spoke of their classes being “shared with Biomed as well, and I also teach second year civil engineers” (A4). This makes it more challenging to modify the content, as any changes will have to align with the learning outcome requirements of each programme. This issue can be compounded by financial considerations. Within these shared modules the class sizes can be quite large, particularly in the common entry first-year programmes, and therefore bring in a greater amount of funding to a school. It was explained that “if your school runs the module, the

university will give you the funding and because there's 330 students in first-year engineering, it's worth so much compared to smaller groups. It's ten times the size so it's guarded" (A4).

Among the interview participants was the head of a recently established degree programme. This programme in mechanical and sustainability engineering was in its fourth year of operation at the time of the interview, and so is one of the newest engineering programmes in the country. Despite being a new programme there were still legacy issues and multiple parties to please. For instance, as it is one of "a number of programmes at the university [which is] mechanical and something else" (A15) a lot of the content is part of a pre-existing "common core of mechanical engineering subject matter" (A15). Creating a new programme like this was deemed more practical than "retrofitting an existing programme" (A15) as it gave more freedom to design the "more programme specific modules" (A15). Generally, programmes are made up of pre-existing modules which might be shared between a number of programmes. Creating a new programme offers some additional latitude in creating new, specific content. Even in this case deciding on course content was described as "one of the toughest pieces of work that I've been involved in" (A15).

6.1.2 Academic Input

While there is a single appointed coordinator for each degree programme, staff were keen to highlight that they are not the sole arbiter of the course content. "So, it's not a case that one person, the programme director, has complete control over the programme" (A1). Instead "It's really done by a consensus manner" (A1) with the programme coordinator responsible for bringing the degree programme through the design/review process. These programmes are composed of a series of somewhat independent modules, and so altering the programme content involves coordinating with the various other academics involved, both internal and external to the school or department and the various industrial partners and professional bodies.

The specific limitations of what could be changed by the programme director alone were described by one participant as "minor changes and tweaks" (A13). At this particular institution the programme director could themselves carry out "a CE3, or Course Evaluation Three process [by which] you can tweak some modules" (A13). The scope of these changes is somewhat limited with the examples given being "updating modules to refer to newer standards" (A13), or "changing the amount of time spent on certain subjects" (A15). Anything more significant than this usually involves a wider group of people.

Larger changes such as replacing whole modules or a fundamental shift in content requires a more involved process. One participant explained that in their institution the process "involves assembling a panel of people and agreeing those changes" (A13). Similar panels were described by a number of participants with slightly different group titles such as "an engineering programme board" (A1), "a programme steering committee" (A3) or "the engineering course board" (A10). The makeup of this panel is somewhat dependent on the specific programme and institution, but one typical example of a mechanical engineering degree programme steering committee was described as follows. "Myself [as] the programme director, the programme director for the master's programme... we have the subject director.... And then we also have the head of teaching and learning... and then sometimes as well, we could have the head of school on that. So it's usually about 4 or 5 different people" (A1). This panel is collectively responsible for deciding upon the learning objectives for students in the

programme, and designing the programme to achieve these. "The steering committee [has] a curriculum review process... and that can lead to two things. It can be changing the set of modules that make up the program, or it could be changing the content of individual modules" (A3).

As well as internal input, degree programmes will engage in a process of getting feedback from external academic staff also. Rather than being part of a design process, this is considered an assessment, though it can still have a direct effect on the makeup of the programmes. These external examinations are typically done by fellow academics and are intended to ensure that the programme is keeping pace and meeting the same standards as its counterparts in other universities, both in Ireland and internationally. "You might get heads of school from UK universities, European universities coming in on that panel" (A4). These panels "bring a perspective that's from outside the university and give an opportunity... to discuss and reflect on the programmes" (A1). The frequency of these reviews varied from "something that happens on a yearly basis" (A1) to "every two to three years" (A13).

6.1.3 Professional Body Input

Perhaps the most significant means by which engineering degree content is influenced by external sources is through the accreditation process by a professional body. In Ireland, the professional body responsible for accrediting engineering degree programmes is Engineers Ireland. An accredited degree is required to achieve the professional titles of Chartered Engineer, Associate Engineer and Engineering Technician. According to their own documentation, the Engineers Ireland accreditation process is "an objective evaluation and approval of third level engineering programmes, ensuring that they meet international standards, the needs of the engineering profession and broader responsibilities to society, environment and economy" (Engineers Ireland, 2021). The criteria for this assessment are included in Appendix D. As discussed by a participant, the objectives of Engineers Ireland are more broad than individual businesses or industries and so their input avoids some of the issues of specificity discussed above. While discussing the various means of assessing industry needs one participant suggested that "the best way is through Engineers Ireland, because they do have the very broad profession in mind" (A4).

Receiving and maintaining this accreditation is a major goal for most of the programmes included in this study. It was described as "the big stick that we get beaten with" (A4). Becoming a chartered engineer "allows [engineers] to sign off on structures over a certain height" (A2) or "to work internationally and have their degree recognised as being the equivalent of [a local] qualification" (A1). Staff believe that this is an important factor for students in the context of young people planning on emigrating after graduation. "There's a preference for them to be chartered so that they can go to Australia and work on large projects and stuff" (A11).

While the accrediting body doesn't directly prescribe course content or teaching methods, they do have a significant amount of influence over university degree programmes. By setting the requirements for accreditation, some participants felt that they are by proxy directing the design of these degrees. Accreditation is seen as crucial and so meeting the requirements is considered one of the major criteria for engineering educators. It was explained that "they're not supposed to be telling us how to design the program. They're just specifying what they'd like to see in the graduates coming out of the program. It's up to us to figure out how to get

that or make that happen" (A3). As another participant put it, "Engineers Ireland would have a set of programme outcomes... and we think about reverse engineering something to fit that" (A12).

Some staff described the accreditation criteria as "guidelines... but there's not enough in those to determine what you should do in the classroom" (A14) so they felt that the criteria still left a lot of freedom to design the programme how they see fit. They described being satisfied with this level of guidance stating "I think it's right...that it's not too prescriptive. I think there's enough there as a conversation starter" (A14). However, others described the accreditation as having an almost direct effect on course content. Much in the same way that the specification stage of an engineering project establishes limits and sets the direction for much of the work, the evaluation criteria set out by an accrediting body can be among the most influential factors in designing an engineering degree programme. One participant suggested that "practically speaking, accreditation is a very powerful force for making changes. You know, they can come in and say 'there's no sustainability in first-year. We're not accrediting your course', and like that, there will be sustainability in first-year, you know, because of course we have to have our course accredited. You know, it's essential. And so they really are very very powerful, those accreditation bodies" (A4).

6.1.4 Industry Input

Another external influence on the design of engineering degree programmes comes directly from industry. Universities seek feedback and guidance from those employing graduates as a means to ensure that the graduates are being equipped with the skills that industry needs. This is done through a range of channels "either officially or unofficially" (A11). For instance, many participants discussed having an "industry advisory group" (A2) which they would consult with up to "once or twice a year" (A1). "This will have a number of industry representatives who are invited to be part of this committee" (A1). In terms of composition, participants described trying to get "a broad range" (A3) of contributors and "a mix of public and private companies" (A2). Specifically, one participant suggested "the multinational sector, some representatives there, some from the SME sector, some maybe from larger indigenous companies and maybe from possibly some of the professional societies as well... It's a relatively tight knit group of about maybe 6 to 10 individuals, and that would be rotated usually on a three-year basis" (A1).

Another commonly cited mechanism for interacting with industry is during student internships and work placements. Academic staff "do site visits on [students'] internships" (A6), which involve meeting with the students' direct supervisor. A key question during this meeting, according to one participant is "are there additional skills that maybe we could integrate into our programmes that might be useful for your sector?" (A8).

As well as this there are a number of groups deliberately created to support collaboration between private industry and education. The Regional Skills Fora are a series of nine organisations established by the Department of Further and Higher Education, based in different regions of the country with the aim of facilitating collaboration between employers, education and training providers, enterprise agencies, local authorities and government bodies. One of their expressed goals is to "make sure employers and enterprise get the education and training responses they need" (Regional Skills, 2022). Similarly a participant referred to a group called STEM Southwest. This is a cluster, comprising industry partners,

Higher Education Institutes, local government and the Southern Regional Skills Forum working to maximise the capacity of the STEM sector in the South West of Ireland (Stem South-West, 2024). The participant described this group as a “significant player from our point of view because a lot of the multinationals and a lot of the employers of our students would be on that forum [...] informing us” (A12).

Through these various channels, a significant amount of feedback from employers makes its way to academic engineering staff. One participant described it as a “constant to-ing and fro-ing with the employers” (A11). There was a lot of expressed enthusiasm for this feedback and “collaboration between industry and academia... we are always interested to say, ‘what, what do you need from our students that you currently mightn’t be getting?’ And then we might be able to respond to that” (A12). “Meeting the needs of industry” (A13) was described as a key objective by more than one participant while selecting programme content. “The things we try to focus on is the kind of content and things that students will need in terms of scientific background and practical background in terms of going into industry particularly” (A2). As a result, industrial partners including private corporations have a significant amount of influence over the makeup of an engineering degree curriculum.

Across the interviews a number of participants raised concern about a particular issue which arises during the interactions with industrial partners. This centred around the level of specificity with which employers would like students to be trained in certain areas. It was stated multiple times that educators “look at the emerging trends that they’re seeing that are needed within industry” (A1) and even that they look at their programme and “try to... tweak it towards the main companies that are around the place” (A11). At the same time staff must balance the needs of employers with the best learning outcomes for their students. “Now, you have to be very careful with that because people from Industry X will say ‘Oh topic Y is really important to us and we think that all engineering graduates should know about that’ and other people might have no interest in it at all” (A3). This sentiment was echoed multiple times with another participant saying “you have competition for curriculum space, and there’s always going to be a voice out there saying, you know, ‘we need graduates who can do X, Y, and Z’, and now they only want graduates who can do this. And next week they’ll be telling us they need that. And it’s kind of, ‘oh, look, a squirrel’” (A9).

There are limits on the amount of material that can be covered and so the common approach described was to try to provide a broad foundation and make a determination about which newer and emerging areas are necessary for a broad range of areas. For instance, one participant discussed a reluctance to incorporate “trendy technology” and “buzzwords like ‘the internet of things’” (A11). On the other hand another programme is introducing a whole new module to facilitate specific material based on feedback from the broader industry. “There is an increasing realisation within the engineering sector that the use of data and data analytics is increasingly important within all of engineering. So we are introducing a new module which is data analytics for engineers” (A1). If an emerging technology or area appears to have a broad enough application it may be incorporated. If not, it is considered something which will have to be learned as part of specific on-the-job training. “People who employ them are going to have to add on some specific training for whatever they need in their particular world and whatever they think is important. But we’d be trying to produce graduates who at least have some knowledge of the basics and can be trained up in that narrow niche area very easily. If they have the foundations there. They can learn the extras without too much trouble” (A3).

6.2 Difficulties Integrating Non-Technical Content

In previous chapters we saw that the majority of engineering programmes are composed largely of technical, mathematical and scientific content and that ensuring that engineering students are highly competent technical experts is a high priority for educators. In some cases, this has been to the exclusion of almost all else. In discussing these priorities, one programme director outlined their perception of the focus of engineering programmes. "I think there's a technical, a business and there's an environmental and kind of society element to what we're doing and all engineering problems. And I think that in prior times, it's probably focused mostly on the technical piece... maybe the business piece because obviously the economics... that's probably the second priority. But the third piece, which is more societal, and kind of environmental, and it's about the people, that piece, I think has been missing for a while now" (A2). In Chapter 5 it was discussed that most engineering educators had not considered the promotion of values as an active part of their curriculum design. Here, participants described a curriculum design process in which multiple parties pushed for different outcomes, leaving little opportunity or motivation to include such content. "There are learning outcomes that need to be achieved and I just need to, you know, first and foremost, tick that box. And quite often the learning outcomes don't feature explicit reference to societal links or societal impact" (A12). This has, in part, lead to the persistent techno-social divide in engineering education, whereby technical skill and competencies are prized and non-technical knowledge is pushed to the extremities and devalued (Conlon, 2008; Cech, 2014a; Riley and Lambrinidou, 2015; Kramer, 2022; Martin and Polmear, 2022; Murphy, Christensen and Conlon, 2022).

Some non-technical elements have been introduced into the engineering curriculum over time. Participants described the increased amount of professional skills, such as teamwork and communication, in their programmes as well as the new inclusion of sustainability. However, this introduction of non-technical content into engineering education has faced significant resistance from a number of sources and resulted in shortcomings in its implementation. The following subsections will examine some of the causes and sources of this resistance and discuss the ways in which non-technical content has been incorporated, successfully or otherwise, into engineering education.

6.2.1 The Crowded Curriculum

The engineering curriculum at Irish universities is full. The timetable is at capacity "but there's always more to put into the curriculum.... but we're very lax to or hesitant to drop anything so the curriculum has gotten much more packed" (A2). This was a consistent theme while discussing the makeup of the curriculum. Staff expressed frustration in relation to the pressure from external bodies to include additional content, saying "you just don't have time to do everything" (A9). This is also the experience of students, who reported that "it's obviously not a course that is very, you know, leisure time friendly" (S1) and "we are always in the engineering building, and we are always studying 24-7" (S2), with staff agreeing that the student workload is "very high. It's very intense, really" (A4). While these external bodies do have significant influence on the course content, the heavily loaded curriculum means that attempts to introduce new content are met with resistance. "There's always pressure at the end to get more stuff in and at some point, you have to take stuff out to make space for it. Those are always the difficult decisions, the bits that you want to chuck out. Everybody says, 'Oh, but we couldn't, we need all of that. It's really important, it's fundamental' " (A3). With the

programme already packed, introducing new material demands substantial effort, and a consensus that it is highly important or relevant. Therefore, examining the content that has made it into the programme in recent years provides insight into what is valued by its curators.

A participant described the difficulty they had in attempting to add a sustainability module to the first-year programme at their university. The participant believed that this module was “going to be important for education and also from an accreditation point of view, because what we all have to do is show that we're addressing the United Nations sustainability goals in the program” (A4). This module was initially rejected as a core module, before being considered as an optional choice for students. Despite sustainability content being a requirement from the accrediting body, and the programme coordinator supporting it, the change “was rejected because, again, nobody wanted to make space in the program” (A4).

One suggestion for why this happened was the financial incentives which influence university programme design. As discussed in section 6.1.1, departments are partially funded based on the number of students enrolled in a module which they provide, meaning a large class like first-year engineering is worth more to a school than smaller groups. As a result, schools currently running modules for the large first-year groups have a financial interest in maintaining them and are therefore reluctant to make space for a new module.

However, this participant also described a cultural barrier being partially responsible. In this particular program, “a relic from the past has been that we have two modules in physics... and there's a lot of duplication, for example, and I feel it would be better to take one module of physics to reorganise it properly, free up a slot for something like sustainability” (A4). They believed that it was the suggestion that an engineering department would “step away from maths and physics and look at the bigger picture” (A4) that caused the resistance. As they put it, “you can imagine that all the professors are there saying, ‘what? Reducing physics in first-year? Scandalous!’” (A4). This reaction is consistent with previous findings in which academic engineers believed that removing content for “something that is not engineering” constituted a “sacrifice” (Xavier, Wint and Orbaek White, 2022).

By contrast, some new materials have managed to make it into the programme more recently. For instance, “we set up a new computer-based module in first-year” (A4). This module was introduced “just in 2018” (A4), and what the participant felt made the process easier in this case was that “I kind of showed that we really were the odd man out amongst our peer universities” (A4). They “looked at 25 universities and particularly the ones that had common first-years. And they more or less all had a basic course in computer programming” (A4). The participant believed that they successfully demonstrated that their programme was at risk of falling behind their peers/competition and that this was what made the difference in terms of convincing the department staff to make room in the programme for it. In a sense, it was the thought that graduates from other Irish universities would have a competitive edge over graduates from this university in terms of relevant skills, which paved the way for this change.

