Gender, knowledge, and curriculum: engineering educators' contribution to curricular disciplinary knowledge practices

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Author's declaration: I declare that this thesis is my own work and has not been submitted in substantially the same form for the award of a higher degree elsewhere.

Signature ....

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Abstract

The lack of women in engineering education and the engineering workforce is a longstanding challenge in Australia, along with many parts of the world. This problem has been framed as both a social justice issue and as an issue that impacts on the size and innovation capacity of the engineering workforce. This study examined the engineering disciplinary knowledge practices in one institution, through perceptions of engineering academics. Using the sociology of the transmission of knowledges of Bernstein and the post-structural feminist lens of Connell's gender regimes, I sought to 1) understand the perceptions of gender and of engineering knowledge amongst academics teaching within an undergraduate engineering degree, and 2) link those perceptions with the contribution of academics to the knowledge relations and social relations within curricular disciplinary knowledge practices, and the gendered legitimate student identities that they make available.

The study is insider research and focused on academics and an undergraduate degree at a university in Australia, across several engineering disciplines. Utilising an interpretive, qualitative research methodology I interviewed 15 academics about their beliefs about gender and engineering knowledge, related to their educational practice. Using a reflexive approach that acknowledges my personal history as a woman engineering academic leader, I analysed interview transcripts to develop categories of perceptions about gender and about engineering knowledge. I used documents and website material from Engineers Australia to connect to the elements of professional accreditation apparent in these perceptions.

My findings revealed that disciplinary knowledge practices in curriculum reinforced knowledge relations that valorise engineering technical knowledge as content over professional skills as context. The purposes and outcomes of an engineering education varied from a personal development outcome of technical competence, through to the public good of engineering in saving society and the environment. Gender was either seen as not relevant or as being a neat binary, with women and men characterised as opposites in capabilities, motivations, and interest. Viewing disciplinary knowledge practices through the lens of gender regimes revealed a series of binaries in tension, which are hierarchical and gendered: between content and context, between technical rationality and emotional altruism, between heteronormativity and diversity, between the academy and industry. These hierarchical binaries serve to create legitimate student identities that are well aligned to the traditional masculine, heterosexual, and mathematically and scientifically capable man – the “authentic” engineer.

The study presents a model showing the gender regimes operating within curricular disciplinary knowledge practices. The model depicts the relationships between singular knowledge modes, regionalised engineering curriculum, and the purpose and outcomes of an engineering education viewed towards the field of practice. These are overlayed by gendered divisions of labour, power relations, gender cultures and symbolism, and the place of emotions and human relations. Illuminating the gender regimes in operation in these disciplinary knowledge practices has implications for those practices to be changed. I argue that by disrupting beliefs about engineering knowledge and gender, I can engage with engineering academic colleagues to create more inclusive curricular disciplinary knowledge practices.

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Chapter 1: Introduction

Engineering education and the engineering profession continue to struggle with a lack of gender diversity. For over 35 years in Australia, plans, policies and projects have existed in universities which aim to increase the number of women in engineering education and arrest what is often framed as “a leaky pipeline”(Clark Blickenstaff, 2005), with limited success. The situation is similar in the U.K. and the U.S.A. The focus of many of these activities has been on women themselves, as though engineering itself can remain untouched. This thesis takes a different approach, instead seeking to understand the way in which gendered engineering identities may be “made and remade in cultures and practices” within engineering curriculum (Stonyer, 2001). It reports on research that investigated the perceptions of engineering academics regarding gender and engineering knowledge. This provides a means to uncover the disciplinary knowledge practices that inform curriculum development in the context of the study. In this introductory chapter, I begin to explore the context and background and my personal positioning as an academic leader in engineering education at the institution which is the site of the study. I articulate the research questions that guided my research and introduce the organisation of this thesis.

1.1 Motivating this study

I was assigned female at birth and identify as a woman. I am an engineer and an educator. Currently I occupy the role of Associate Dean, Learning and Teaching in a Faculty of Engineering at an Australian university. In chapter 4 I will explain more of my personal history but in this introductory chapter, I outline briefly the motivation for this research study, providing the reasoning that led me to seek answers to the research questions that framed it.

My first academic position involved a 50% service role as a Women in Engineering Coordinator at a small regional university in Australia. It was 1996 and I was the only woman and the youngest academic in the School of Engineering. Since that time, Australian universities have continued to offer programs and activities aimed at attracting, retaining, and supporting women to study engineering. While I have had a varied career in universities, I find myself once again within a faculty and as part of a committee tasked with supporting a Women in Engineering Program. The other members of that committee are all young women academics, from each of the engineering schools within the faculty, and professional staff who are focused on student recruitment.

Women in Engineering programs within universities have achieved little success, as measured by the percentage of women who study engineering in Australia which remains stubbornly low. The latest figures show that 17.7% of engineering graduates are female (18.9% enrolments) (Briggs, 2023, p. 95). And yet, at a recent event with the engineering professional association, Engineers Australia, two men in the audience suggested that the profession should stop focusing on “equity” because it had “gone too far”. They openly expressed their view that boys were no longer being attracted to engineering and that females got all the opportunities. As the Chair of my state Women in Engineering Committee for the professional association I was called on to answer this challenge. It was with a strong feeling of déjà vu that I responded trying to explain the contrary evidence to their statements.

My motivation in undertaking this research is to move away from the ideas that permeate much of the discussion around women in engineering within my university, within engineering education more broadly, and within the engineering profession. The everyday narrative almost always focuses on women – what can we do to show women that they are capable, that they will be interested, and that they can achieve their (presumed) career and life choices within engineering. As I have encountered this style of narrative again and again for over 30 years, I increasingly challenge whether the shifts do not happen because we are not looking at what the real challenge is. I want to be a part of identifying the cultural, social, and historical antecedents that got us here, breaking the habits that keep women out rather than trying to inspire them in. This research study focuses then on my local context, shifting the spotlight from women to academic disciplinary knowledge practices and seeking to understand how they may work to keep women and other gender diverse people out or at the very least uncomfortable. I will return to this motivation and my personal history again and again throughout this thesis but particularly in Chapter 4 where I give a fuller account of that history and the way in which it informs my methodological decisions within this study.

1.2 Context

I fully explore the context of my study as part of Chapter 4 Methodology and Methods. By way of introduction, I note here that this study is insider research (Trowler, 2012) conducted in an Australian university within one faculty with responsibility for teaching degree programs in several disciplines of engineering at both undergraduate and postgraduate level. In considering the organisational arrangements of the site of study, my focus is on academics within the teaching team for the Bachelor of Engineering (Honours) degree, which leads to graduate eligibility to become a Professional Engineer following experience. I explain in later chapters the nature of this pathway.