In this case, because “there is an increasing realisation within the engineering sector that the use of data and data analytics is increasingly important within all of engineering” (A1), there has been a series of modules introduced, beginning with this “introduction to engineering computing in Stage 1” (A1) and continuing up to the ability to “develop quite comprehensive modelling programs to model and solve engineering problems in Stage 3” (A1). This is “something that we've seen through our industry collaborators is becoming more and more

important over the last 3 to 4 years. We're now making changes to reflect that" (A1). As already discussed, a number of participants warned against programmes taking every demand from industry and adding it to their curriculum. What appears to be successful in instigating change, is a combination of pressure from the accrediting body and industry demand.

6.2.2 Build Through or Bolt On?

When we compare the amount of time and resources dedicated to the technical and non-technical aspects of engineering education there is evidently an unequal distribution of time and resources. One participant estimated that "it would be 70:30. So 70% technical skills and 30% for the others" (A2). As was discussed in Chapter 4, the majority of programme module lists contained a maximum of one module which did not suggest it was predominantly technical in nature, far less than 30%. Participants explained that this difference is because non-technical content is integrated within technical modules. "What we try and do is we build them through, rather than kind of, you know, bolt them on" (A7). A number of other participants echoed this saying things like "I guess like general soft skills communication would be a big one, like whether we explicitly say it or not, every time they're giving a presentation, there's an element of just like, how good is the presentation" (A6).

Integrating subjects into existing classes like this has been effective in the case of some transversal skills. For instance, participants were happy to report that in spite of the persisting reputation of engineers as unsociable, "we had an industry advisory group meeting in the last couple of months in civil engineering here. And one of the things which employers are saying actually is that they're really good at communication and putting presentations together" (A2). This is effective in the case of a skill like communication or presentation, where repeated practice and exposure are effective learning techniques. In the case of a subject such as ethics or social justice, though, there is a significant amount of knowledge to be communicated. In an already busy full curriculum this results in insufficient coverage of these subjects and students reporting that "there was a very small bit somewhere and it was so small I've forgotten which module it was in, but I do remember some very small sliver of ethics somewhere" (S11).

Contrast that with the approach taken for the technical content, where students are taught subjects from first principles and steadily built up. The attitude held among staff is that "we still emphasise, very strongly, fundamentals because our belief is if you don't understand the fundamentals, you don't necessarily understand the processes which are built on top of fundamentals" (A1) and that "it's by understanding the fundamentals that you can really understanding what's going on" (A1). This bottom-up approach makes up a significant portion of an engineering degree. Staff estimated that "usually the first three years are more, let's say, focused on the fundamentals and the last 1 or 2 years, depending on whether it's a bachelor or master's program, tends to be more towards the application side" (A1), and that "in the later years, third and fourth year, the topics begin to get more applied and perhaps more interesting" (A6). The engineering curriculum contains a large amount of this fundamental theory even though staff participants acknowledge that "the amount that I actually use now is very, very limited, you know, a small portion of everything that we were taught" (A4). In one case a student reported a professor introducing some aspect of maths by saying "You're never going to use this but here we go" (S11).

Having this bottom-up approach for technical subjects, while non-technical content receives minimal class time and is introduced later in the degree programme, limits how integral to the

curriculum the non-technical topics can feel. Integrating ethics into other engineering modules would appear to address some of the concerns raised in previous work (Martin and Polmear, 2022) and is the approach recommended by the accrediting body. However, participants expressed scepticism about whether that is a feasible approach. "Engineers Ireland would like it to be included everywhere. Almost every module would include some bit of ethics. And that doesn't really work" (A3). This resistance was common with many participants carving out exceptions for modules which they felt were too technical to have an ethical aspect, saying things like "obviously there will be maybe maths modules and things like that where it would be difficult to bring it in" (A13), and "there are some modules where it probably makes sense that it's not covered because you're dealing with a very specific technical topic" (A5). This highlights a major issue of integrating non-technical material into the existing curriculum. With so much of the early years of the degree filled with very dense technical material, into which staff feel it is unsuitable to introduce social or ethical material, it will always appear as an add-on. It is unsurprising that recent work found that 56.2% of fourth year engineering students at an Irish university reported that their engineering education had focused "on technical subjects only" (Murphy, Christensen and Conlon, 2022).

6.2.3 So, What Does Make It In?

As discussed above, there are multiple stakeholders with different requirements and preferences as to what goes into an engineering programme curriculum. The programme director, in conjunction with the steering committee, is then responsible for striking a balance and satisfying these demands as much as possible. Based on the discussions with participants in this study, as well as findings from previous work we can see how this process shapes the course content for engineering programmes, and how the introduction of content such as ethics, sustainability and non-technical skills has been handled throughout this process.

Staff reported that changes within the engineering education curriculum are "driven largely by the engineering accreditation process" (A9). Examples were given of the maths requirements for progression from a Level 7 to a Level 8 being increased at the request of the accrediting body as well as the increase in content relating to sustainability and ethics. "So, the sustainability is coming from EI (Engineers Ireland) as far as I know... And so the ethics is coming from EI as well" (A6). "We need to achieve a certain learning outcome. At the end of the day here, you know, as a lecturer, that's my primary goal" (A12). Given the importance of accreditation to these institutions, having a topic included in the accreditation criteria is the most direct method of establishing it as a learning outcome. This is in line with results from the UK, in which engineering educators suggested that accreditation requirements were the best means by which to introduce non-technical content, such as social justice (Xavier, Wint, and Orbaek White, 2022).

Issues have been found with the introduction of non-technical material into accreditation criteria. Some have described a "box-ticking" effect, whereby criteria encourage only the minimal acceptable level of a subject to be included. This has been the case in relation to both ethics and social justice (Martin and Polmear, 2022; Xavier, Wint and Orbaek White, 2022). Also, issues have been reported in relation to the accrediting body's ability to assess programs which do introduce additional non-technical materials. The assessment panels are often composed of traditionally educated engineers, who lack the expertise needed to assess its

relevance (Grimson and Murphy, 2013; Jamison, Kolmos and Holgaard, 2014; Conlon, Martin, Nicoleau, *et al.*, 2018; Murphy, Christensen and Conlon, 2022).

Conversely, some non-technical materials have been more successfully integrated. Transversal skills such as communication and teamwork, for instance, are now a feature in a meaningful number of modules within some programmes. One potential difference here is that while subjects like ethics were being requested by the accrediting bodies alone, employers have expressed the need for students to have developed transversal skills also. In a UK based study an interviewee reported that their accreditation process had begun to "examine a bit more in detail soft skills, but what they're looking at really is the skills that graduates need for working in an office as opposed to how they're going to address social injustice issues." (Xavier, Wint, and Orbaek White, 2022). Similarly, there has been some industry recognition of the need for engineers with knowledge of sustainability. Having this dual push for a topic to be included, appears to be a key factor in motivating a successful integration of a subject. Staff are keen to ensure that their students are equipped with skills that are "needed within industry" (A1). Without this demand from employers, participants feel that these changes "wouldn't last anyway, you know, if you were producing a bunch of fellows there who had skills that no one wanted, that gets around very quickly" (A11).

It has been proposed that in order to address the needs of society in a more holistic manner, engineering students will need to be equipped with more than just those skills demanded by industry (Conlon, 2008), however it appears that the needs of employers are still considered the arbiter of what is an important skill for an engineering graduate. This raises questions as to the effectiveness of accreditation in advocating for the needs of society in engineering education.

Interestingly, this rule seems to be applied differently to technical content. Participants reported that neither employers, nor the accrediting body have expressed an issue with the technical competency of students. One participant here reported that "We rarely have debates with [the accrediting body] over the technical content of the program. The things that come up for discussion are mostly around things like ethics and design and product design or things like that" (A3), while another explained that in conversations with employers about issues with the skills of graduates, "a lot of discussion is not so much around the technical ability of the student because often that is almost a given, but it's also about their ability to be a team worker, to be a communicator, to be a person who asks questions" (A1). Despite this, the possibility of removing any technical content is still considered "scandalous" (A4). For non-technical content, the attitude appears to be to achieve the minimum level required by employers and the accreditation body, while the highest achievable level of technical content is included.

Engineering educators, for their part, are at the centre of the struggle for curricular space. They must balance the need to meet the requirements of the accrediting body and satisfy employers, while they also "try to do our best for the students" (A2). For many this means equipping them with the skills "that students will need in terms of... going into industry particularly" (A2). The cost of attending university in Ireland is significant, and for many this is considered an investment. Students, and their families, increasingly occupy a role akin to that of consumers purchasing an education (Gibbs, 2002). As discussed in Chapter 4, a large portion of the marketing material for engineering education focuses on the employability of engineering graduates, and so there is an expectation that undertaking one of these degrees will yield some return on investment.

In a few cases, this was discussed from the opposite perspective. A minority of staff described their role as “trying to meet the needs of the industry” (A14) by supplying skilled graduates. They described engineering education as a part of a supply chain, with comments like “you know, we’re very much focused as academics that the product has to go out somewhere. We have to sell it out to some area of industry” (A8). However, for most the expressed attitude was “I certainly think I serve the students, I’m trying to get them career ready, you know, and I need to do whatever I need to do for them to have the opportunities they need” (A12). Within this dynamic, including materials which are not currently required by employers, “would be doing our students a disservice” (A14). This approach to curriculum design believes that the needs of the student are best served by meeting the needs of industry, which are then prioritised. However, this leaves little room for the needs of society and so non-technical content, such as ethics, values, or social responsibility are excluded.

6.2.4 Retrospective Reflections Only

In describing how issues around the non-technical aspects of engineering are included in students’ assignments, one engineering programme director explained the following. “Students undertake a capstone project... And in their conclusions part of the report, they have to devote a section to the issue of sustainability. And the question they’re asked is to identify at least 2 or 3 of the 17 UN sustainability goals which are relevant or pertinent to your project...then they consider the, I guess, the overall aim and objectives of their project and identify where they fit best on the issue of ethics” (A1). They then went on to say, “it also appears in the design modules and again in the project there is a section in their conclusions where the students reflect on ethical issues which are associated with the work” (A1). In both of these cases, the ethical and sustainability component for the student is included in the conclusion of the report. It is a reflective task and a self-assessment of their already completed work. It takes place during the reporting when the technical design and implementation work has already been completed, and thus has no bearing on the design of the project. This again separates the technical work from the social considerations, with the social aspects being presented as secondary to the technical. This was articulated by a student who had recently completed their final year project. From their perspective “it doesn’t seem like it’s always taken the most seriously by the people who are [teaching it]. This sounds really bad, but even in terms of like the final project, it was kind of like, ‘Oh yeah, just maybe write like a page on ethics. We’ve just given you like two slides. You can just kind of refer to them, like it didn’t sound like it was taken seriously as like a very important part of the final project. So, I suppose if you think of it like that, then it doesn’t make you feel like you should take it very seriously” (S5).

6.2.5 Not Graded and Too Easy

Another contributing factor to the persisting techno-social divide appears to be a disparity between how the non-technical and technical aspects of students’ work are graded. Students are often made aware of the weighting of various aspects of their assessment, and they use this to decide how much focus, time and effort to commit to each aspect of a given module. One participant described it as “very disheartening, you know... if you’re teaching or, there’s a subject there and the main question from the students is “will this be on the exam?”. That’s where they’re being motivated. So the focus goes off the teaching and the learning and into just assessment and hitting the grades. But the grades often aren’t a good reflection of whether

somebody would be a great... engineer or a great research student" (A7). This technique of focusing specifically on the exam materials is a popular and successful strategy among students, which has the effect that if materials are not specifically being assessed they are perceived as less important. Engineering staff are aware of this with one reporting, "what I've learned in teaching students, third-level students is, for the most part, unless they're being assessed on something, they're not going to pay too much attention to it" (A6). Student participants admitted to engaging in this kind of grade focus, suggesting that it was a result of the competition in the university admission process in Ireland. They believe that "you have to be very grade driven... You were driven by grades to get in [to engineering] through the Irish school system and then you get there, and you're still driven by grades. And sometimes you have to be" (S4).

As discussed above, the ethics and sustainability aspects integrated into some projects form part of the conclusion of the students' reports. When included within a project designed for teaching another topic, there is rarely a large portion of the grade attributed to reflections like this. With regards to the capstone project for one degree programme the coordinator reported that "we don't actually include it essentially as a grade and as a proportion, but it is what we would regard... You must include it. So, if you don't include it, the final report or the project is considered not complete" (A1). An engineering programme is demanding in terms of course load for students, and we should expect that students will reduce the amount of time spent on aspects of their work which do not carry much reward (Scardamalia, Bereiter and Lamon, 1994). If a student will receive the same grade for an ethical and sustainability reflection that meets the bare minimum requirements as for a well-developed, thoughtfully constructed assignment that takes more time and effort, it is likely that they will choose the first option.

Similarly, another participant suggested that because one of their modules which focuses on transversal skills "is easy and everyone does reasonably well, that probably biases the perception of it." (A12). This participant felt that the module in question is not taken seriously by students, and that they do not commit the same effort to it as to others. "I think the students, when we talk to them in later years they might refer to the C.I.T (Creativity Innovation & Teamwork) module, as a joke or, you know, 'that was a piece of cake', because... Well, in my experience their main focus is on the end goal like the grade" (A12).

In contrast to this a lot of the other subjects included in engineering education are considered "very intense" (A4). Many participants discussed "the level of academic rigour involved in an engineering program" (A8) as being very high, or pointed out that "it's always the same subjects that [the students] keep failing. The likes of physics and mechanics. So, I suppose the more mathematical ones, the more demanding ones really would be, the ones that keep causing all the issues" (A4). The reported perception among students was that lecturers believe "that's the bar of what an engineer should be. If [students] can't meet that and they shouldn't get the degree" (S11). These mathematical subjects set the standard for what is expected of students and establish a belief that "in broader engineering, you know, anything worth doing is going to be tough" (S4). By extension, those subjects which are felt to be too easy are perceived as being worth less. Within the current context of engineering education, such subjects are not taken seriously and as such will not be accepted by students as part of the core engineering skillset.

6.2.6 External Teachers

One perspective which has been found in previous literature suggests that engineering educators struggle to integrate non-technical subjects into their programmes as they themselves are the product of a technically-focused education and lack the expertise to teach non-technical subjects. This has been found to be the case in relation to both ethics (Martin and Polmear, 2022) as well as social justice issues (Xavier, Wint, and Orbaek White, 2022). A common approach is to have an educator from outside the school deliver non-technical content, though this runs the risk of the topic being perceived by students as external to engineering. In one example module discussed by a participant here, students are taught about four major topics "There's management, law, ethics and economics" (A5). In this case, only the management section is taught by a member of the engineering faculty. "There's another lecturer who teaches ethics and economics and a lecturer and practising lawyer teaches the law section of it. So those two lectures are external to the school and brought in to teach those parts because they're specialists in those" (A5). There are benefits of using external lecturers for subjects like this in that it ensures that the lecturer is very knowledgeable about the specific subject. Another staff member discussed integrating ethics education into their module and stated "an external person would do a much better job of this than I would... The only part I see myself doing is the environmental piece" (A6). The counterpoint to that is it raises the question as to why an engineering lecturer is an expert in management or environmental issues but not these other subjects. From the perspective of a student, the management and environmental content may appear as more relevant to the skillset of an engineer. Students can be selective in accepting a socialising influence during their education. This selection is made, in part, based on the degree to which this would-be-mentor resembles the student's mental image of a professional in their chosen field (Cohen, 1981a; Cornelissen and Van Wyk, 2008). Seeing content delivered by a non-engineer may limit how effectively they will integrate this content into their professional identity.