1.3 Research questions

In considering the challenge of gender diversity in engineering, in this study I have taken a step back to look at the broader system of the engineering profession and engineering education. Moving from a focus on individual women who follow a career trajectory through high school, engineering education, and into the profession, instead I look more closely at the engineering education system from the perspective of engineering academics and the curriculum, recognising that shining a light on these disciplinary knowledge practices uncovers a different focus for interventions that address gender diversity.

This research sought to answer the following research questions within my institutional context:

1. What are academics' perceptions of gender and of engineering knowledge?
2. What do these perceptions reveal about disciplinary knowledge practices in engineering curriculum?
3. What do knowledge relations and social relations in engineering curriculum reveal about gendered legitimate student identities?

1.4 Organisation of thesis

Following this introductory chapter, the thesis provides a framing for the study by reviewing the literature around three key areas: the study of women in engineering and engineering education, the nature of engineering knowledge that is reflected within engineering curriculum, and the role of academics in engineering education. The research outcomes are informed by two theoretical lenses, which are explained in Chapter 3: Bernstein's pedagogic device and Connell's gender regimes. I have used these theoretical lenses to highlight the gendered disciplinary knowledge practices that are revealed in academic perspectives of gender, engineering knowledge and about engineering students. Chapter 4 discusses both methodology and details of the methods used, also noting my approach to reflexivity and acknowledging the particular need for this in insider research. Chapters 5 to 7 provide an analysis of the interview data generated along with proposing a model of the knowledge relations and social relations that were revealed by the interview analysis. These chapters show the ways academics in my study engage disciplinary knowledge practices that frame what counts as engineering knowledge, their aspirations for the outcomes of their teaching, and the ways in which they think about their students particularly as it relates to gender. This leads to Chapter 8 where the implications for change, of the model are presented.

1.5 History repeats

To conclude this introductory chapter, I share an anecdote that reinforces once again the motivation for moving beyond Women in Engineering programs as a driver of change. The professional association of which I am a part, Engineers Australia, has an annual cycle of Excellence Awards and a Hall of Fame recognising both contemporary and historical engineering excellence. As I finalise my thesis, I have learned that the first head of an engineering school at my institution who is nearly 90 may be put forward as a worthy candidate for the Hall of Fame. In investigating his history, we have uncovered that when he became head of the school he was particularly supportive of increasing the number of women studying engineering. He set up the first Women in Engineering program in the 1970s. Again and again we have focused on women in attempts to address gender diversity. In this thesis I offer an alternative, not to take away from the current actions but to incorporate new strategies into our efforts.

Chapter 2: Review of the Literature: Gender and knowledge in engineering education

In this chapter I frame my research project within research about gender and engineering education. I explore three areas: gender and women in engineering; engineering knowledge, education, and the curriculum; and the influence of engineering educators on curriculum and pedagogy. I make the argument through this review that across the engineering profession and engineering education there is a persistent experience for women of clashing discourses about gender identity and the nature of engineering, that this clash is connected to what counts as engineering knowledge, and that academics and teaching teams can impact on this experience through the engineering education system.

2.1 Gender and women in engineering

As noted in Chapter 1, the problem that this research seeks to address is the continued under-representation of women in engineering education and engineering practice. After providing a brief history of approaches to framing this problem in the Australian context, I discuss studies of the experiences of women students in engineering education and women engineers in engineering practice, concluding with recent research that has addressed the experiences of people of diverse gender and sexuality.

In Australia, from the mid-1980s, higher education moved from being an elite to a massified system. It was during this time that universities and the engineering profession began to focus on the problem of a lack of women in engineering. By the early 1990s, most Australian universities who taught engineering had introduced programs to address this problem and from 1994 to 2005 there was an Australasian

Women in Engineering Forum run alongside the Australasian Association for Engineering Education annual conference (Mills, 2011). Approaches to addressing the “problem” included attempts to create gender inclusive curriculum, focusing on ensuring that women had the relevant maths and science capabilities required for enrolment, and funded Women in Engineering programs that offered networking and support to women students (Mills, 2011; Moxham & Roberts, 1995). Stonyer mapped the ways in which this problem was framed, highlighting that much of the work up until 2000 adopted a liberal or radical feminist approach (Stonyer, 2001). She made clear the possibilities for a post-structural feminist advocacy that interrogated the discourses, social practices, power relations, and identities in practice within engineering educational contexts. Her focus on post-structural feminism resonates with the current study, but most calls to action around women in engineering, in both engineering education and in the engineering profession, continue to align to liberal feminist and radical feminist ideals. The USA and UK have followed a similar trajectory.

Studies of the experience of women in engineering education and engineering practice reveal women experiencing challenging negotiations between discourses and identities. These reflect tensions between socio-cultural and local discourses about engineering and about gender and the identity positions that are made available and taken up by women. These tensions are even more pronounced when considered from an intersectional perspective. Faulkner in her ethnographic studies of working engineers, succinctly captured the discourse-identity tensions in engineering practice through highlighting the way that technical/social dualism dominates thought about engineering alongside a range of other binaries (Faulkner, 2000, 2007). She notes the challenge in these dualisms, which she saw in the practices of working engineers: the co-existence within engineering of both parts of the binary in tension, and the hierarchy and gendered nature of the dualisms. As she notes technical is “socially coded” as masculine, and social as feminine, and “authentic engineering” is technical. Faulkner notes then that women must negotiate between being gender authentic or an authentic engineer (Faulkner, 2000).

Studies of women entering and progressing through engineering education show the way that early confidence, due to success in maths and sciences is eroded through encountering local cultures that amplify cultural stereotypes about engineering. Tonso embedded herself within engineering education and worked with student teams (Tonso, 2006a, 2006b). Her studies provide a comprehensive picture of the dynamic and nuanced interaction between campus culture and individual identity negotiations. She identified nearly 30 different campus engineer identities in three categories: Nerds, Academic-achievers, and Greeks (social-achievers) (Tonso, 2006a). Overwhelmingly these identities were associated with men and masculinity. While of some relevance to this study, as Tonso notes, these campus engineer identities are particular to the local US campus on which her study took place (Tonso, 2006a, 2006b).

Across studies of women’s experiences in engineering in the US, Australia, UK, Norway, and Sweden a form of “moderate essentialism” operates (Trowler, 2014a) – persistent cultural themes about engineering as a discipline which are nonetheless nuanced by local, institutional, and national contexts (Berge et al., 2019; Foor et al., 2007; Nyström et al., 2019; Powell et al., 2012; Stentiford, 2019). What is common in these studies is that, while nuanced, the cultural themes about engineering are aligned with masculinity, and a particular form of masculinity that is performed and expected in engineering classrooms and engineering workplaces. One site where this masculinity is revealed is in classroom interactions between peers. Stentiford found in exploring women's experience of "laddish" behaviour in engineering classrooms at an English university, for example, that women described two different forms of "laddish" masculinity exhibited by their male peers: one which was hostile and another that was friendly or genial. Care must be taken though, not to oversimplify the interplay between gender identities and discourses about engineering. As Stentiford found, "women can and *do* actively construct a range of different feminine and masculine subjectivities in order to produce un/viable engineering identities" (Stentiford, 2019, italics in original). In her study of computer and mechanical engineers, Holth found that there were contradictory stories amongst the narratives and life stories she analysed, illuminating examples of "passionate men and rational women" performing alternative gender practices that challenge the stereotypes (Holth, 2014).

In some studies, women choose to take up positions that reject femininities and align themselves with masculinity, while continuing to hold onto hegemonic gender beliefs. In their study of girls and women in engineering in Portugal, Saavedra, et al studied the discursive construction of identities adopted by women studying and working in engineering, highlighting the four different positions that women adopted from aligning with the male norm, aligning with their own group (of women), being indifferent or rejecting the impact of being in a male-dominated environment, to fearing male-dominant environments (Saavedra, Araújo, Taveira, et al., 2014). Participants in many studies often grapple with positioning and subjectivities, their gender identities and professional identities when faced with both hegemonic beliefs about gender and stereotypes about engineering that clash and contradict. This reinforces the idea that “identities are done in practice, fluid and subject to change” (Gonsalves et al., 2019), and leads to both caution in generalising and optimism in the possibility for change.

Societal discourses about the nature of engineering are manifest across much of the marketing collateral and learning resources created within institutions. Berge, et al, used critical discourse analysis to analyse a series of websites about engineering programmes in a Swedish institution (Berge et al., 2019). While these reveal stereotypical norms about gender, they also highlight that there are intersectional elements that are always at play including social class, ethnicity, and socio-economic status. It is not enough to consider gender on its own.

Finally, I note that much of the research to date, even as it questions hegemonic beliefs about gender has tended to focus on gender diversity in terms of women. There is a growing scholarship that seeks to broaden focus, to question the heteronormativity of engineering and to understand the experiences of those from diverse genders and sexual orientations (Cech & Waidzunas, 2011; Leyva et al., 2016). This will be explored further in the next chapter where I introduce a theoretical framework for considering gender (Connell, 2006).

2.2 The nature of engineering knowledge

> “Engineers work in technical contexts to create, implement, and maintain reliable solutions that meet client needs within constraints such as those imposed by technical and manufacturing feasibility, time, budget, business context, codes, regulation, ethics, politics, and impacts on safety, health, the environment, local community, and global society.” (Passow & Passow, 2017)

As I noted in the previous section, and as will become clear through the outcomes of my study, the “problem” of gender in engineering education and the profession is inextricably linked to the nature of engineering knowledge and the ways in which that knowledge is translated into engineering curriculum. In this section, I review the debates and research trajectories within engineering education and engineering epistemology regarding the nature of engineering knowledge. As Kant and Kerr note in their review of engineering epistemology, the investigation of engineering knowledge as a field of study has been approached from several disciplinary perspectives including sociology, history, design theory, and engineering itself (Kant & Kerr, 2019). The study of engineering knowledge is characterized by attempts to distinguish it as a field in its own right.

Discussions of engineering knowledge often begin by distinguishing engineering from science and reinforcing that it is not simply applied science and an unproblematic extraction of scientific knowledge. The distinction is framed as a difference in the goals of each discipline: engineering is inextricably linked to action in the world and as such incorporates a normative approach beyond the descriptive focus of science and applied science (Kant & Kerr, 2019; Zwart, 2022). Engineering has as its goal the production of something in the world, whereas science has the goal of increasing the store of knowledge as an end in itself (Zwart, 2022). These different goals often lead to a tension between practical and theoretical knowledge as a basis of engineering. As Kant and Kerr note, there is an everyday understanding of science as being about discovery with engineers simply “doing” things, by applying that discovery knowledge in “relatively straightforward and epistemologically uninteresting ways” (Kant & Kerr, 2019). Grimson and Murphy even suggest that engineers are simply “users of knowledge” that has been appropriated from other disciplines to solve specific problems (Grimson & Murphy, 2015).

While distinguishing engineering from applied science, there nonetheless remains a view that science knowledge forms an important core to development as an engineer. The primacy of science knowledge as a basis for engineering knowledge and therefore a requirement for engineering curriculum and engineering practice, has its roots in the historical picture of an engineer as a pragmatic, lone man, designing some object using heuristics derived from experienced application of scientific principles. This is reinforced in the idea that the core practice of engineering is problem solving through design (Passow & Passow, 2017). Gainsburg, et al in their study of engineering knowledge in structural engineering practice differentiated between the historically established knowledge (formal or theoretical knowledge) and that which is generated in the course of practice (Gainsburg et al., 2010). In their observational study of structural engineers, they concluded that over two thirds of the knowledge that was being deployed was knowledge generated during practice. Their study concludes with the suggestion that engineering education should shift to reflect this deployment of practice knowledge, by creating curricula that "mirror the knowledge demands of the profession".

An implied hierarchy of theoretical knowledge over practical knowledge can lead to an implied distinction between engineering knowledge and what have been termed "professional skills" (Winberg et al., 2020). Despite empirical studies that show that, for example, engineers spend more than half of their work time in communicating with others (Passow & Passow, 2017), that they draw on knowledge of other people in their work (Gainsburg et al., 2010), and that the engineering method involves “distributed networks and teams” (Kant & Kerr, 2019), these are assumed to be practices involving individuals drawing only on knowledge generated through practical experiences. Kant and Kerr note that this stems partly from an idea that science is the dominant (or only) form of knowledge within an analytical engineering epistemology, with an attendant higher status given to “more rational forms of knowledge”. They note “as a result it is often taken for granted that if a particular form of knowledge is not scientific, it becomes untenable” (Kant & Kerr, 2019). The outcome of this is that some forms of engineering knowledge are moulded into scientific knowledge, whilst still denying any knowledge basis for the social practice of engineering or ignoring the cognitive basis of engineers’ ways of knowing and acting in the world. There is a tension then in thinking about engineering knowledge as being different to science knowledge while linking it to engineering practice which draws on this theoretical knowledge in particular ways and to engineering curriculum, which is nonetheless dominated by natural and physical sciences and mathematics.