On the other hand, in a number of institutions staff discussed the provision of other subjects like maths education by external departments. Through a collaborative effort, specific modules have been designed to cater to the needs of engineering students within these fields. These modules "are called something like mathematics for engineers... And they are delivered by people in the maths department. But clearly, they have been designed for engineers" (A10). In another institution this collaboration went further. A staff member explained "you have a mathematics department which teaches your maths, and your physics department teaching your physics, and chemistry, teaching chemistry" (A9). And in these cases, nobody has suggested that engineering students are not taking their maths, physics or chemistry education seriously.

It is possible that as these technical subjects are already widely accepted as part of the engineering identity, and intersect with the material in other engineering classes, students have opportunities to see these subjects applied in an engineering context, and so the fact that they are delivered by an external educator is not an issue. However, with non-technical subjects, which receive far less class time, are often only included later in the programmes, and which do not intersect effectively with current content in other subjects, having an external educator may perpetuate the sense that these are not engineering subjects. This would be consistent with findings by Martin and Polmear (2022) which state that, for engineers, the skills needed to address social issues feel divorced from traditional engineering knowledge.

6.2.7 Patchwork Modules

In multiple programmes, non-technical skills did receive a dedicated module. These modules often contained an array of separate topics grouped together under titles such as “Professional Engineering Management” (A5), “Engineering Professionalism” (A13), “Design and Innovation” (S8) “Creativity Innovation and Technology” (A11) and “Creativity and Design” (A2). Within these modules a wide range of materials are covered. One such module was described as “kind of unusual in that it has a few quite distinct sections in it. There's management, law, ethics and economics” (A5). This isn't unique however, as multiple institutions have modules of this kind. In many cases they contain this kind of patchwork of different skills and topics which do not neatly fit into other modules. .

One such module is a “creation innovation and technology module, which every first-year student has to undertake, and it's basically kind of an introduction to third-level [education]” (A11). Another participant said of the same module “we'd actually talk about when you've got a task to write a document. How do you start? What do you do? You know, what's the methodology behind it.... Likewise, we do it on presentations, presentation skills, you know, creating a PowerPoint” (A12). Another participant discussed “Engineering Professionalism which is just report writing, referencing, you know, all that sort of stuff” (A13). These skills are all valuable to an engineer. However, with the range of topics included they appear to lack the focus of some of the dedicated technical modules.

These modules are also often one of the main places where social and ethical considerations get included in the curriculum. A number of participants described including this kind of content in these modules. For instance, “we do have a responsibility to the environment and sustainability and, you know, to society. So I think that that's something that we were very keen to put into the creativity and design module” (A2), “the other feature would be general problem-solving strategies for some sort of real world issues that can arise when working in teams or groups. How do you solve those human issues without conflict or whatever?” (A12) and “it's also about innovation and, you know, trying to introduce the UN Sustainable Development Goals and all that kind of stuff” (A11). One of the results of this is that each topic receives relatively little attention. Staff felt that they could not cover each topic in as much depth as they would like, saying “I talked about them a little bit, but I either need to kind of teach them in more detail I think, or, or leave them out and focus on something more and kind of just to be able to get into [...] each area in enough detail to make it useful” (A5).

Some of the topics are included in these modules for the purpose of meeting accreditation requirements. As one participant explained, some of these topics may be dealt with passively in other modules but “this kind of gives us one place where we can say that we're kind of definitely dealing with it deliberately” (A5). However, it was mentioned that this has created an effect whereby their existence means that it's easier to exclude these topics from other modules. “I've been prompted to think about ethics by the programme director and I'm thinking, ‘Oh, ethics, can we not move that into professional engineering instead?’” (A6). This is consistent with previous studies in which it has been found that engineering staff are reluctant to take on topics like ethics, and that it is often a subject assigned to junior staff (Martin and Polmear, 2022).

6.3 Effects and Socialisation

Part of professional socialisation is the adoption of the values and beliefs of a profession, and formal education is one of the major venues of this socialisation process (Simpson, 1979). As students learn to adopt the professional identity of an engineer, the content and values that they are exposed to are internalised. As was discussed above, the engineering curriculum, for a variety of reasons, has a heavy focus on technical content, while the relevance of ethical and societal impacts and considerations are minimised. Scientific detachment is encouraged, and a depth of technical competence is the top priority. After this some ancillary skills which prepare a student for the workplace have some utility, while additional content such as ethics is included to the extent that accreditation requires.

In this section I first examine some of the major attitudes and beliefs instilled in students over the course of their education, as expressed by interview participants. After this, the results of a cross-sectional survey carried out among engineering students at University College Dublin are discussed in order to determine what effect this socialisation process has had on the value profiles of engineering students.

6.3.1 Conditioned to Ignore Social Considerations

The divide between technical and ethical/social responsibility material has a conditioning effect on the ability of students to engage with both equally. With so much of the degree focusing on technical, mathematical and scientific material, the non-technical content appears out of place to students when it is included. A staff member remembered experiencing this effect during their own engineering education. "Speaking from my own experience as an undergraduate engineer, you're sitting in classrooms and you're learning so much technical information that you're almost conditioned to take in this specific technical information, probably that helps you pass exams. And then when you come to like kind of a high-level topic, students see it as like a light touch thing" (A6). This highlights one of the major dilemmas with trying to integrate non-technical material into engineering education. Having so much of the degree focus on the fundamentals, which are technical in nature, relegates other content to seeming secondary or ancillary. Many subjects encourage students to take a problem and "boil it down" (A6) and "reduce things to numbers" (A5), removing anything which is not relevant to the central core issue. In fact, this strategy is often taught in second level maths classes where students are presented with a scenario written in text form and are required to extract the mathematical information and decide which equations to apply. Think of trains leaving stations at given speeds. As one participant put it "They've come out of Leaving Cert. And there's always a nice, simple equation that you plug a few numbers into, and they want to plug those numbers into the equation" (A15). With the maths requirement for entry into engineering being quite high the students who achieve this will have been successfully applying this approach to breaking down a problem for a number of years and have received a lot of positive reinforcement for doing so.

Ethical and social considerations appear non-scientific in nature compared to the rest of the material which students have previously encountered in their engineering degree. According to a participant here, "in contrast to what we normally get, it seemed very... like philosophical" (A6). As such, when students are trying to understand a problem that they are presented with, and they apply their regular "boil it down" (A7) approach, these ethical and social

considerations are not something which is going to make the cut. Students pointed to the prioritisation of cold logic when approaching problems and how they believed that hinders their ability to adequately account for the “softer” aspects of user needs. They believed that engineering students “do really well in the logical sort of sense. I feel like sometimes when it comes to understanding people, and understanding people’s concerns and everything, we might be lacking in that sort of sense. But I feel like that’s just the way we were taught. Like in the course, we were taught how to just think logically” (S10) and that “having empathy or like, you know, like just emotional intelligence I feel is very important. And I feel like we don’t really see that that much” (S10) in engineering education. It should be pointed out that it’s not impossible to empathise and think logically about a situation at the same time, and that the two don’t have to oppose each other, but the fact that this is a perception among students is evidence of the prevalent attitude towards non-technical subjects. With the amount of positive reinforcement that students have already received in favour of applying this approach to their engineering work, suddenly changing, or even reversing, this practice would require a significant and persistent effort to be effective.

6.3.2 Right and Wrong Answers

An issue which arises from the heavy focus on mathematical skills is that it conditions students to search for unambiguously correct answers. This inhibits the ability of students to deal with elements of uncertainty in their work and to tackle imperfectly defined problems. This is an issue which begins before university education, with the Irish educational system frequently being criticised for encouraging this particular style of learning (McCoy and Major, 2007; Kirwan, 2015). However, according to participants here, the content of engineering education continues this trend.

“In many of our subjects there is a right or wrong answer. It’s a mathematical thing and that’s it. But life is not like that” (A4). The problems this causes was reported widely among participants, with a common issue being that students struggle “particularly if you give them something open ended and come up with an idea and develop it, you know, they don’t like that at all” (A13). This echoes findings which have found an aversion to uncertainty and ambiguity among engineering students (Xavier, Wint and Orbaek White, 2022). A number of participants directly drew the connection from the mathematical focus to this aversion to uncertainty. “I suppose traditionally engineering students... have to have some sort of grá [love] for numbers, and you know that there has to be this numerical solution that we can put to this, some scientific solution that we can put to this” (A8).

Being conditioned to expect binary, right or wrong answers can affect the ways that students think about engineering. One staff participant suggested that incoming students had a tendency to rush into mathematical calculations immediately upon being presented with a problem, saying “they’ve come out of the Leaving Cert where there’s always a nice, simple equation that you plug a few numbers into, and they want to plug those numbers into the equation” (A15). A UK based study found that a significant proportion of engineering students identified as perfectionists, a trait which encompasses an aversion to uncertainty. These students were also less inclined to produce designs which served communal needs (Al Kakoun, Boy and Xavier, 2024).

The nature of social and ethical considerations, as well as the required styles of thinking to understand different perspectives on public benefit all involve the need to deal with uncertainty

and ambiguity. Cultural context and social interactions are rarely quantifiable in a way that suits a mathematical approach. Instead, this style of thinking encourages the continued divide between technical and social considerations, and a reductive approach to engineering problem-solving.

With its orientation towards scientific rationality and positivist empiricism, engineering education leaves little room for any kind of interpretation or subjectivity. When asked about whether they believed that personal beliefs and perspectives can influence engineering work one student responded “I don't really think so. Mainly because of how I feel like engineering is just very logical. And that's part of why I like engineering. I feel like a lot of the time there's a right answer and one right answer, really. So, I don't really think so. I haven't really run into anything in my engineering degree that I think would be a point of contention for someone with different beliefs than me” (S13). An engineer who believes that different perspectives won't affect engineering work is unlikely to seek these perspectives and so any problem will be approached from a purely technical position.

6.3.3 Sense of Responsibility and Accountability

As has been discussed, the work of engineers can have significant and far-reaching consequences. An important part of engineering socialisation is coming to understand that. Staff here highlighted the need to instil students “to have that sense of responsibility” (A7). Multiple participants expressed that “it's also a very, very important awareness that an engineer needs to have that there's, you know, what they're doing is important because there's consequences to what they do” (A12). This same message was expressed by students too, with many understanding that, “you have a responsibility as an engineer to acknowledge and understand your impact on society, the environment, and the economic situation of the world or the country... you have a responsibility to yourself and to the profession to do the best work that you can produce in an ethical way” (S5).

Previous research has found that engineering ethics education, in Ireland and abroad, has been centred around case studies, particularly those involving engineering failures and disasters (Colby & Sullivan, 2008; Hess, 2013; Hess & Fore, 2018; Martin, 2020; Conlon, 2022), and has been concerned with aspects such as health and safety (Nicolaou et al., 2018; Martin et al., 2020; Murphy et al., 2022). This approach has been found to be of limited use, as it fails to account for the role of engineering in the overall direction of the project. Interview participants in the current research project discussed the importance of an engineer understanding the consequences of their work being carried out diligently and ensuring the safety and quality of their work. In the course of their education “something that has been discussed is failures of buildings and bridges, and how as a doctor, you would have responsibility for the one person you're operating on... but as an engineer, you can end up hurting and killing a lot more people than just the one person in front of you. Like the bridge in Tacoma that collapsed because of the wind” (S2). This is in line with staff participants who suggested that “I think that's how we do the best job. So, if you're a civil engineer, for example, and you're building a bridge. The best way you can do your job is to make sure that it is done to the highest possible standards, to make sure it's absolutely safe, to make sure you've properly, you know, taken account of the variations that can occur, different weather patterns, whatever that is. So, you, as an engineer, are doing the really responsible thing and the right

thing there. I think that's how you best serve people... I think that's where we really have to be responsible. And that's where our duty of care is" (A7).

While students do understand the sense of responsibility that an engineer has with regards to the rigour and safety aspects of their work, they don't necessarily believe that an engineer can reasonably be held accountable for the wider decisions made about a project, or if their work "gets used for nefarious purposes" (S13). This is largely related to the corporate setting of engineering work, with one student explaining that "within the teams I've worked on, to be honest, you feel pretty powerless at that kind of a level. Because you just feel as part of, like you're part of this big machine" (S11). Students are unable to see an avenue for an engineer to exercise control over this aspect of how their work impacts society, other than by leaving a job, and so they do not believe that it is reasonable to lay this responsibility at the feet of the engineer. This is consistent with an individualistic approach to engineering ethics, focusing on the actions of a single engineer and the agency that they have in a given situation. The ethical content of engineering education, has been criticised for taking this approach and for failing to address the context in which the engineer works (Conlon, Martin, Nicoleau, *et al.*, 2018; Martin, Conlon and Bowe, 2021a).

One conclusion which can be drawn is that students do appear to be internalising the sense of responsibility which an engineer should have. Whether through explicit teaching or implicitly through their growing understanding of the profession, students appear to understand that engineering work has public consequences. One student suggested that this happens "kind of by osmosis" saying "I don't think there was like a lecture, where we sat down, and they told you 'this is why engineering is such a consequential thing to society'. I think it's maybe just over time you realise you actually have a lot of influence on how the world works" (S4). However, this responsibility is constrained somewhat by the students' perceptions of the role of the engineer as an employee, and the narrow scope of engineering ethics which they are exposed to through education. There is the potential here that engineering students, equipped with the necessary tools, could be in a position to better understand the wider context of engineering work and potentially expand this sense of responsibility to encompass a wider definition of societal benefits.

6.4 Survey Results

In this section I will examine the results from a cross-sectional study conducted among students studying at University College Dublin. The survey sampled students in the College of engineering in the first and final years of their degrees. The survey was carried out between November 2021 and January 2022. The survey assessed students' personal value priorities as well as their social engagement metrics. As was the case in Chapter 4, data from the European social survey results for 2021 was retrieved (ESS ERIC, 2022). Data from two groups from the ESS was examined for the purpose of this chapter: respondents to the Irish ESS aged between 18 and 19 years old, and those aged between 21 and 23 years old. These are the approximate age ranges of those in the students in each of the years being sampled. Throughout this section, students in the first-year participant group will be referred to as "Eng1" and the final-year participant group will be referred to as "Eng4". The younger cohort from the ESS data will be referred to as "ESS1", with "ESS4" referring to the older group.

The Schwartz value data here uses the within-individual centred scores which are calculated by subtracting each individual's mean response to all survey questions from each value score

and adding 3.5 to each in order to re-centre the values on the original 1-6 scale. This is recommended in order to highlight the relative importance of values rather than the absolute value (Schwartz, 2016; Sandy *et al.*, 2017; Rudnev, Magun and Schwartz, 2018).

6.4.1 Schwartz Values

6.4.1.1 Engineering Students

Figure 6.1 shows the mean value profiles of engineering students in the first and final years of their degree programmes. We can see that the values here form a broadly similar structure on the polar plot. A series of t-tests were carried out to compare the value scores of the Eng1 group with Eng4. No significant differences were discovered across the ten values.