There are those who have considered the relationship between engineering knowledge and disciplines beyond the natural and physical sciences. This can take the form of exploring the ways in which engineers might “appropriate” knowledge from humanities and the social sciences (Roby, 2024; Sørensen, 2009). This perspective is grounded in a recognition of the complexity of contemporary engineering and technology practices due to global challenges such as climate change and sustainability alongside the growth in a connected citizenry, at least in the Global North, meaning that engineers can no longer simply serve up a technical solution without accounting for its socio-political consequences. Sørensen suggests that social science appropriation in engineering is problematic and confused, since this knowledge is “normally implicit” and embedded as “individualised, polytechnical interdisciplinarity” (Sørensen, 2009). In this view, social science and humanities knowledge is seen as separate from engineering knowledge. This separateness is different from the rejection of engineering knowledge as applied science. It reinforces that engineering knowledge encompasses some of the declarative knowledge of science, whereas it ignores the knowledge of humanities and social sciences.

The perceived hierarchy of theoretical knowledge over practical knowledge has meant that engineering curriculum in universities has tended to foreground scientific technical knowledge while inferring that practical knowledge, being purely contextual, can be left to experiences or simply viewed as professional skills that can only be developed in practice. There are arguments against this view of practical knowledge as being purely contextual. Wolmarans argues for disrupting the assumed opposition of specialised theoretical knowledge and purely procedural or contextual practical knowledge (Wolmarans, 2022). In analysing a series of assessment tasks within an engineering program, she argues for the “conceptual nature of the knowledge of context”. She frames this as conceptual knowledge deployed in interrogating the material relations in the details of the context. She describes the necessary capability of engineers to move from a contextual case to an understanding of material relations embodied in that case before they can then apply scientific symbolic knowledge to the solution – in her example the design of a structure (Wolmarans, 2022). This process draws on conceptual knowledge of the details of the context. It might be argued that engineers require a similar capability to move from the contextual case to an understanding of the social relations prior to drawing on social science and humanities specialised knowledge in creating a solution.

Across studies of engineering knowledge and engineering epistemology, there is contention and debate between a view that engineering is not applied science but does draw on science, and whether engineering knowledge in use is theoretical, formal knowledge or practical knowledge drawn from experience. In curriculum, engineering knowledge in Australia and in a range of other countries is governed by an organisation known as the International Engineering Alliance (IEA). It has members from 41 jurisdictions within 29 countries and mediates agreements on engineering educational qualifications and professional competence. The agreements are for qualifications as an Engineer, Engineering Technologist, and Engineering Technician, each governed by different Accords. I am most interested in the Washington Accord which informs the degree program offered at my institution. The IEA achieve recognition through statements of Graduate Attributes and Professional Competencies (International Engineering Alliance, 2021). I will return to these later in the thesis, but simply note here that the Knowledge and Attitude Profile speaks to a grounding in natural sciences and mathematics, but in the most recent development has incorporated a new statement that a Washington Accord program should provide "awareness of relevant **social sciences**" (International Engineering Alliance, 2021, bold in original).

Regarding engineering knowledge, one debate that has been ongoing within engineering education for many years is the balance within curriculum of technical knowledge and competence versus what is often referred to as "soft skills", albeit without recognition that these may have a knowledge component. The 1996 review of engineering education in Australia had the title "Changing the Culture" and called for the incorporation of more "generic" or "soft skills". And yet, it seems that there has been little change. The Australian Council of Engineering Deans commissioned a report into the requirements of an engineering education for graduates of 2035 and once again called for a “greater emphasis on practice, including the human dimensions of engineering” (Illing, 2021). Employers and engineering managers also note the lack of “soft skills” in graduates (Munir, 2022). And yet few of these calls engage critically with questions of what “soft skills” are and if they may have a knowledge component. Nor do they address the reasons why we continue to see a valorisation of technical competence in curriculum and particularly in assessment practices in engineering education. I will return to this in later chapters.

2.3 The impact of academics on engineering curriculum and pedagogy

In the recent publication of an International Handbook of Engineering Education Research, there is a chapter entitled “The Overlooked Impact of Faculty on Engineering Education” (Cutler & Strong, 2023). It notes that a drive for change in engineering education often relies on changed efforts of the academic teaching team. In this section, I explicitly highlight three areas where the influence of academics and teaching teams are key to both understanding and disrupting engineering education.

The first impact of academic teaching teams is in their role in determining curriculum, what should be incorporated and how, along with the organisational arrangements of curricular elements. As van Dijk, et al note in their conceptual analysis of teacher expertise and disciplinary knowledge in higher education, “disciplinary knowledge is transformed into a curriculum through active decisions, by an educational community, including both individual teachers and teaching teams” (van Dijk et al., 2022). I explore the nature of that transformation further in Chapter 3 through Bernstein’s pedagogic device, but I emphasise here the key influence of academics in that transformation (Singh, 2002). Ashwin has made similar arguments in his critique of the ways student-centred learning can obscure the role of academics and disciplinary knowledge practices in making knowledge accessible for students and in focusing on what counts as knowledge (Ashwin, 2021; van Dijk et al., 2022).

The second area of influence of academics is as carriers of discursive repertoires around gender, creating narratives within their practice that frame gender and the nature of engineering in problematic ways. This has been repeatedly observed in engineering education practice through the positive narratives that academics create about the experience of women in teamwork, ignoring the negative lived experiences of women and in particular, the consequences of being forced into particular team roles (Beddoes & Panther, 2018; Radovic & Sanchez, 2020). Women are often positioned as being strong leaders and organisers, with a high capability and confidence in “soft” or “non-technical skills”. In ill-defined teamwork practices, this means they are excluded from taking on “technical” roles (Meadows & Sekaquaptewa, 2013). At the same time, academics more highly value “technical” skills, despite the fact that “soft skills” are recognised as being both important and challenging to develop in engineering curriculum as I noted in the previous section (Berdanier, 2022). This erodes the confidence of women students and has consequences for the development of ‘authentic’ engineering identities (Meadows & Sekaquaptewa, 2013).

Finally, academic decisions about educational practices directly influence classroom experiences for women students. In her 2022 thesis, Beverly developed a conceptual framework that explored the relationship between women’s perceptions of inclusive instruction and classroom climate on socioemotional outcomes including engineering self-efficacy and engineering confidence and capability (Beverly, 2022). This model incorporated a range of factors related to instructors within the classroom context, particularly their empathy, care, and perceived bias. While this focused specifically on the experience of women students, Vogt's study on the influence of faculty (academics) on student outcomes in engineering, showed that student/professor relationships as measured through faculty distance, had the most influence on overall success via its link to self-efficacy (Vogt, 2008). Cutler and Strong in their review of impacts of faculty explored the link between epistemological beliefs and practices reinforcing the key role of academic teaching teams in influencing student experience (Cutler & Strong, 2023).

One area where engineering education research is growing in terms of changing towards greater diversity is in the development of an approach to inclusive education. This is not necessarily new work. In 1995 in Australia, a practice guide on Gender-Inclusive Curriculum in Engineering was published (Moxham & Roberts, 1995). However there have been more recent moves to conceptualise what an inclusive pedagogy and curriculum might encompass. Farrell, et al developed a sociocultural learning framework for inclusive pedagogy in engineering, for example (Farrell et al., 2021). However, in Cross and Cutler's study on engineering faculty perceptions of diversity, which looked at faculty commitment and preparedness to incorporate diversity and inclusion into their practice, they found that while academics valued diversity and inclusion, they felt there was not enough resources and supports available to incorporate it into their practices. As I will argue in this thesis as well there is concern that engineering academics and teaching teams may be conceptualising diversity in problematic ways (Cross & Cutler, 2017). Engineering academics are thus influential in disciplinary knowledge practices in curriculum, and carriers of gendered discourses about students and about the engineering profession.

2.4 Women, engineering knowledge, and engineering academics

In conclusion to this chapter, I note that women are both under-represented in engineering education and the profession, and also caught up in complex discourses and identity work related to gender and the nature of engineering. The nature of engineering knowledge is a contested concept, but with mostly broad agreement that natural sciences and mathematics, the technical and theoretical components being important, even though there are multiple claims that engineering is not applied science. Finally engineering academics have a key role to play in the mediation of engineering knowledge into curriculum, which has implications for the experiences of students including the gendered learning identities it makes available. In the next chapter I explain two theoretical frameworks that are useful in analysing gendered disciplinary knowledge practices in curriculum, which I utilise to analyse data generated through interviews with academics and analysis of policy discourses within my context.

Chapter 3: Theoretical Frameworks: Pedagogic Discourse and Gender Regimes

In this chapter I explore two theoretical frameworks which I bring together to inform an analysis of the findings of this study. The first, drawn from the sociology of knowledge as articulated by Bernstein is pedagogic discourse within the pedagogic device and is used to illuminate relations of power and symbolic control within educational systems (Bernstein, 2000; Singh, 2002). The second, drawn from the relational theory of gender, is the notion of gender regimes developed as an empirical tool by Connell (Connell, 2006). In the final section of this chapter, I make the case that knowledge relations and social relations, evidenced in pedagogic discourse, can be connected to show how curriculum decisions have implications for gendered student identities.

3.1 The Pedagogic Device and Pedagogic Discourse

In this section I explore Bernstein's pedagogic device as a theoretical framing and an analytical tool to investigate an educational context. Across his lifetime, Bernstein engaged in a dialogue to develop and refine a sociological theory of education (Singh, 2002). The iterative cycle of articulating the theory, engaging in empirical research studies, addressing critique, and adjusting for new insights has led to a complex and nuanced "sociology for the transmission of knowledges" (Maton & Muller, 2007). Bernstein was critical of the idea that educational systems were simply "relays" for power and cultural reproduction evident in society. Rather he suggested that it was important to look within educational systems to investigate educational practices which of themselves were sites of contestation around cultural (re)production (Bernstein, 2000, p. 3). Thus, his theory provides analytical tools for uncovering the power, symbolic control, social relations, and practices within educational systems rather than just seeing educational systems as a site to illuminate the macro-structure of society (Maton & Muller, 2007). In examining the disciplinary knowledge practices in my research context, this makes Bernstein's theories useful regarding the possibilities of changing the impact of gendered structures within this engineering educational context (Bernstein, 2000, p. 28).

3.1.1 Overview of the pedagogic device

For the purposes of this study, the pedagogic device provides a useful tool to analyse relations within disciplinary knowledge practices. I use the term disciplinary knowledge practices to encompass what counts as knowledge, who is recognised within a disciplinary community, and how knowledge is progressed, transmitted, or reproduced within a site of analysis (Ashwin, 2009, p. 87; Bernstein, 1990, 2000) These practices are evident in academic perceptions of curriculum and engineering knowledge. As I will show in later sections, disciplinary knowledge practices in curriculum are inextricably linked to gender regimes.

The pedagogic device gives an account of the way in which knowledge is transformed within educational systems. It recognises that disciplinary knowledge practices within curriculum and learning and teaching interactions are not the same as those operating in research. The pedagogic device shows the way that knowledge is changed as it moves through research, curriculum, and student learning (Ashwin et al., 2012). It is centred around a set of fields, ordered by a set of rules. These show the way knowledge is transformed and regulated from its original site of production (within research) through curriculum and on to learning and teaching interactions. Along with this transformation of knowledge, disciplinary communities develop practices which legitimate identities of knowledgeable people within the disciplinary knowledge practices. This is summarised in Figure 3.1 and Table 3.1 below.