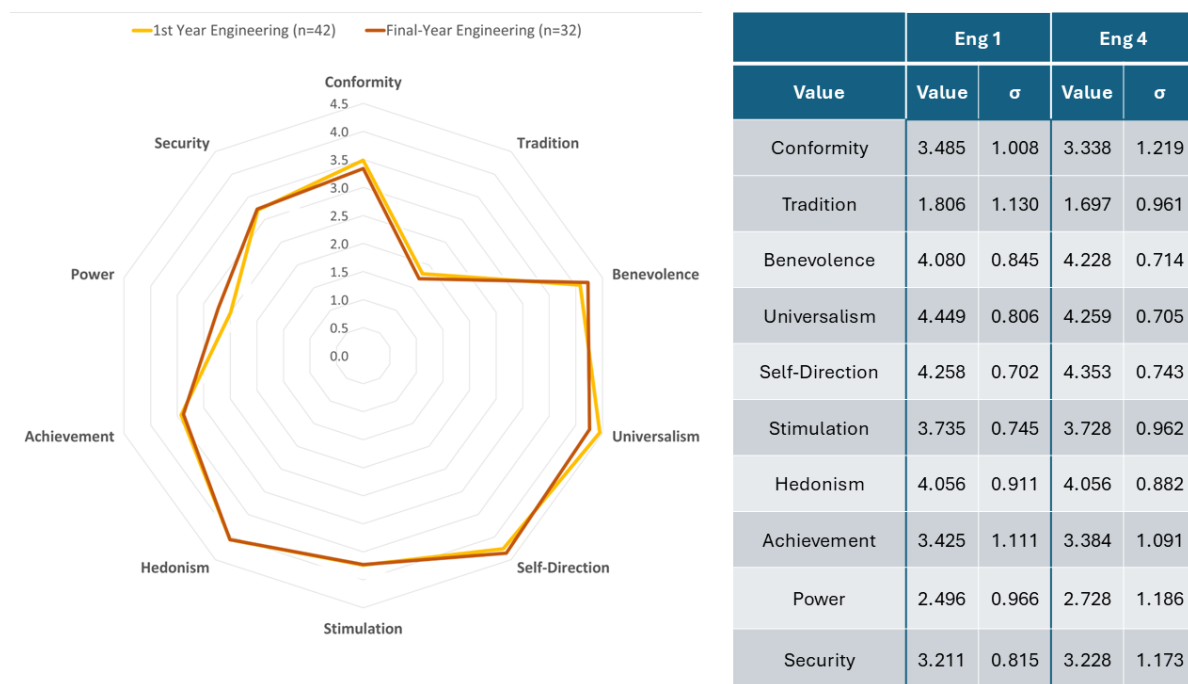


Figure 6.1: Mean Schwartz Values of First-Year and Final-Year Engineering Students

Figure 6.2 shows the higher order values of engineering students plotted on the dual axes of *self-enhancement/self-transcendence* and *openness-to-change/conservation*. For both groups, we can see that the results are largely grouped in the *openness-to-change/self-transcendence* quadrant. While it is a small sample, it is notable that across all 74 students sampled, only 2 participants fell within the *self-enhancement/conservation* quadrant, representing just 2.7% of the total engineering sample. 72.9% of all engineering student respondents fell within the *openness-to-change/self-transcendence* quadrant.

Independent t-tests were conducted on the mean axial scores. These are calculated by subtracting each individual's *conservation* score from their *openness-to-change* score, and their *self-enhancement* score from their *self-transcendence* score. These tests found no significant difference.

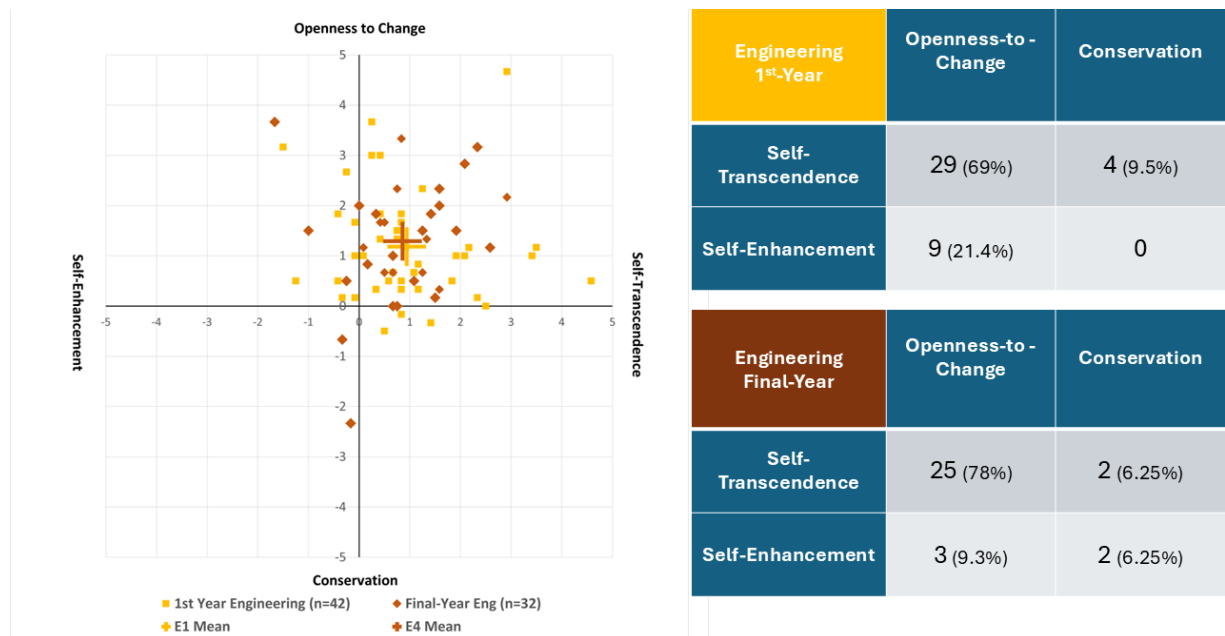


Figure 6.2: Engineering Students Higher Order Value Priorities by Year

Table 6.1: Mean Value Priorities of Engineering Students by Year according to Survey Data

1 st Year	Final Year
Universalism	Self-Direction
Self-Direction	Universalism
Benevolence	Benevolence
Hedonism	Hedonism
Stimulation	Stimulation
Conformity	Achievement
Achievement	Conformity
Security	Security
Power	Power
Tradition	Tradition

Table 6.1 shows the value rankings of first and final year engineering students, based on the mean score that each value received. The priorities of both groups are very similar with two pairs of values being inverted in each group. Final-year engineering students ranked *self-direction* as the most important value, ahead of *universalism*, which was favoured by first-year students. The values of *conformity* and *achievement* were ranked in 6th and 7th place respectively for first-year engineering students, while final-year students ranked *achievement* above *conformity*. Referring back to the mean scores in Figure 6.1, the difference between

the mean scores for these pairs of values for both groups are very small, suggesting that these are marginal differences and not a strong value priority.

Table 6.2 shows these ordinal rankings alongside the value priorities of the ideal engineering graduate according to staff interview participants. As was explained in Chapter 5, these were created by having the participants rank these values in the order that they would like to see a graduate of their degree prioritise them. Based on these rankings each value was given a score of 1-10. The mean of these scores was then calculated to give an average value priority. As this survey was carried out in a traditional university (as opposed to a technological university) both the total combined staff ranking and the university staff rankings are included here.

Table 6.2: Value Priorities of Surveyed Students alongside the Ideal Rankings according to Staff

Student Survey Data		Values Ranking Exercise	
1 st Year Students	Final Year Students	University Staff	Combined Staff
Universalism	Self-Direction	Universalism	Self-Direction
Self-Direction	Universalism	Self-Direction	Benevolence
Benevolence	Benevolence	Benevolence	Universalism
Hedonism	Hedonism	Stimulation	Stimulation
Stimulation	Stimulation	Achievement	Achievement
Conformity	Achievement	Security	Security
Achievement	Conformity	Power	Tradition
Security	Security	Tradition	Power
Power	Power	Hedonism	Conformity
Tradition	Tradition	Conformity	Hedonism

In many ways the surveyed student value profiles are similar to the ideal engineering value profile. *Self-direction*, *universalism*, *benevolence* and *stimulation* are all in the top half of the student rankings and the staff rankings. The major difference is the higher prioritisation of *hedonism* by surveyed students. While staff suggested it should be in last or second-last position, it was ranked in 4th place for students, above *stimulation*. This was predicted by more than one staff interview participant who joked “that’s probably the student’s favourite, but it’s probably bottom of my list” (A3). *Conformity* is the other value which staff had ranked in the bottom two positions. Students scored it higher, in 6th, and 7th positions for first-year and final-year students respectively.

6.4.1.2 Final-Year Engineering Students and European Social Survey Data

Table 6.3 shows the mean value priorities of final-year engineering students along with the scores based on the data from the ESS4 cohort. These are a randomised cross-section of the Irish population of approximately the same age as the average final-year year engineering students.

We can see many different value priorities between these two groups. *Self-direction*, for instance, is rated in 4th position by the ESS4 group, while these engineering students consider it the most important value. *Benevolence* is the most important value to the ESS4 group with both the students and staff in this group rating it in 3rd. *Security* was rated in 2nd place by the ESS4 cohort with final-year engineering students rating it in 8th position. *Power* and *tradition* are the bottom ranked values for both of these groups. Universalism is an important value to both groups, though these engineering students rated it above benevolence, while the ESS4 group had it two places lower.

Table 6.3: Mean Value Priorities of Final-Year Engineering Students Survey Data and ESS4 Sample

ESS4	Final Year
Benevolence	Self-Direction
Security	Universalism
Universalism	Benevolence
Self-Direction	Hedonism
Achievement	Stimulation
Hedonism	Achievement
Stimulation	Conformity
Conformity	Security
Power	Power
Tradition	Tradition

Figure 6.3 shows a polar plot of the mean value profiles of the ESS4 group and final-year engineering students. We can see some visible differences between the profiles here, in contrast to the broadly similar patterns seen in Figure 6.1 above. As an average of the general population, the ESS4 profile is considerably more centred and rounded than that of the engineering students, which favours the bottom half of the chart and drops sharply for the value of *tradition*.

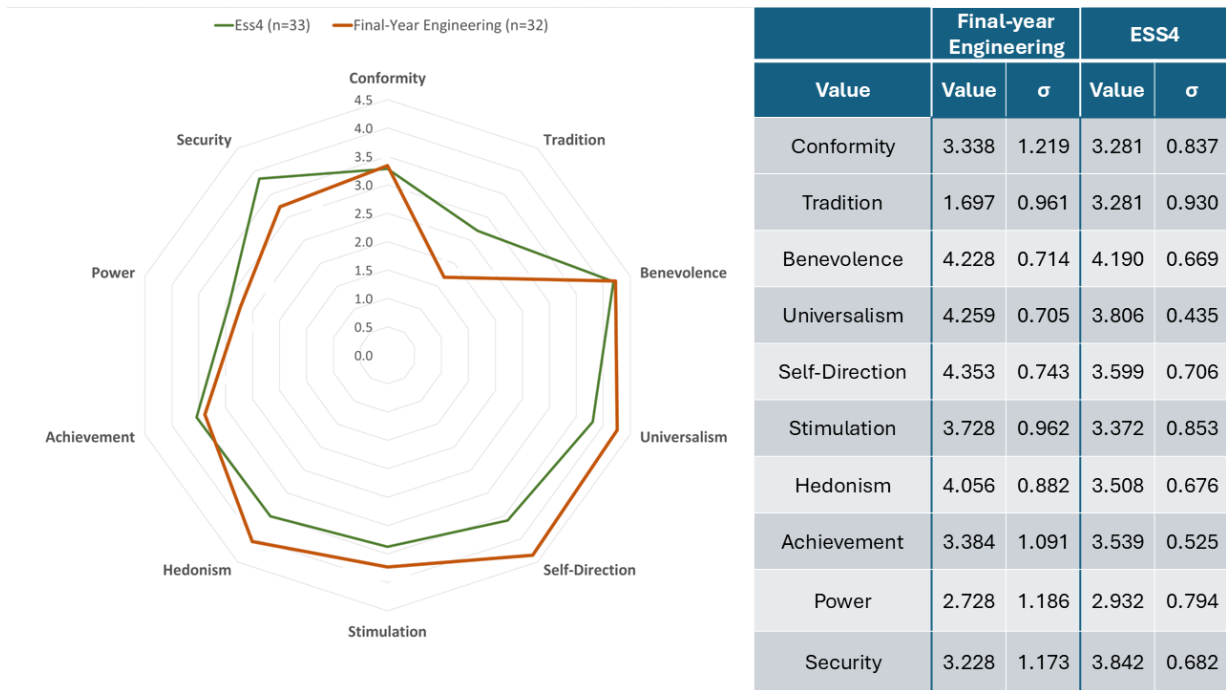


Figure 6.3: Mean Schwartz Values of Final-Year Engineering Students and the ESS4 group

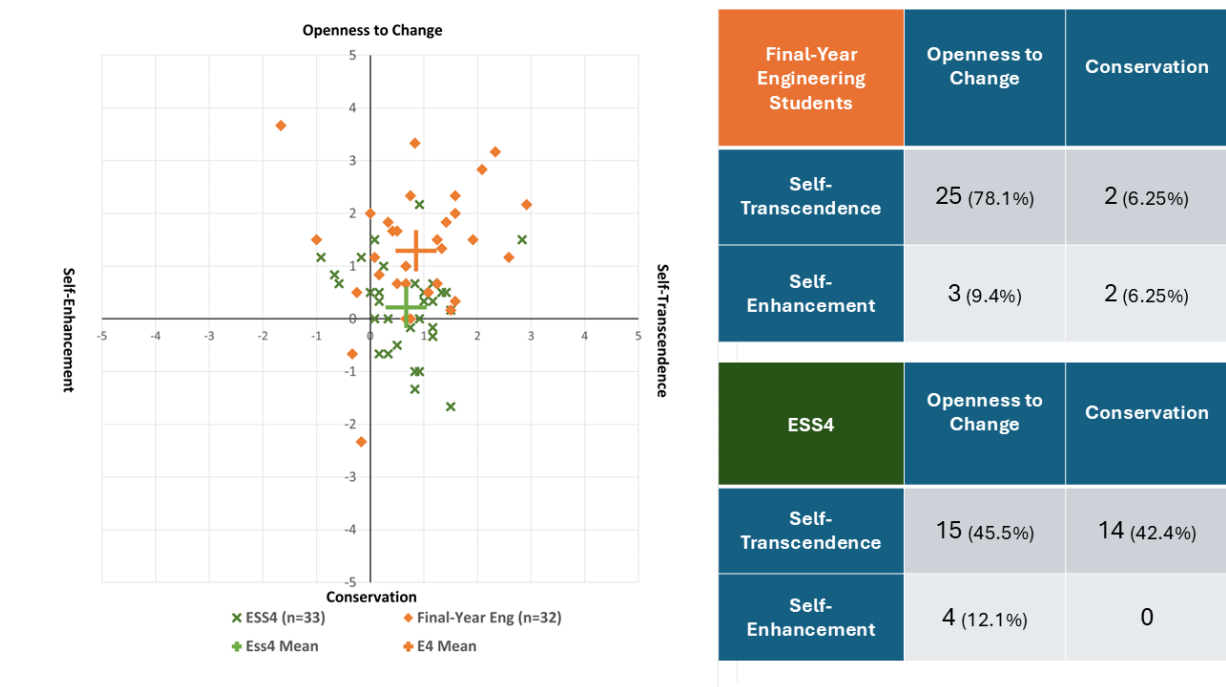


Figure 6.4: Final-Year Engineering Students & ESS 4 Higher Order Value Priorities

Examining Figure 6.4 we can see that the data points for the ESS4 group are clustered closer to the origin than the engineering students. While still a minority a much greater proportion of the ESS group favour *conservation* over *openness-to-change* than is the case with engineering students.

Table 6.4 shows the results of independent t-tests comparing the mean higher-order value scores of these two groups. The Eng4 group scored significantly higher than the ESS4 group

for *openness-to-change* with a large effect size ($t_{\text{openness}}(63)=4.134$, $p>0.05$, $d=1.36$), and significantly lower for *conservation*, with a correspondingly low effect size ($t_{\text{conservation}}(63)=-3.139$, $p>0.05$, $d=0.97$). There was no significant difference for *self-enhancement* or *self-transcendence* scores.