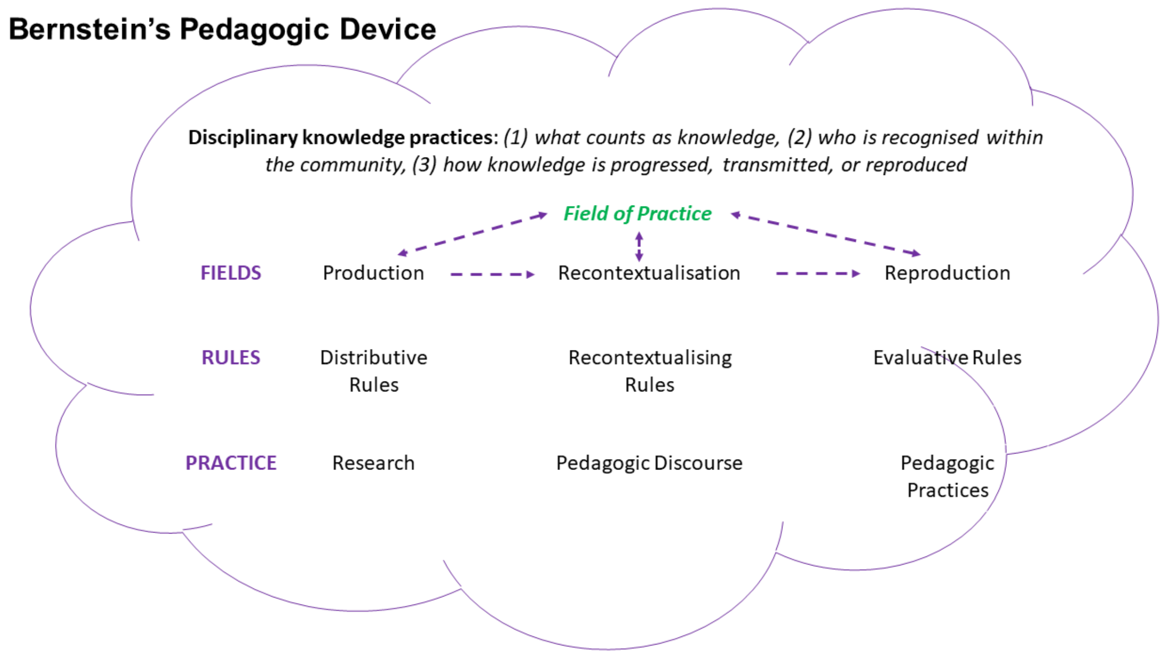

Figure 3.1 Bernstein's pedagogic device.

It is important to note that disciplinary knowledge is not simply passed from one field to another, rather the transformation through each field is a site of struggle mediated by the global, institutional, and local context, such that the practices evident in one context may look very different in another. Thus, the disciplinary knowledge practices of physics as a research field are not the same as physics curriculum in universities, nor are they precisely the same in every institutional context. There is a valorisation of knowledge and a legitimating of identities that occurs through this regulation and distribution which has implications for the differential distribution of knowledge in society (Maton & Muller, 2007).

Field (Practice)	Definition	Ordered by rules	Analytical Details
Production (Research)	Arena in which knowledge is generated, discipline-as-research	Distributive rules	Specialised knowledge (Power, Legitimate identities)
Recontextualisation (Pedagogic discourse)	Transformation of knowledge into “teachable” material, discipline-as-curriculum	Recontextualising rules	Classification, Framing, Instructional discourse, Regulative discourse (Knowledge)
Reproduction (Pedagogic practices)	Teaching, learning and assessment practices, discipline-as-pedagogic text	Evaluative rules	Pedagogic text, Visible and Invisible Pedagogies (Consciousness)

Table 3.1 The fields and rules of Bernstein’s pedagogic device, along with definitions and analytical details that can be discerned within a context and discipline. This provides an analytical framework to investigate disciplinary knowledge practices (Ashwin, 2009, p. 90; Bernstein, 2000, p. 28; Case, 2015, p. 55; Singh, 2002).

In Table 3.1, I have noted analytical details, as well as the fields and rules within the pedagogic device. Bernstein developed several analytical concepts that enable discernment of the characteristics and details of the operation of power, control, and legitimate identities within fields and contexts. I have listed Classification and Framing against the field of recontextualisation although these are concepts that can be discerned in other places. For the purposes of this study though, they are most pertinent to curriculum, the field of recontextualisation, so I will leave their explanation to section 3.1.3.

Within the pedagogic device, Bernstein argued that the distributive rules, recontextualising rules, and evaluative rules are hierarchical. Within the field of production, for example, power operates to define what counts as knowledge in a discipline, who is recognised within the disciplinary community, and what are the accepted means by which new knowledge becomes part of the discipline. This then places limits on what can be transformed into curriculum, albeit as another site for contestation (Bernstein, 1990, p. 180). In the context of professional disciplines within higher education such as engineering education, there is another field to consider, which is the field of (external) practice (Bernstein, 2000, p. 85; Young & Muller, 2015, p. 205). I include reference to this in section 3.1.3 on the field of recontextualization.

3.1.2 Research: the field of production and distributive rules

Disciplinary knowledge practices in research are regulated by the distributive rules in the field of production. This occurs through the structuring of power relations, legitimating disciplinary identities, and regulating legitimate ways of thinking and practice within the discipline (Bernstein, 1990, p. 180). In research, disciplines differ in what counts as knowledge, who is recognised within the disciplinary community, and what are the acceptable ways for knowledge to be progressed. This is not to say that this is an entirely social or cultural process and that knowledge cannot exist separately to the discipline community. As Young and Muller argue "knowledge matters" particularly given that research can limit the possibilities within the curriculum (Young & Muller, 2013). Bernstein was interested in the different ways that disciplinary knowledge practices created knowledge discourses and developed distinctive knowledge structures.

Bernstein articulated two layers of differences between knowledge discourses within disciplinary knowledge practices. Firstly, that there are differences between the common or mundane discourses (horizontal discourses) and the esoteric, sacred, or specialised discourses (vertical discourses) (Singh, 2002). This is a recognition of the differences between everyday knowledge and that which is specialised within disciplines in a higher education context or a school subject, for example.

Secondly, we can see differences in specialist discourses between those with hierarchical knowledge structures and horizontal knowledge structures. In hierarchical knowledge structures, the development of the discipline over time is towards increasing generality. New knowledge builds on and integrates with existing knowledge, “to create very general propositions and theories” (Bernstein, 2000, p. 161). This knowledge structure is most associated with the natural and physical sciences. Young and Muller use the term “powerful knowledge” to describe specialised knowledge structures which are hierarchical, since they suggest they exist independently of particular knowers (Young & Muller, 2013). This independence of knowledge beyond the “knower” has been used to suggest that there is emancipatory potential within hierarchical knowledge structures, since anyone should be able to learn them (Case, 2013, p. 55; Muller, 2015).

Horizontal knowledge structures, on the other hand, are progressed not through an integration and generalisation of knowledge but rather through the addition of new specialised formulations with their own languages, which are not necessarily related to existing knowledge (Case, 2015, p. 51). The humanities and social sciences are most associated with horizontal knowledge structures. In horizontal knowledge structures there is a serial collection of specialised knowledge, with speakers of each being similarly specialised (Bernstein, 2000, p. 168). In horizontal knowledge structures it is possible then to be the “wrong kind of knower” (Maton, 2004).

In engineering, Case draws on Bernstein and other social realist approaches, to interrogate student learning in higher education (Case, 2011). While not specifically focused on the field of production, she suggests that “in engineering - at least in engineering science … “, we have hierarchical knowledge structures (Case, 2013, p. 55). I will return to this reading of engineering knowledge as being engineering science in Chapter 7, given its implications for the nature of disciplinary knowledge practices within curriculum.

3.1.3 Curriculum: the field of recontextualisation and recontextualising rules

The field of recontextualisation is of most interest in the current research study since it is the arena of curriculum. It is understood as the ‘teachable’ material that is selected and relocated from research (and the field of practice) into curricular structures. In the shift from research to curriculum, disciplinary knowledge practices are transformed to become “virtual or imaginary practices” (Bernstein, 1990, p. 184). Bernstein referred to disciplinary knowledge practices in the field of recontextualisation as pedagogic discourse.

In developing ways to describe the disciplinary knowledge practices within curriculum, Bernstein made use of the concepts of classification and framing. Classification relates to power relations and Framing relates to forms of control. In this section, I describe the way these are articulated within the field of recontextualisation.

3.1.3.1 Classification

Classification refers to the extent to which disciplinary knowledge practices are clearly differentiated from each other (Ashwin et al., 2012). Classification can be characterised as either strong or weak dependant on the strength of the boundary around a knowledge structure (Bernstein, 2000, p. 11). As an indicator of power relations, the separateness that comes with strong classification reflects a site in which power is exercised by maintaining the interests of certain groups at the expense of others or certain knowledge structures as distinct from others. Strong classification can be associated with both hierarchical and horizontal knowledge structures in research, since classification reflects only the relationship between the knowledge structure and other knowledge structures.

Modes of knowledge production are linked to the way disciplinary knowledge practices are classified and the strength of classification. With respect to the disciplinary knowledge practices within curriculum, Bernstein identified three modes of knowledge production that reflect different types of disciplinary knowledge practices: singulars, regions, and generic modes.

Singulars are knowledge production modes which are strongly classified and clearly separated from other disciplinary knowledge practices. Maintenance of strong boundaries reflects power relations in operation. The "pure" disciplines are generally acknowledged as singulars, for example physics or sociology (Bernstein, 2000, p. 52). In disciplinary knowledge practices which are singular, content and legitimate identities can each be strongly bounded (Donnelly & Abbas, 2018).

Regions, in contrast, are weakly classified and are created through the selective integration of knowledge from singulars into legitimate knowledge relations. Engineering is one of the most commonly cited examples of a regionalised knowledge structure and most often directly linked to singulars in the natural, physical, and mathematical sciences (Case, 2011). It is tempting to see this link between science and engineering as a ‘natural’ form of regionalisation but Bernstein, in seeking to interrogate power relations, suggested that “regionalisation of knowledge implies a recontextualising principle: which singulars are to be selected, what knowledge within the singular is to be introduced and related?” (Bernstein, 2000, p. 9). In contrast to curricula that focus on singulars and the development of disciplinary identity, Bernstein suggests that regions focus more towards the application of knowledge in employment, through looking towards both singulars as well as to the field of practice (Ashwin et al., 2012). This is pertinent to the current research context where academic perceptions of engineering knowledge reflect tensions and choices in the disciplinary knowledge practices between engineering science and engineering in practice.

Generic mode knowledge is an “empty” mode of knowledge, a recent construction of a work and skills agenda, which exists outside the specialised knowledge discourses. Associated with generic or transferable skills in higher education, Ashwin et al, argue that this knowledge mode has dominated in recent policy shifts in “market-oriented” pedagogic discourse associated with high quality learning (Ashwin et al., 2015). This sense of generic mode knowledge is a move away from the idea that knowledge matters and has been accompanied by a shift towards a focus on student-centred learning (Ashwin, 2021). There is a risk with generic mode knowledge that student learning outcomes become so contextualised as to inadequately prepare graduates to think beyond the current context.

The extent to which disciplinary knowledge practices as pedagogic discourse are understood as a singular, region or generic mode is the result of struggles and tensions between multiple voices. Pedagogic discourse, as reflected in the curriculum in a particular site, reflects complex tensions and choices mitigated by global, institutional, and local influences (Ashwin et al., 2012). It defines what counts as legitimate knowledge within curriculum and legitimate student identities to be taken up.

In professional disciplines, such as engineering, the regionalisation of knowledge occurs through turning towards singulars but also to the field of practice. In the field of recontextualisation, Bernstein distinguished between the *official recontextualising field,* regulated beyond the actual site of learning and a *pedagogic recontextualising field*. (Bernstein, 2000, p. 33). The official recontextualising field is created by, not only the state (in the form of, for example Higher Education legislation) and the institution but also by professional accrediting authorities such as Engineers Australia. The *pedagogic recontextualising field* reflects the way academic disciplinary communities within the local context further transform disciplinary knowledge practices. In this study, I show through illuminating academic perceptions of engineering knowledge that this has implications for the autonomy and struggle of educators (Bernstein, 2000, p. 33) and as a consequence the legitimate identities made available for students.

3.1.3.2 Framing

While classification refers to the boundaries between disciplinary knowledge practices and other disciplines, framing refers to the knowledge and social relations within disciplinary knowledge practices (Bernstein, 1990, 2000). To look at the framing of disciplinary knowledge practices within pedagogic discourse is to understand the systems of control operating within two domains which Bernstein referred to as *instructional discourse* and *regulative discourse* (Singh, 2002).

Pedagogic discourse can be understood as comprising both instructional and regulative discourse, not as separate discourses but as one discourse with the regulative aspect dominating (Bernstein, 1990, p. 184).

Instructional discourse refers to the selection, location, pacing, and sequencing of content within curriculum (Ashwin, 2009). This reflects choices about knowledge and legitimate conceptual relations, which Maton (2007) refers to as epistemic relations. *Regulative discourse* refers to the social relations regulating interaction between actors within the field of recontextualisation including students, academics, managers, administrators, and support staff (Ashwin, 2009).

Regulative discourse is particularly important in framing appropriate and legitimate forms of student identity. In the second section of this chapter I suggest that regulative discourse reflects gender regimes in an engineering education context. This is not to imply that the instructional discourse, the selection and ordering of content is not relevant to (gendered) identities that are made available to students. Rather it recognises that the dominance of regulative discourse is intertwined with the knowledge relations revealed in instructional discourse – knowledge and identity are linked.