Table 6.4: Higher-Order Values t-test: Final-Year Engineers and ESS4 group

	Conservation	Self-Transcendence	Openness-to-Change	Self-Enhancement
Mean Final-Year Engineer	2.75	4.24	4.05	3.39
SD (Final-year Engineer)	0.617	0.560	0.375	0.496
Ess4 Group	3.28	4.00	3.49	3.33
SD (ESS4)	0.463754	0.441100	0.445288	0.440640
DoF	63	63	63	63
α	0.05	0.05	0.05	0.05
t_{cv}	2	2	2	2
t	-3.139	1.755	4.134	0.466
Cohen's d	0.97	0.48	1.36	0.13

Table 6.5: Schwartz value t-test: Final-Year Engineering Students & ESS4 group

	Security	Conformity	Tradition	Benevolence	Universalism	Self-Direction	Stimulation	Hedonism	Achievement	Power
Mean Engineer	3.23	3.34	1.70	4.23	4.26	4.35	3.73	4.06	3.38	2.73
SD (Engineer)	1.173	1.219	0.955	0.714	0.705	0.743	0.962	0.882	1.091	0.753
Mean (ESS4)	3.217	3.809	2.050	4.957	4.698	3.865	3.531	4.161	2.887	1.791
SD (ESS4)	0.682	0.837	0.930	0.669	0.435	0.706	0.853	0.676	0.525	0.794
DoF	63	63	63	63	63	63	63	63	63	63
α	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
t_{cv}	2	2	2	2	2	2	2	2	2	2
t	-2.641	0.245	-4.299	0.222	2.466	4.553	1.581	3.082	-0.778	-0.818
Cohen's d	0.636	0.057	1.068	0.058	0.772	1.035	0.408	0.700	0.187	0.198

* t value exceeds t_{cv}

Table 6.5 shows the results of a series of t-tests carried out on the value scores between the ESS4 cohort and the combined 4th & 5th year engineering student group. The engineering students scored significantly higher than the ESS4 group for the values of *universalism* ($t_{\text{universalism}}(63)=2.466$, $p>0.05$, $d=0.772$), *self-direction* ($t_{\text{self-direction}}(63)=4.553$, $p>0.05$, $d=1.035$) and *hedonism* ($t_{\text{hedonism}}(63)=3.082$, $p>0.05$, $d=0.7$), all with a large effect size. The ESS4 cohort

scored more highly for the values of *tradition* ($t_{\text{tradition}}(63)=-4.299$, $p>0.05$, $d=1.068$) and *security* ($t_{\text{security}}(63)=2.641$, $p>0.05$, $d=0.636$).

In Chapter 4 of this thesis, a similar analysis was conducted between 1st year engineering students and the ESS1 group. This analysis found a similar pattern of significant differences, in the same direction for the values of *tradition*, *universalism* and *self-direction*. While there were differences in the values of *hedonism* and *security*, and they were in the same direction as we see here, they were not significant in the previous test.

6.4.2 Social Engagement

Figure 6.5 shows the mean responses of each year group of engineering students to the social engagement questionnaire portion of the survey. While it should be noted that the variations between groups here are small, there are some interesting differences. In Chapter 4 it was established that engineering students had lower expectations about the importance of ethical and social content, and of a broad education in the humanities, than either nursing or law students. The graph here shows that final-year students, having experienced the majority of the degree programme, scored the importance of ethical and social issues the same as the first-year group, and rated the importance of a broad education in the humanities lower.

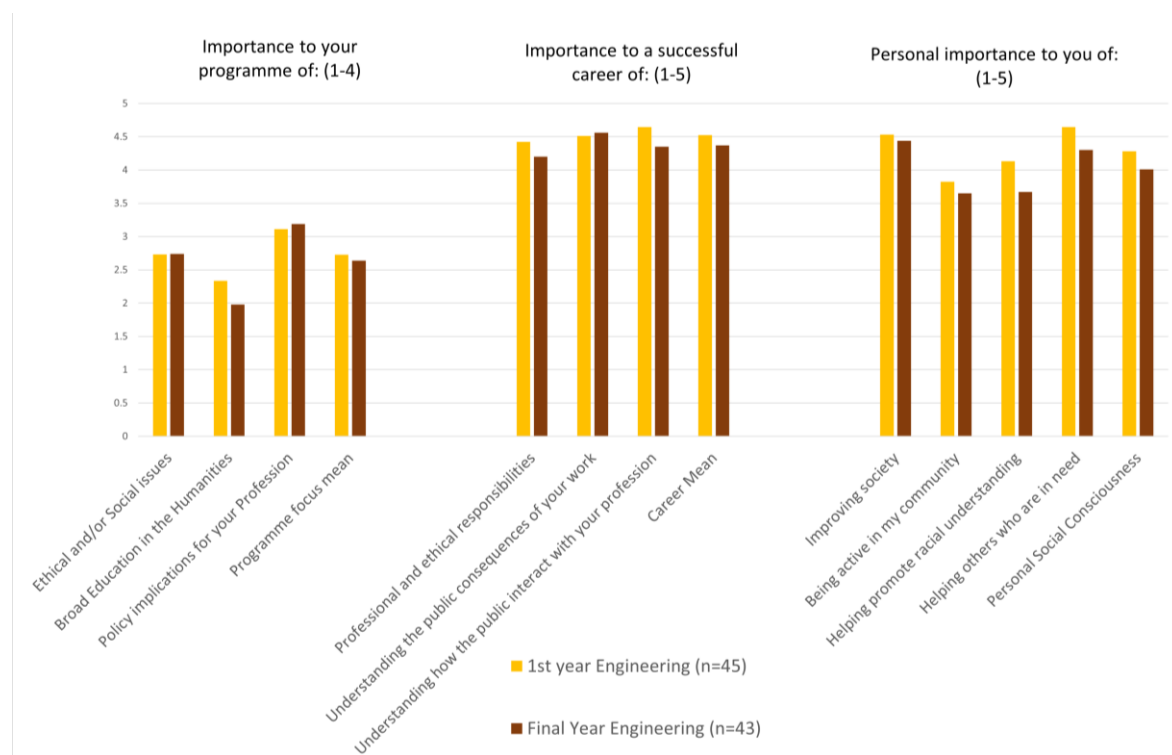


Figure 6.5: First and Final Year Engineering Students Social Engagement Metrics

It is notable then that despite steady level of programme content relating to ethical and social issues, the perceived importance to a successful career of professional and ethical responsibilities decreased slightly. Student interview participants described certain non-technical aspects of their degree programme feeling “like a little bit of an afterthought” (S5). This, as well as previous research which has found that social considerations and ethics are viewed as ancillary or an add-on to engineering, corresponds to the findings here. It suggests

that ethical and social considerations are not considered part of the engineer's core skill set, and that despite the inclusion of content in the later stages of the degree, they are not perceived as important to a career in engineering.

Finally, looking at the third section of Figure 6.5 we can see the personal social consciousness metrics of both groups. It is interesting to see that there is a decrease, albeit minor, across all measures. The personal importance to participants of "improving society" is very similar across all three groups. On the other hand, a t-test carried out to compare the mean scores of 1st and 5th year engineering students for the third item, "the personal importance to you of helping others who are in need", revealed a significant difference with a medium effect size ($t_{\text{helping}}(86)=2.036$, $p>0.05$, $d=0.43$), with final-year engineering scoring significantly lower for this metric. Together these results are consistent with an understanding of the engineering profession which sees major global and societal issues as within its remit, but that also encourages scientific detachment in its practice.

6.5 Conclusion

The engineering curriculum is densely packed with material, and this is unlikely to change in the near future. Engineering educators work to equip engineers with the full suite of skills which they will need in their careers. As new technologies are developed and implemented, the range of potential tasks and the body of knowledge which an engineer may need increases. Decisions need to be made to prioritise what content will make it into the curriculum and what will not. However, the current structures which govern the creation and curation of engineering degree programmes resist change, and despite a variety of inputs, results in a very narrow range of perspectives being represented.

The role of the engineer is often described in terms of a problem-solving service to industry and society. In curriculum design negotiations, there are significantly more voices advocating on behalf of employers than on behalf of society more broadly. This is born, at least in part, by a desire to offer students the greatest range of opportunities upon graduation. Much of the engineering identity, as discussed in Chapter 5, revolves around being an employee. The employment rate of graduates is also one of the most tangible metrics of success available to a university department. In this context, the needs of industry are held as a central priority in the engineering curriculum design process.

There seems to be a lack of a strong voice arguing on behalf of society. Claris and Riley (2012) frame this in terms of "an investment into the profession", where students learn to operate within its power structures, as opposed to developing a "critical view that might lead to investment in changing the profession". They suggest that for the integration of more critical perspectives to be effective these ideologies may need to become more widespread across the profession. Faculty members often express scepticism about the demand for graduates with strong social or ethical training, arguing that employers do not prioritise these skills. While these changes may ultimately benefit the profession and wider society, there are currently no incentives for a particular university to be the first mover in overhauling their programmes. In this context the role of the professional body in steering the direction of engineering education is likely to be vital.

The accreditation process is a recognised pathway by which non-technical content can be introduced into the engineering curriculum, though the data presented here has indicated that

it can encourage box-ticking rather than meaningful engagement with non-technical topics. These subjects get included to the minimum acceptable level without fully being integrated into the core engineering identity. The social impact and ethical aspects of assignments are not heavily weighted during assessment, resulting in these topics receiving less attention from both students and staff. Just as students believe that minimal attention to ethical considerations will not be penalised, staff similarly perceive that underdeveloped ethical content in programme design will not lead to significant consequences in accreditation reviews.

The current level of social content in Irish engineering education remains low, both in terms of quantity and depth, yet it is being endorsed by Engineers Ireland through the accreditation process. While accreditation has incorporated social criteria, there is a case to be made that this inclusion has not gone far enough. The accreditation process generally sets out broadly defined end goals, allowing universities a degree of freedom in how they achieve them. However, the power to deem the content acceptable still lies with the accrediting body. Participants in this study, with a single exception, were involved in programmes which hold this accreditation, meaning the coverage of social content has been approved. On the one hand, programmes have faced pushback and had their accreditation questioned or removed over the level of mathematics required, including disputes about the entry-level maths standards. On the other hand, Engineers Ireland continue to accredit programmes that contain at best limited quality and quantity of social content. This raises questions about the effectiveness of accreditation as a tool for driving meaningful change in this area in engineering education, or the commitment of the professional body to driving such changes.

The perceived lack of utility of these “soft” subjects in the engineering workplace is a commonly cited reason for their limited coverage. However, this stands in contrast to technical subjects which are still taught from first principles, often to a depth that exceeds what most engineers will practically require. This disparity reflects an engineering culture that highly values the ability to deconstruct and understand a technical system down to its nuts and bolts yet fails to apply the same rigorous analysis to non-technical topics. This approach is indicative of the broader issue within engineering education, a reluctance to engage deeply with social and ethical dimensions, which are often perceived as less tangible or less relevant to private industry.

The value of socially oriented and ethical content does not seem to have infiltrated the culture of engineering education. Accreditation requirements exist in relation to non-technical content, but academics, being steered by what they believe to be the necessary skills and knowledge required by engineers in industry, see these as ancillary, rather than essential. The minimal inclusion of social and non-technical subjects in the engineering curriculum is noticed by students, as is evident in the survey results. Furthermore, the addition of modules covering ethics in the final year does not appear to be influencing the perception of students as to how important these are to a working engineer.

Ultimately this tension between the technical and non-technical elements of the curriculum is driven by the limited class time, and natural human limits on what one student can learn in a semester. Perhaps a solution to alleviate this is to encourage the recognition of disciplines beyond engineering, that is, to acknowledge the limitations of engineering and its perspective on the world (Riley and Lambrinidou, 2015). It is not possible for an engineer to be an expert in all things; though, it is possible for them to recognise this, and to understand when external

expertise, including from beyond the STEM fields, is necessary. However, current curriculum designs do not accommodate, and arguably deter, the inclusion of epistemologies which stray from the scientific positivism which engineering considers its domain.

There is evidence here of a conditioning effect embedded in the engineering curriculum, where the focus on scientific rationality and mathematical rigour shapes students' approach to problem-solving and understanding the world. Both staff and employers have reported an aversion among students to dealing with the elements of uncertainty that engineering work invariably entails. While this technical focus is maintained in the name of employability, it ultimately negatively impacts on the effectiveness of the student as an employee. This belief that engineering methods can access an absolute truth exemplifies a flawed positivist mindset, overlooking the complexities inherent in real-world scenarios. As a result, students may struggle to navigate the uncertain and multifaceted challenges they will face in their professional careers.

There is also some evidence of the downward trends in social engagement beliefs previously reported elsewhere (Cech, 2010, 2014a). However, these do not appear to have manifested in the personal values of engineering students. The personal profiles of the first and final year engineering students in this study show no significant differences. It should be noted that the data collected here was not longitudinal and so this cannot be discussed in terms of a change or consistency over time. However, it can be seen that the value profiles of these engineering student groups are consistently different from the national sample of their age groups. The value priorities of engineering students appear to closely resemble the ideal priorities described by engineering educators in Chapter 5. *Self-direction* and *universalism* were the most desirable values according to staff, and engineering students scored significantly above the ESS sample for both of these. As with all self-reported survey-based research, there is a risk of social-desirability bias affecting the results (Datler, Jagodzinski and Schmidt, 2013; He *et al.*, 2014) which may account for some of the similarity between these two sets of results. However these results are then indicative of the normative structures within engineering education and reflect what participants believe to be socially desirable.

With engineering students being significantly more likely to favour the higher order values of *openness-to-change* and *self-transcendence*, there is reason to be positive as these value priorities are conducive to holding public welfare in high regard. As was the case in Chapter 5, we can see students express a sense of responsibility with regard to public safety. The high placement of *universalism* and *benevolence* among the value profiles of students is consistent with this. The decline in social engagement values appear to be more closely related to the norms of the engineering profession which curtail the expression of these values.

The capacity for a more socially-engaged engineering appears to exist within the students, however the professional identity which they adopt over the course of their education discourages this. The needs of employers are not necessarily the needs of society, and the objective of engineering is to serve both. The role of accrediting bodies like Engineers Ireland is important in steering the direction of engineering education towards a more balanced approach that includes social and ethical considerations. However, this needs to be followed by a genuine campaign to ensure that these changes are meaningfully adopted. Without a strong, unified push to redefine the priorities within the curriculum, these aspects will continue to be treated as secondary.

Chapter 7: Conclusion

The purpose of this thesis was to explore and understand the professional socialisation of engineering students during their formal education from a values perspective. This was investigated by examining three major elements of engineering education. In Chapter 4, the recruitment of engineering students was explored. A thematic analysis of the university prospectus documents produced by each Irish university engineering department was conducted, and the results were analysed alongside the transcripts of interviews with university engineering department staff and students. The values appealed to in this advertising material, in terms of the role of the profession and the value of an engineering degree, were the primary areas of focus. The final aspect of this chapter was an analysis of survey results, which compared the personal values of first-year engineering students at an Irish university to their peers studying law and nursing, as well as the results of an Irish sampling of the European Social Survey. The purpose of this was to determine the value profile of those students who choose to study engineering.

Chapters 5 and 6 of this thesis investigated the values which are promoted within engineering education. Chapter 5 was concerned with establishing what participants believe it means to be a good engineer. It presented an analysis of interviews with engineering students and staff from Irish universities. By focusing on participants' descriptions of the ideal engineering graduate, in terms of their skills and competencies, the role they play in society and industry, and their values, this chapter established an aspirational profile for what engineering education is working to produce.

Chapter 6 continued this analysis, this time exploring the values promoted through the engineering education curriculum. Staff interviews addressed the processes and objectives which guide curriculum design, while students offered insight into their experience of education and how it affected their understanding of engineering as a profession. This chapter also discussed the results of a cross-sectional survey aimed at comparing the personal values and social engagement levels of first-year and final-year engineering students. These were also compared to the ideal value profiles produced in Chapter 5, providing a deeper understanding of the socialising effects of engineering education.

The following section revisits the research questions that motivated this thesis, drawing conclusions for each from the data presented in the previous three chapters.

7.1 Research Questions Answered

7.1.1 RQ1: What are the values being appealed to during the recruitment of engineering students?

The portrayal of the engineering profession during the recruitment of engineering students conveys a number of messages which speak to the values of engineering as well as the identity of the profession. Within these there are some points of tension as different aspects of the portrayal present conflicting value implications.

Throughout the recruitment material the profession is portrayed both in terms of its traditional roots, as being closely related to craftspeople and trades, as well as a more modern, scientific interpretation. This ambiguity in the nature of engineering work has led to a depiction of

engineering which sits somewhere between the *realistic* and *investigative* career types. This may be, in part, responsible for the common misconception among incoming students that engineering education features significant amounts of hands-on making and building, rather than the reality of a theory-intensive curriculum. This depiction of engineering as a hands-on subject, along with the heavy use of language related to practical applications of engineering skills and the role of the engineer as an employee, fits the categorisation as a *realistic* profession.

In the same documents, engineering is also portrayed as a scientific endeavour, appealing to the students' intrinsic interest in technology, and highlighting the use of maths and science to solve technical challenges. This may more accurately describe the tools and techniques of modern engineering, though it has the added effect of introducing the idea of scientific detachment and objectivity to the engineering identity, which is a potential hindrance to a profession which professes to be in the business of solving problems for the benefit of society.

Problem-solving remains the defining feature of engineering in the various definitions presented in the recruitment materials. Previous work has related this to an intrinsic desire to help within the engineering mindset (Riley, 2008). This is evident within the findings of this thesis as the contributions of engineering to societal progress across a variety of fields and disciplines are cited in the prospectuses. However, in the way these problems are framed, we observe some of the concerns previously highlighted by the Engineering for Social Justice (E4SJ) movement. The prospectus materials present engineers as problem-solvers for society, but only through a narrow, technological lens, overlooking the need for broader skills and understanding. This focus on technical and scientific subjects neglects the wider range of expertise required to address society's challenges. It implies that mastery of technical skills required by industry are the best tools an engineer can acquire and are the only means by which the profession contributes to the welfare of society.

This desire to help others would appear to appeal to *self-transcendence* values. Specifically, *universalism* is emphasised more than *benevolence* due to the impersonal language and the society-wide perspective in which these issues are framed.

The recruitment materials also appeal to students' intrinsic interest in technology and emphasise the importance of creativity and innovation in engineering. The profession is depicted as valuing innovation, and developments in technology are framed as progress, and therefore inherently good. It is a technocentric view which may contribute to the idea that simply by developing new useful technological solutions, engineering is meeting its objectives. This understanding of engineering appeals to the intellectual curiosity and creativity of students, and aligns to the values of *self-direction* and, to a lesser degree, *stimulation*.

The level of mathematics in engineering education is perceived as the dominant barrier for entry into engineering education. This reinforces the idea that engineering is solely about maths and obfuscates the range of other aptitudes which are desirable in an engineer. This may deter students with other relevant abilities and interests. It creates a direct tension in relation to the creative elements of engineering. While maths can be a creative discipline, the public perception of maths is often far more rigid and prescriptive (Schoenfeld, 1989; Prendergast *et al.*, 2018). The experience of maths in Irish education is disconnected from the creativity of broader mathematical concepts in the minds of Irish secondary school students (Prendergast *et al.*, 2018). Students described themselves or peers being deterred from engineering by the rigid maths-centric perception.

Finally, the role of engineers as employees is prominent in the marketing materials. Marketing staff confirmed that this inclusion is in part intended to reassure the parents of students that this degree is a worthwhile investment. However, it also serves to reinforce this aspect of the engineering identity in the minds of students. This appeals to the *self-enhancement* values of potential students, specifically *security*.

7.1.2 RQ2: What are the values of those who enter engineering education?

The value priorities of incoming engineering students do appear to conform to some of the trends that would be expected of an *investigative* profession. *Universalism* and *self-direction* being a top priority, and being scored significantly higher than the ESS cohort, while *tradition* is ranked in last place is consistent with research from other countries (Knafo and Sagiv, 2004; Arieli, Sagiv and Roccas, 2020). Engineering students favoured *openness-to-change* to a greater extent than any of the other groups included here. They also favoured *self-transcendence* marginally more than the national average for their age group, though less than the other student groups.

This, along with the prominence of *benevolence*, ranking among the top three values for engineering students, suggests a genuine desire to help and do good within their value priorities. This is further supported by the high scores given to the importance of “improving society” and “helping others in need”. However, while the numerical score for *benevolence* among engineers is similar to that of law students and the ESS group, engineering students scored lowest for it (3rd) among the groups, which may reflect the profession's more detached approach to problem-solving.

Interestingly, incoming engineering students expected the least content related to social engagement in their degree of any of the three disciplines surveyed. The narrow definition of engineering is evident in the lower score for “broad education in the humanities”. This is consistent with the techno-social divide which has previously been observed in the culture of engineering education.

Overall, the value structure of those choosing to study engineering appears to be compatible with a desire to work towards societal benefit. However there are aspects which appear to suggest early indications of the beliefs about the profession which limit its ability to fully achieve this.

7.1.3 RQ3: How is the ideal engineering graduate described by those in Irish engineering education?

Chapter 5 investigated how those in engineering education described the ideal engineering graduate, with a specific interest in value priorities. These represent an aspiration in terms of the graduates that teaching staff in engineering departments would like to produce. The students' perspectives on this are an indication of what they believe they should be attempting to emulate.

As was the case in the recruitment material, the ideal engineer is expected to be a problem-solver and an innovator. However, they are defined primarily in their role as an employee. While the descriptions included the skills an engineer should have, the kinds of work they would be expected to do, and upon prompting, the values they should hold, the ever-present

frame of reference for what constitutes a good engineer, was whether they are desirable to potential employers.

Staff preferred to discuss the ideal engineer in relation to the skills with which they would be equipped rather than in terms of values, though the skills included point to implicit values and norms of practice. These skills were centred around a clearly defined core of natural sciences and mathematical ability. Transversal skills such as creativity and communication were included, though were considered secondary to technical competency. Certain skills such as critical thinking and investigation were included, though the scope of their application was limited by the context in which the engineer was imagined to be working.

Good engineering was defined in terms of many of the same qualities associated with science. A strong belief in the norm of objectivity is evident in the descriptions of good engineering work, as was a preference for a scientific rationality and positivism. Problems are believed to be best understood by removing social contexts, and addressing the core technical issue. Non-technical factors are considered bias and should be excluded from decision making. The notable exception to this is economic factors, which are an acceptable criteria for engineers to include. This highlights where engineering was described as distinct from science. While scientific knowledge and objectivity are valued, good engineering includes an emphasis on usefulness and effectiveness. The focus remains on solving practical problems rather than pursuing discovery. This was again emphasised through the focus on industrial applications.

Ethical and environmental considerations featured in these discussions, though again they were considered secondary criteria. Ethics in particular was discussed in negative terms, as a limitation on engineering work. Due to the narrow scope of ethics included in engineering education, it is seen primarily as a box an engineer must tick in order to be allowed to pursue a project. Sustainability on the other hand has managed to gain a little more traction in terms of becoming a valid and valuable engineering decision-making criteria. Participants related this to increasing pressure on industry to improve the sustainability of their operations.

This relates to the peculiar relationship between the ideal engineer and *power*. Participants discussed the social impact of engineers as being constrained and directed by external forces. The example of environmental sustainability is illustrative of an external influence regulating industry in such a way that pursuing something which has wide societal benefits becomes a valid objective for engineering. Engineers operate within the corporate environment and so company objectives are determined by management. While engineers are prepared for management roles and are equipped with necessary skills, they tend to conform to existing business practices rather than challenge them. Critical thinking is valued in engineering, but it is applied as analytical problem-solving within set boundaries rather than questioning the broader context of the profession. Although engineers are acknowledged to have the potential to contribute to the public good, there is hesitation in defining what that public good should be. The creative thinking expected of engineers is typically applied to technical challenges, not to the larger social or ethical implications of their work.

As mentioned above, participants did not discuss the values of the ideal engineer until prompted. However, once asked, the value rankings produced by staff and students showed some notable common themes. *Self-transcendence* and *openness-to-change* values are favoured over their opposites, which is consistent with a profession which identifies itself around problem-solving and innovation. The similarities between the value profile described by staff and that described by students suggests that while values have not explicitly formed

a conscious part of the learning objectives in the curriculum, students may be receptive to the implicit values being communicated.

7.1.4 RQ4: What are the values promoted by engineering education at Irish universities?

There were no significant differences between the average personal value scores of first-year and final-year engineering students. There were some minor differences in the overall value rankings, including *self-direction* becoming the highest value priority. Although the differences in social engagement metrics were not statistically significant in many cases, a slight downward trend was observed across several metrics, lending some support to the notion of a culture of disengagement within engineering. While these changes were relatively minor, there was evidence of a number of potential conditioning effects. The curriculum's emphasis on scientific rationality and mathematical rigour conditions students to approach problems with a technical mindset, which may hinder their ability to navigate real-world challenges that involve uncertainty and complexity.

Universalism remained a high priority for engineering students, however they perceived potential conflict in exercising it in their engineering career, suggesting that it was naive and idealistic to imagine an engineer being true to this value in their work. While the value is held in high regard, it does not appear to qualify as a legitimate criteria for engineering decisions.

While the process of designing an engineering curriculum involves a range of stakeholders, collectively these appear to represent a relatively narrow range of perspectives. The needs of industry are represented through a number of channels and with so much of the engineering identity couched in the role as an employee, these voices are listened to. This isn't a problem in isolation, however these voices in isolation are. Many of the largest employers of engineers are private enterprises and so are beholden to the needs of private interests. The needs of society are accounted for only in so far as is legally required or profitable. There is a lack of a strong independent or democratic advocate lobbying on behalf of the needs of society. While the professional body wields significant influence, and offers some encouragement in this direction, it appears to be insufficient to affect real change as of yet.

The value of social and ethical content has not deeply influenced engineering education. There is a tension between the technical and non-technical elements of the curriculum, driven by limited class time. Whether by intent of design or not, the current curriculum design reinforces the techno-social divide. It devalues non-technical epistemologies and discourages the inclusion of knowledge outside the traditional scientific and technical focus of engineering. While technical subjects are taught from first principles, non-technical subjects are often neglected or receive minimal coverage, reflecting an engineering culture that prioritises technical knowledge over other forms. Students perceive these subjects as ancillary, and even late-stage ethics modules do not significantly impact their views on the importance of these areas in their future careers.

Students articulated views about the nature of engineering that suggested that a degree of disengagement is embedded within the professional identity of an engineer. There is evidence of a belief in the myth of objectivity and value-neutrality in engineering, with many students convinced that technical methods can transcend issues of values and bias to reveal an objective truth. This perspective implies that engineering analysis is capable of navigating beyond the complexities of social bias, fostering a detached approach to problem-solving.

The value profiles of engineering students showed a high placement of the *self-transcendence* values of *universalism* and *benevolence*, values which are associated with social justice as well as the welfare of society. These values suggest students who at a fundamental level do desire to contribute to the public wellbeing. However, the conception of societal responsibility within the engineering role appears to be narrowly defined. It is largely confined to issues of safety and accountability for faulty design work, with little recognition of responsibility for the broader applications of technology. The utilisation and societal impacts of technological solutions are perceived as beyond the control and responsibility of the engineer. This limited view underscores a reluctance to engage with the ethical and societal dimensions of engineering practice.

7.2 Concluding Discussion

This thesis set out to investigate the values and norms within engineering education in Ireland, by answering the four research questions listed above. In doing so, the personal values of engineering students and the values promoted by educational institutions, as well as the perception of the norms governing engineering practice from within engineering education have been revealed.

At a value level, those choosing to study engineering appear to have the desire to serve the public interest, as well as a capacity for creativity and self-motivation which are hugely valuable in an engineering career. This profile closely resembles the ideal profile described by teaching staff at Irish universities. Furthermore, these values appear to persist throughout their education. Instead, any sense of disengagement or disinterest in public welfare appears to stem from engineering-specific norms.

Engineering students are learning to think about problems in specific ways, the criteria to use for assessing their engineering decisions, and the role that engineers should expect to play during their careers. They are learning what constitutes valid engineering knowledge, and what should be considered bias. The alignment of the engineering profession with the academic practices of science leads to students only valuing technical and scientific epistemologies, while non-technical forms of knowledge are devalued and disregarded. Engineering education fosters the belief that the skills and knowledge currently employed by disciplines outside of the STEM field lack value or utility.

At present, what is considered an engineering skill is largely defined in relation to the perceived needs of employers. Engineering students are learning that their job is to solve problems for industry and society, while only industry has a say in how they do this.

This thesis began with a call for the engineering profession to embrace its role in “designing transformations”, not just joining in the execution. Professionals have both a duty to serve and an obligation to lead (Florman, 1996). Without the critical thinking skills required to interrogate the social and political context of their work, and the capacity to assess the outcomes on a much broader range of criteria, engineering cannot be said to be leading. It is, at best, middle-management.

After graduation, engineers will have a significant impact on the world. The personal values of students suggest that this would be a positive contribution. However, the current norms of engineering practice, as they are presented in engineering education and perceived by students, teach them that these values must be excluded from their engineering work.

While I have stopped short of suggesting solutions for changing this engineering culture, the contribution of this thesis is to offer a critical reflection on the current values within engineering education. Just as the first stage in an engineering design process is to thoroughly define and understand the problem at hand, this thesis offers a foundational insight into the challenges we face, paving the way for more informed and effective solutions in the future.

7.3 Limitations and Directions for Future Work

The research methods applied in this thesis have been well-rooted in established theoretical frameworks and have been employed in previous studies. Considerable efforts have been made to ensure the quality of this research and the validity of its findings. This research provides a novel and useful contribution to the field. Nevertheless, it is important to acknowledge the limitations inherent in any study.

Firstly, it should be acknowledged that I, as the researcher, have a bias in favour of reforming and redirecting engineering towards a more socially engaged and beneficial state. As has been outlined in section 1.3, I believe that the profession has a great capacity to benefit society, but also that there is well-documented evidence that it is falling short of this. Researcher bias is a common limitation of qualitative research. Steps were taken to mitigate the influence of this, though it can never be entirely removed. It is possible that another researcher may draw different conclusions from the same data set. What is presented here is my interpretation of the data, informed by careful analysis, and should be interpreted as such.

The sample population for the quantitative aspects of this study was confined to a single university and so results should not be generalised beyond this study. Students are a heavily sampled population for survey-based research and as a result universities are careful about allowing excessive access to external researchers. Excessive sampling of a single group can lead to lower quantity and quality of responses to future research (Porter, Whitcomb and Weitzer, 2004). Requests to distribute the survey at other Irish universities were denied, primarily on the grounds that these universities understandably want to maintain a healthier research pool for their own researchers. A future, collaborative project with access to multiple institutions would allow for a more comprehensive mapping of the field.

The sample size for interview participants is another limitation. As is the nature of qualitative interview-based research, there is always the potential to increase the number of interviews and gather a wider pool of perspectives. Within the timeframe and resources allotted to a PhD project, it is necessary to decide what constitutes a wide enough sample. In the case of this research, the final sample size was not decided upon in advance, but rather as interviews progressed, and a saturation point was reached in terms of new perspectives being expressed, the sample was deemed sufficient. It was also compared against studies using similar methodologies and deemed to be comparable. While this study captured a meaningful breadth of perspectives, it is not all encompassing.

Another potential consequence of this sample is a bias in relation to socioeconomic background. The makeup of the student population enrolled in higher education in Ireland is not representative of the socioeconomic makeup of the wider population. 10% of students enrolled in higher education in Ireland in 2022 are from disadvantaged backgrounds, compared to approximately 15% of the wider population of the equivalent age. Affluent areas are over-represented, making up 18% of the student population and 15% of the wider population (HEA, 2022a). Furthermore, the university where the survey was distributed skews

even further towards the affluent. 34% of students come from affluent backgrounds, 39% are from marginally above average, 21% are from marginally below average and 5% come from disadvantaged backgrounds (HEA, 2022b). Socioeconomic status can influence personal values, as well as the degree to which values can be actioned, so the value priorities of these groups of students may not be representative of the wider engineering student population (Schwartz, 2009).

Participation in all aspects of this study was voluntary. No incentives were offered to interview or survey participants. This introduces the potential for self-selection bias. In the case of academic staff interview participants, those with an interest in engineering education as a research topic may have been more inclined to agree to participate. Student interview participants were initially contacted through student engineering societies, and so those involved in the running of these societies were more likely to volunteer to participate. These students are elected to their positions and so in some way represent a wider student population, they may not, themselves be 'the average student'. Web-based surveys can suffer from self-selection bias. For instance when participants are made aware of the subject matter of the survey, those with stronger opinions, positive or negative, are more likely to participate (Bethlehem, 2010; Khazaal *et al.*, 2014).

This research was carried out between March 2020, and September 2024, with quantitative data collection taking place during the 2021-2022 academic year. The 2019-2020 and 2020-2021 academic years were disrupted by restriction due to the Covid-19 pandemic. The class groups sampled during their final years of their engineering degrees spent a portion of their time engaging in remote learning, and so had an atypical educational experience. Similarly, internships and work placements which some students undertook during this time would have been affected by restrictions. It is difficult to account for how this may have affected the outcome of their professional socialisation process.

For pragmatic reasons this research used the original Schwartz value theory, consisting of ten basic values (Schwartz, 1992). A refined version of this theory, consisting of nineteen values, offers a more precise measure of human values. It offers greater depth of understanding and has better predictive power in terms of how values influence behaviour (Schwartz, 2017). However, applying this model requires a significantly longer survey to be completed by each participant. Also, as the European Social Survey uses the original model, there is no widely available comparable data set available to the researcher which uses the refined Schwartz value theory.

The research design for the quantitative aspect of this thesis used a cross-sectional sampling strategy. This is consistent with the approach taken by several of the studies cited in this thesis (Canney and Bielefeldt, 2015b; Al Kakoun, Boy and Xavier, 2021; Murphy, Christensen and Conlon, 2022), though differs from the work by Cech (2010, 2014a) which was central to the motivation of this study. This choice was made due to time constraints, as repeated sampling of a single cohort of undergraduate students throughout their entire degree programme is not possible within the confines of a PhD research project.

Formal education is an important stage in the professional socialisation process, however it is not the end of it. Personal values are stable though can change over time. It is possible that four or five years of education is not sufficient for these changes to fully take place. A significant finding of this study is that beliefs about the role of an engineer are being internalised in a way which is not immediately reflected in the personal values of students.

Staff interview participants described noticing a change in student behaviour after completing work placement. Immersion in the engineering workplace is another potentially potent means of professional socialisation. A study which focuses on the professional socialisation of engineers in the early stages of their career may offer further useful insight.

By the same token, this study showed that the value priorities of these engineering students had been established before entering the degree programme. The nature of the relationship between this value structure and the decision to study engineering is still unexplored. Furthering this understanding may be useful in understanding and increasing recruitment into the engineering profession and so represents a potentially important area for future research.

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Appendices

Appendix A: Values Survey

A.1 Survey Recruitment Email

The following is the text of the email circulated by the university school/college offices to students:

Dear Students,

Thank you for taking the time to read this message. You are invited to participate in a research project I am conducting as part of my PhD. The aim of this study is to investigate the personal and professional values of students at various stages of their education. The goal is to collect a sample from students of various disciplines, and as such your class group is being asked to participate.

The survey does not relate to any personal identifiable information and your responses will be strictly anonymous. All information gathered will be used solely for research purposes. Participation in this study is voluntary. The survey will take less than 10 minutes to complete. I would greatly appreciate it if you could take the time to participate.

To take part, please click [here](#).

If you have any questions relating to the study, contact me at: cormac.deasy@ucdconnect.ie

Thank you for your time,

Best regards,

Cormac Deasy

PhD researcher

School of Mechanical & Materials Engineering

University College Dublin

A.2 Survey Questions

Survey for Non-Engineering Students

Q1. Due to university research policy we are unable to accept participants under the age of eighteen years for this study.

Are you aged 18 years or over?

Answers: -Yes

-No

Q2. With what are your preferred pronouns?

Answers: -He/Him

-She/Her

- They/Them
- Unlisted (please specify) <Text entry available>
- Prefer not to say

Q3. What age are you?

Answers: <Text Entry>

Q4. In which school of UCD are you studying?

- Answers:
- Quinn School of Business
 - Sutherland School of Law
 - The School of Nursing, Midwifery & Health Systems

Q5. What year of your studies are you currently in?

- Answers:
- 1st year
 - 2nd year
 - 3rd year
 - 4th year or higher

Q6. With regards to your current program of study, rate the following on a scale 1-4 (1=very unimportant to 4=very important)

(6a) The importance to your program of ethical and/or social issues.

(6b) The importance to your program of broad education in the humanities and social sciences.

(6c) The importance to your program of policy implications for your chosen profession.

Q7. Rate the importance to a successful career in your chosen profession of each of the following (1=very unimportant to 4=very important):

(7a) Professional and ethical responsibilities.

(7b) Understanding the public consequences of your work.

(7c) Understanding how the public interact with your profession.

Q8: Rate, on a scale of 1-5 (1=very unimportant to 4=very important) the personal importance to you of:

(8a) Improving society.

(8b) Being active in my community.

(8c) Helping promote racial understanding.

(8d) Helping others who are in need.

Q9: Here we briefly describe some people. Please read each description and think about how much each person is or is not like you. Indicate, using the 6-point scale from “not like me at all” to “very much like me”, how alike you this person is.

- i. They believe they should always show respect to their parents and to older people. It is important to them to be obedient
- ii. Religious belief is important to them. they try hard to do what their religion requires.

- iii. It's very important to them to help the people around them. They want to care for their well-being.
- iv. They think it is important that every person in the world be treated equally. They believe everyone should have equal opportunities in life.
- v. They think it's important to be interested in things. They like to be curious and to try to understand all sorts of things.
- vi. They like to take risks. They are always looking for adventures.
- vii. They seek every chance he can to have fun. It is important to them to do things that give him/her pleasure.
- viii. Getting ahead in life is important to them. They strive to do better than others.
- ix. They always want to be the one who makes the decisions. They like to be the leader.
- x. It is important to them that things be organized and clean. They really do not like things to be a mess.
- xi. It is important to them to always behave properly. They want to avoid doing anything people would say is wrong.
- xii. They think it is best to do things in traditional ways. It is important to them to keep up the customs they have learned.
- xiii. It is important to them to respond to the needs of others. They try to support those they know.
- xiv. They believe all the worlds' people should live in harmony. Promoting peace among all groups in the world is important to them.
- xv. Thinking up new ideas and being creative is important to them. They like to do things in their own original way.
- xvi. They think it is important to do lots of different things in life. They always look for new things to try.
- xvii. They really want to enjoy life. Having a good time is very important to them.
- xviii. Being very successful is important to them. They like to impress other people.
- xix. It is important to them to be in charge and tell others what to do. They want people to do what they say.
- xx. Having a stable government is important to them. They are concerned that the social order be protected.

Survey for 1st year Engineering Student Survey

Q1. Due to university research policy we are unable to accept participants under the age of eighteen years for this study.

Are you aged 18 years or over?

Answers: -Yes
 -No

Q2. With what are your preferred pronouns?

Answers: -He/Him
 -She/Her
 -They/Them
 -Unlisted (please specify) <Text entry available>
 -Prefer not to say

Q3. What age are you?

Answers: <Text Entry>

Q4. Are you a First Year Engineering Student?

Answers: -Yes

-No. If so please specify your course and year. <text entry>

Q5. Which domain of engineering do you intend on studying?

Answers: -Mechanical Engineering -Electrical/Electronic engineering

-Civil Engineering -Chemical Engineering

-Undecided at this point

Q6. With regards to your current program of study, rate the following on a scale 1-4 (1=very unimportant to 4=very important)

(6a) The importance to your program of ethical and/or social issues.

(6b) The importance to your program of broad education in the humanities and social sciences.

(6c) The importance to your program of policy implications for engineering

Q7. Rate the importance to a successful career in engineering of each of the following:

(7a) Professional and ethical responsibilities.

(7b) Understanding the public consequences of technology.

(7c) Understanding how people use machines.

Q8: Rate, on a scale of 1-5 (1=very unimportant to 4=very important) the personal importance to you of:

(8a) Improving society.

(8b) Being active in my community.

(8c) Helping promote racial understanding.

(8d) Helping others who are in need.

Q9: Here we briefly describe some people. Please read each description and think about how much each person is or is not like you. Indicate, using the 6-point scale from “not like me at all” to “very much like me”, how alike you this person is.

- i. They believe they should always show respect to their parents and to older people. It is important to them to be obedient
- ii. Religious belief is important to them. they try hard to do what their religion requires.
- iii. It's very important to them to help the people around them. They want to care for their well-being.
- iv. They think it is important that every person in the world be treated equally. They believe everyone should have equal opportunities in life.
- v. They think it's important to be interested in things. They like to be curious and to try to understand all sorts of things.
- vi. They like to take risks. They are always looking for adventures.

- vii. They seek every chance he can to have fun. It is important to them to do things that give him/her pleasure.
- viii. Getting ahead in life is important to them. They strive to do better than others.
- ix. They always want to be the one who makes the decisions. They like to be the leader.
- x. It is important to them that things be organized and clean. They really do not like things to be a mess.
- xi. It is important to them to always behave properly. They want to avoid doing anything people would say is wrong.
- xii. They think it is best to do things in traditional ways. It is important to them to keep up the customs they have learned.
- xiii. It is important to them to respond to the needs of others. They try to support those they know.
- xiv. They believe all the worlds' people should live in harmony. Promoting peace among all groups in the world is important to them.
- xv. Thinking up new ideas and being creative is important to them. They like to do things in their own original way.
- xvi. They think it is important to do lots of different things in life. They always look for new things to try.
- xvii. They really want to enjoy life. Having a good time is very important to them.
- xviii. Being very successful is important to them. They like to impress other people.
- xix. It is important to them to be in charge and tell others what to do. They want people to do what they say.
- xx. Having a stable government is important to them. They are concerned that the social order be protected.

Survey for Final-Year Engineering Students

Q1. Due to university research policy we are unable to accept participants under the age of eighteen years for this study.

Are you aged 18 years or over?

Answers: -Yes
 -No

Q2. With what are your preferred pronouns?

Answers: -He/Him
 -She/Her
 -They/Them
 -Unlisted (please specify) <Text entry available>
 -Prefer not to say

Q3. What age are you?

Answers: <Text Entry>

Q4. What stage of your degree are you currently at?

Answers: -BE1 -BE4
 -ME1 -ME4

Q5. Which domain of engineering are you studying?

Answers: -Mechanical Engineering -Electrical/Electronic engineering

Q6. With regards to your current program of study, rate the following on a scale 1-4 (1=very unimportant to 4=very important)

(6a) The importance to your program of ethical and/or social issues.

(6b) The importance to your program of broad education in the humanities and social sciences.

(6c) The importance to your program of policy implications for engineering

Q7. Rate the importance to a successful career in engineering of each of the following:

(7a) Professional and ethical responsibilities.

(7b) Understanding the public consequences of technology.

(7c) Understanding how people use machines.

Q8: Rate, on a scale of 1-5 (1=very unimportant to 4=very important) the personal importance to you of:

(8a) Improving society.

(8b) Being active in my community.

(8c) Helping promote racial understanding.

(8d) Helping others who are in need.

Q9: Here we briefly describe some people. Please read each description and think about how much each person is or is not like you. Indicate, using the 6-point scale from “not like me at all” to “very much like me”, how alike you this person is.

- i. They believe they should always show respect to their parents and to older people. It is important to them to be obedient
- ii. Religious belief is important to them. they try hard to do what their religion requires.
- iii. It's very important to them to help the people around them. They want to care for their well-being.
- iv. They think it is important that every person in the world be treated equally. They believe everyone should have equal opportunities in life.
- v. They think it's important to be interested in things. They like to be curious and to try to understand all sorts of things.
- vi. They like to take risks. They are always looking for adventures.
- vii. They seek every chance he can to have fun. It is important to them to do things that give him/her pleasure.
- viii. Getting ahead in life is important to them. They strive to do better than others.
- ix. They always want to be the one who makes the decisions. They like to be the leader.
- x. It is important to them that things be organized and clean. They really do not like things to be a mess.
- xi. It is important to them to always behave properly. They want to avoid doing anything people would say is wrong.
- xii. They think it is best to do things in traditional ways. It is important to them to keep up the customs they have learned.

- xiii. It is important to them to respond to the needs of others. They try to support those they know.
- xiv. They believe all the worlds' people should live in harmony. Promoting peace among all groups in the world is important to them.
- xv. Thinking up new ideas and being creative is important to them. They like to do things in their own original way.
- xvi. They think it is important to do lots of different things in life. They always look for new things to try.
- xvii. They really want to enjoy life. Having a good time is very important to them.
- xviii. Being very successful is important to them. They like to impress other people.
- xix. It is important to them to be in charge and tell others what to do. They want people to do what they say.
- xx. Having a stable government is important to them. They are concerned that the social order be protected.

Appendix B: Student and Staff Interview Recruitment

B.1 Staff Recruitment Email

The following is the text of the email used in the recruitment of staff participants for the interview process. The referenced information sheet is included below:

Dear Name & title,

Thank you for taking the time to read this message. I am a PhD researcher in the school of Mechanical and Materials Engineering at University College Dublin. My research is on Engineering Education, specifically the values and norms of Engineering and the socialising effects of Engineering Education. As part of my research I will be carrying out interviews with a number of staff and students from Irish universities in the coming months. As the <programme director(or equivalent title)> of <course title> at <University name> I would greatly appreciate it if you would agree to participate in an interview.

The focus of the interview will be on topics such as the content of your course and your thoughts on the wider Engineering profession in general. There will be no questions which relate directly to personal identifiable information. Should any such information arise, it will be removed from the transcription. Please see the attached information sheet for further details on the privacy policy.

The interview should take no more than 90 mins and can be arranged at a time and location convenient for you. Participation in this study is entirely voluntary. Participants are under no obligation to take part, and are free to withdraw from the study at any time before your interview and up to one month after your interview.

I would sincerely appreciate it if you could take the time to read the attached information sheet and consider participating in this study.

If you would like to take part, or have any further questions, please contact me at cormac.deasy@ucdconnect.ie

Best regards,
Cormac Deasy
PhD Candidate
University College Dublin

B.2 Staff Participant Information Sheet

Social Values in Engineering Education: Student & Staff Interviews

This study is being conducted by Cormac Deasy in the School of Mechanical and Materials Engineering at UCD under the supervision of Professor Donal Holland. This study forms part of a PhD research project which investigates the social values present in Engineering Education.

The study will involve interviews with parties involved in engineering education including both staff and students as well as individuals involved in student-run Engineering Societies.

The content of these interviews will provide a range of insights and perspectives on the values and ideals of Engineering Education.

As the director of an Engineering Undergraduate Programme you have been invited to participate. Should you agree to be involved in this research, you will be asked to take part in an individual interview. This can be carried out in person or via Zoom.

The content of these interviews will be recorded, analysed and used for academic publication. Interviews will be audio recorded and later transcribed. The original recordings will be stored securely on a password protected drive and accessible only to the researcher for up to three months before being transcribed. Upon transcription, all identifiable and potentially identifiable information will be removed. Any quotes or extracts from these interviews, which are used in the final thesis or for publication, will be entirely anonymous.

Participation in this study is entirely voluntary. Participants are under no obligation to take part, and are free to withdraw from the study at any time before your interview and up to one month after your interview. Should you choose to withdraw after the interview has taken place the original recording of your interview will be excluded from the transcription process and deleted.

Informed Consent

By agreeing to participate in this study you are agreeing to the following:

- To participate in an interview and have your voice recorded.
- To have the audio recording retained by the researcher for up to three months.
- To have the content of these interviews transcribed and retained by the researcher with all identifiable information removed.
- To have the content of the transcript used for research and publication.

This study has been approved by the UCD Human Research Ethics Committee (Reference Number LS-C-23-44-Deasy-Holland).

If you have questions about any part of this study, please feel free to contact the researcher, Cormac Deasy, at cormac.deasy@ucdconnect.ie.

B.3 Student Recruitment Email

The following is the text of the email used in the recruitment of student participants for the interview process. The referenced information sheet is included below:

Dear Society Committee,

Thank you for taking the time to read this message. I am a PhD researcher in the school of Mechanical and Materials Engineering at University College Dublin. My research is on Engineering Education, specifically the values and norms of Engineering and the socialising effects of Engineering Education. As part of my research, I will be carrying out interviews with a number of staff and students from Irish universities in the coming months. As the committee of the Society Name at <University name> I would greatly appreciate it if a number of your members would agree to participate in an interview. Student societies are an important part of the educational experience and so I feel your input would be enormously valuable.

The focus of the interview will be on topics such as the aims of your society, the content of your degree course and your thoughts on the wider Engineering profession in general. There will be no questions which relate directly to personal identifiable information. Should any such information arise, it will be removed from the transcription. Please see the attached information sheet for further details on the privacy policy.

The interview should take no more than two hours and can be arranged at a time and location convenient for you. They may be carried out individually or in small groups. Participation in this study is entirely voluntary. Participants are under no obligation to take part, and are free to withdraw from the study at any time before your interview and up to one month after your interview.

I would sincerely appreciate it if you could take the time to read the attached information sheet and consider participating in this study.

If you would like to take part, or have any further questions, please contact me at cormac.deasy@ucdconnect.ie

Best regards,
Cormac Deasy
PhD Candidate
University College Dublin

B.4 Student Participant Information Sheet

Social Values in Engineering Education: Interview Participant Information Sheet

This study is being conducted by Cormac Deasy in the School of Mechanical and Materials Engineering at UCD under the supervision of Professor Dónal Holland. This study forms part of a PhD research project which investigates the social values present in Engineering Education.

The study will involve interviews with parties involved in engineering education including both staff and students as well as individuals involved in student-run Engineering Societies.

The content of these interviews will provide a range of insights and perspectives on the values and ideals of Engineering Education.

As a member of a student-run engineering society you have been invited to participate. Should you agree to be involved in this research, you will be asked to take part in an individual interview. This can be carried out in person or via Zoom.

The content of these interviews will be recorded, analysed and used for academic publication. Interviews will be audio recorded and later transcribed. The original recordings will be stored securely on a password protected drive and accessible only to the researcher for up to three months before being transcribed. Upon transcription, all identifiable and potentially identifiable information will be removed. Any quotes or extracts from these interviews, which are used in the final thesis or for publication, will be entirely anonymous.

Participation in this study is entirely voluntary. Participants are under no obligation to take part, and are free to withdraw from the study at any time before your interview and up to one month after your interview. Should you choose to withdraw after the interview has taken place the original recording of your interview will be excluded from the transcription process and deleted.

By agreeing to participate in this study you are agreeing to the following:

- To participate in an interview and have your voice recorded.
- To have the audio recording retained by the researcher for up to three months.
- To have the content of these interviews transcribed and retained by the researcher with all identifiable information removed.
- To have the content of the transcript used for research and publication.

This study has been approved by the UCD Human Research Ethics Committee (Reference Number LS-C-23-44-Deasy-Holland).

If you have questions about any part of this study, please feel free to contact the researcher, Cormac Deasy, at cormac.deasy@ucdconnect.ie.

Appendix C: Interview Process

C.1 Interview Consent Procedure

<Start Recording>

"This is interview <interview code system> on <date> at <time>."

"Can you please confirm for the recording that you have been given and have read the participant information sheet?"

And do you understand that by agreeing to participate in this study you are agreeing to the following:

- To participate in an interview and have your voice recorded.
- To have the audio recording retained by the researcher for up to three months.
- To have the content of these interviews transcribed and retained by the researcher with all identifiable information removed.
- To have the content of the transcript used for research and publication.
- That you have the right to withdraw from participating, and have this recording deleted up to one month from today.

And understanding all of that, do you agree to participate?

<Proceed to Question 1>

C.2 Staff Interview Questions

The following are the prepared interview questions used during this research project. The interviews were semi-structured and so these questions were used as a guide.

Opening:

- Can you tell me, in your own words, what is engineering?

Engineering Education:

- Can you tell me a little bit about your program?
- What is the aim of engineering education?
- Do you think we achieve this?

Course Content

- How is the course content for your program determined?
- Are there external influences on what is included in the course content?
- Is there anything about the course that you would like to change but can't?
- -how are the ethical and social aspects of engineering covered in this program?
 - Where in the course? How much time is given to it?
 - How do the students respond to this material?

Work Placement

- Do your students have a work placement as part of the program?
- What do you think the benefit of this is?
- What do they learn from this that they can't learn in university?
- Have you had any issues or complaints about work placements or the students?

Graduates:

- What is the most valuable thing that students gain from the course?
- What do you think employers are looking for in a graduate?
- How is success measured for your program?
- How do you personally measure success for your program?
- Are you aware of the employment rates of your graduates?
 - How do you feel about them?
 - (How) Does this influence your teaching?
 - Should it?

Recruitment

Prospectus

- How is the prospectus for your program designed?
 - Who has input?
 - Who drafts the text?
 - Who chooses the images?
- Do you think they are an accurate reflection of the program?
- Do you think they portray what a career in engineering is like?

Motivations

- Why do students choose engineering?
 - Why do they choose your program specifically?
 - What does your program offer compared to other similar courses in the country?
- What are the “right” reasons for choosing engineering?
- What is the ideal engineering candidate student like?
- What kind of misconceptions do you think students have about the profession?
 - -Where do these come from?

Societies

- What can you tell me about engineering societies in this university?
- Are you involved with any? Are other staff involved?
- In what way?
- What is the role of these societies?
- Do you think they achieve this?
- What do they add that formal education doesn't?

The Profession

- What do you think about the engineering profession?
- What does the public perception of a typical engineer look like?
 - How accurate do you think this is?
- How does the engineering profession fit into society?
- What kinds of people do you think succeed in engineering?

The Good Engineer

- Could you describe the ideal Engineer?
- How does this compare to the reality of engineering?
- Who is/should the engineering profession (be) answerable to?
- What does the public perception of a typical engineer look like?
 - And how accurate do you think that is?
- Is there anything you don't like about “the typical engineer”?
- What is a bad engineer like?
- What is bad engineering?

Values

- Do you think that the program should be changing the students' values?
- Do you think it does?
- What values/norms are the staff trying to impart on students?

C.3 Student Interview Questions

Intro

Can you tell me in your own words, what is Engineering?

- Do you consider yourself to be a typical engineer?
 - Why? Why not?
- How do you think the public sees engineers?
 - Do you think that's accurate?

Engineering Education:

- What is the aim of engineering education?
 - Do you think it achieves this?
- Do you agree with this aim?
- How do you think the staff measure success for the course?
- Is this how you measure it?

Course Content

- What kinds of topics did your degree focus on?
- Is there anything about the course that you would like to see changed?
- How are the ethical and social aspects of engineering covered in this program?
 - Where in the course?
- How much time is given to it?
 - What did you think of this material?
 - do you think it's relevant to engineering work?
 - Did you see it at play in your work placement?
 - Did it affect any project work you did?

Graduates:

- What is the most valuable thing that you gained from the course?
- What do you think employers are looking for in a graduate?
 - How do you feel about your career prospects with an engineering degree?
- what are your career plans going forward?
- Tell me about your dream career/occupation.

Work placement

- did you have a work placement as part of your degree?
 - What was that like?
 - What do you think the benefits of this were?
 - What did you learn on placement that you didn't learn in the course?
 - What would you change about your placement experience?
 - Was there any aspect of the work that the company did that you were uncomfortable with or that you disagreed with?
 - How did your placement compare to your expectations of an engineering job?

The Profession

- What do you think about the engineering profession?
- What do you think about an engineer's role in society?
- What are an engineer's responsibilities?
- What kinds of people do you think succeed in engineering?

The Good Engineer

- Could you describe the ideal Engineering Graduate?
 - How does this compare to the reality of engineering?
- Do you have any "engineering idols" or examples of engineers who you would like to emulate? They can be real or fictional.
- Who is/should the engineering profession (be) answerable to?
- What does the public perception of a typical engineer look like?
 - And how accurate do you think that is?
- Is there anything you don't like about "the typical engineer"?
- What is a bad engineer like?
- What is bad engineering?

Values

- Do you think that studying engineering has changed your values?
- What values/norms are the staff trying to impart on students?
- Do you think an engineer's personal values affect their work?
 - What should an engineer do in the case of a value conflict at work?

Recruitment

- How did you pick your university & course? What sources did you look at etc?
- Motivations
- Why did you choose engineering?
 - What made you choose this course specifically?
 - And how does this course compare to other similar courses in the country?
- What kinds of people should choose engineering?
- What kinds of people do we need to become engineers?
- What kind of misconceptions do you think you had about the course and/or the profession?
 - Where do these come from?

Committee Members

- Tell me a bit about your society.
- Do you have a "mission statement"?
- What kinds of activities and events has your society taken part in?
- Have you had any guest speakers?
 - Who?
 - What kinds of topics did they cover?
- Who would be the dream guest?

- What's the best activity that you've had or that you've heard of another engineering society doing?
- What does your society add to the engineering education experience?
- What do you bring that the degree doesn't?
- Are there any staff members involved in running the society?
 - What is their role?

Appendix D: Chartered Engineer requirements

Included here are the requirements to meet the standards of a chartered engineering as per the accreditation requirements set in place by Engineers Ireland (2021).

Chartered Engineer

PO1. Knowledge and Understanding

Advanced knowledge and understanding of the mathematics, sciences, data science, analytics, and other technologies underpinning the branch of engineering.

Indicative graduate attributes include:

- (i) advanced knowledge and understanding of the principles, concepts, limitations and range of applicability of established mathematical methods and data science and analytics;
- (ii) advanced knowledge and understanding of the theoretical bases and the related assumptions underpinning the engineering sciences relevant to their engineering discipline;
- (iii) knowledge and understanding of a wide range of engineering materials, processes and components where relevant to the specialised branch of engineering;
- (iv) advanced knowledge and understanding of related developing technologies and how they might impinge upon the branch of engineering.

PO2. Problem Analysis

The ability to identify, formulate and analyse complex engineering problems.

Indicative graduate attributes include:

- (i) the ability to integrate knowledge, handle complexity and formulate judgements with incomplete or limited information and considering professional responsibilities towards people and the environment;
- (ii) the ability to identify and use appropriate mathematical methods and modelling for application to new and ill-defined engineering problems;
- (iii) the ability to identify, classify, describe and monitor the performance of systems and components;
- (iv) the ability to apply and where necessary adapt emerging technologies and data science to complex engineering problems.

PO3. Design

The ability to design innovative solutions to complex engineering problems.

Indicative graduate attributes include:

- (i) knowledge and understanding of design processes and techniques and the ability to apply them to unfamiliar, ill-defined problems;
- (ii) the ability to design innovative solutions such as novel systems, components or processes, involving other disciplines as appropriate;
- (iii) the ability to investigate and define requirements considering professional responsibilities towards people and the environment;
- (iv) knowledge and understanding of codes of practice and industry standards including: the need for their application, the range of their applicability and how to proceed in the absence of codes and standards;
- (v) the ability to redesign existing products, processes or systems or develop novel products, processes or systems in order to improve productivity, quality, safety and other desired features.

PO4. Investigation

The ability to investigate, experiment and apply standard and specialised research methods.

Indicative graduate attributes include:

- (i) the ability to conduct searches of literature and consult and critically use databases and other sources of information to pursue detailed investigations of an unfamiliar problem;
- (ii) the ability to design and conduct experiments and simulations, to analyse and interpret data, and draw valid conclusions;
- (iii) the ability to critically evaluate current problems and new insights at the forefront of the particular branch of engineering;
- (iv) the ability to incorporate aspects of engineering outside the branch of engineering and consult and work with experts in other fields;
- (v) the ability to contribute to the development of scientific/technological knowledge in one or more areas of their engineering discipline.

PO5. Professional and Ethical Responsibilities

Understanding of and commitment to professional and ethical responsibilities towards people and the environment in the practice of engineering.

Indicative graduate attributes include:

- (i) an understanding and appreciation of the environmental, social and economic impacts of their judgements and to promote the principles and practices of sustainable development;
- (ii) knowledge and understanding of the importance of the engineer's role in society and the need to act with honesty, integrity and objectivity;
- (iii) knowledge and understanding of the importance of equality, diversity and inclusion, and their impact on professional practice;
- (iv) knowledge, understanding and commitment to the ethical usage of technology and data;
- (v) knowledge and understanding of health, safety, cultural and risk issues and commitment to the framework of relevant legal requirements.

PO6. Teamwork and Lifelong Learning

The ability to work effectively independently and in diverse and inclusive teams, and to prepare for lifelong learning.

Indicative graduate attributes include:

- (i) the ability to recognise and make use of the interactions between various engineering disciplines and other professions;
- (ii) the ability to work with a broad range of stakeholders in multidisciplinary settings;
- (iii) knowledge, understanding and active participation in diverse and inclusive teams;
- (iv) recognition of the need for, and the ability to plan and carry through, self-directed continuing professional development (CPD).

PO7. Communication

The ability to communicate effectively on complex engineering activities to diverse audiences.

Indicative graduate attributes include:

- (i) the ability to design and implement effective communication strategies in order to create deeper understanding and maximum impact on a given audience;
- (ii) the ability to succinctly describe the relevant advantages and disadvantages of the various concepts and activities to diverse audiences;
- (iii) the ability to communicate effectively in public, national, international and multicultural contexts;
- (iv) the ability to write technical papers and reports, and synthesise one's own work and that of others in traditional and digital media.

PO8. Engineering Management

Knowledge and understanding of engineering management principles and financial decision-making relevant to the branch of engineering and an ability to apply these to one's own work and to the management of projects.

Indicative graduate attributes include:

- (i) knowledge and understanding of organisational structures, commercial governance and relevant legal principles and contractual arrangements;
- (ii) knowledge and understanding of the management of resources, including human resources;
- (iii) knowledge and understanding of project management and work planning and monitoring tools.