3.1.4 Student learning: the field of reproduction and evaluative rules

The final analytical domain is the field of reproduction, which is ordered and regulated by evaluative rules. In this field, disciplinary knowledge practices are transformed into interactional practices with students, within classrooms and assessment practices. This is a transformation of pedagogic discourse into pedagogic practices (Singh, 2002). The evaluative rules are standards which operate to control legitimate (re)production of disciplinary performances (Bernstein, 2000, p. 115). Pedagogic practices restructure disciplinary knowledge practices, determining what is learned and how learners are judged on their learning outcomes. As Case notes, pedagogic practices in the field of reproduction provide opportunities for academics to directly "influence student access to knowledge" (Case, 2013, p. 54). In the current study, academic perceptions of engineering knowledge reveal this influence by illuminating the criteria by which students are judged on their alignment to the knowledge and community disciplinary practices.

Pedagogic practices can be characterised into two forms: visible pedagogies and invisible pedagogies. Visible pedagogies or performance pedagogies operate where there is strong classification and framing, such that students can clearly see what is required to achieve acquisition through clear and objective testing: a focus on what students know. Invisible pedagogies or competence pedagogies focus on individual student demonstration: a focus on who students are, not what students know (Bernstein, 1990, pp. 70 -72). Case suggests that in engineering education, engineering science subjects, grounded as they are in singulars such as physics and mathematics, are more likely to operate with visible pedagogies. Design subjects, often offered later in an engineering degree, are more regionalised and therefore likely to operate with invisible pedagogies (Case, 2013, p. 54).

In the field of reproduction, once again there are struggles and tensions operating that have implications for both knowledge and knowers. Some have argued that when the disciplines of Science, Technology, Engineering, and Mathematics (STEM) maintain their firm connection to singulars in the natural, physical, and mathematical sciences, the operation of visible pedagogies brings with it the emancipatory opportunity for anyone to learn them (Muller, 2015). This, Case argues in the case of engineering, is due to the strength of the knowledge structure. She cautions that pedagogic practices that weaken knowledge structures such as problem-based-learning, where the classification between disciplinary knowledge practices is blurred, may lead to outcomes more akin to generic modes of knowledge. This may be to the detriment of particular student cohorts such as those from previously academically disadvantaged backgrounds (Case, 2011). When engineering is seen as part of STEM and knowledge in engineering as engineering science knowledge, then the argument goes that with support to acquire pre-requisite knowledge, anyone can succeed in engineering (Case, 2013, p. 55).

In this study, I question Case's assertion that the choice is between engineering as engineering science, strongly aligned to singulars in science and mathematics, or engineering as "professional skills", generic mode knowledge, empty of specialised knowledge practices. An alternative reading is that in pedagogic practices, the disciplinary knowledge practices of natural and physical sciences, and mathematics may create exclusionary and gendered student identities. Rather than a generic mode being the only alternative, there is the possibility of different recontextualising and evaluative rules. Engineering pedagogic practices could create regionalised engineering knowledge practices that incorporate the singulars of social science and humanities, for example. This could shift the legitimate identities made available to students and more closely reflect the field of practice.

3.1.5 Researching the pedagogic device in higher education

To conclude this review of Bernstein's pedagogic device, I make brief mention of the methodological approaches that have been used in higher education to make use of the theory. Ashwin makes the case for the usefulness of Bernstein's theory in analysing teaching and learning interactions in higher education (Ashwin, 2009, pp. 87-104). Subsequently, he and colleagues have continued to develop this approach, researching the discipline of sociology in multiple university contexts (Ashwin et al., 2012). Methodologically, these projects and those taken up by others in critical thinking and engineering, have used an ethnographic approach (An Le & Hockey, 2022; Case, 2011). They have drawn together interview and focus group data with students and academics, videos of teaching and learning interactions, and pedagogic practice documents, such as assessment tasks and subject learning resources. The focus has been on pedagogic discourses (curriculum) and pedagogic practices (learning and teaching interactions) with a primary focus on students and student agency. What has been less explored in these accounts is the contribution of academics (educators), who are subject to certain regulatory structures, but nonetheless exercise agency in shaping the pedagogic discourse and pedagogic practices. I return to this point in Chapter 4 as I articulate the methodology for this research project.

3.2 Gender regimes

In this section, I explore gender regimes, a theoretical framework to describe the relations of power and control, practices, experiences, and patterns of gendered relations within a context (Connell, 2006). I begin by engaging in a definitional discussion around gender, to ground this theoretical framework in post-structural articulations of gender theory. I then map out the aspects of gender regimes, and connect these to pedagogic discourses, as a way of illuminating the relationship between gender regimes and the student identities made available through curricular decisions.

3.2.1 What is gender?

When considering the problem that this research project addresses, the starting point may seem obvious: there are very few women who are engineers. Enrolment forms for university entry when I commenced my undergraduate engineering study collected demographic data through asking the question of whether I was male or female. It is this demographic statistic that has been used to report on the absence of women. Embedded in these statements, however, are everyday assumptions about what constitutes a woman. In both cases, the everyday understanding that operates is the idea that there are two genders in the world, that people can be placed into one category or the other, and that there is something to be naturally inferred by being a woman or ticking the box that says female. (There has been some recent change in this understanding as increasing numbers of young people reject the idea of choosing male or female, man or woman, and a new box has been added to the enrolment form that allows the choice of ‘other’.)

Mendick in her book on masculinities in mathematics, explicitly commences the research reported in the book with a rejection of the everyday understandings of gender, in favour of post-structural definitions developed through the theorising of researchers such as Butler, West and Zimmerman, and Connell (Butler, 2006; Connell, 2006; Mendick, 2006, p. 10; West & Zimmerman, 1987). These definitions reject the idea that gender is a fixed aspect of identity and that it is determined by sex.

Second wave feminism (in the late 1960s and early 1970s) disrupted the traditional understanding of gender as being determined by sex by introducing the idea that gender was socially constructed. The argument was that sex and gender could be differentiated: sex was a biological construct, wholly related to nature, and determined by the type of body you were born with; gender, on the other hand was sociological, determined by the nurture you received as you grew up in a particular social and cultural context (West & Zimmerman, 1987). As Mendick notes, the challenge in this definitional shift is that “in this approach biology is still seen as something that can be separated from the social world rather than something horribly and beautifully intertwined with it” (Mendick, 2006, p. 14).

I was reminded of the “horrible” aspect of this view of biology when I recently underwent training to become a LGBTIQA+ Ally within my university. It coincided with the publication of a news article by the ABC News in Australia about a young woman who discovered when she was 21 years old that she had in fact been born intersex. The reason why she had discovered this as late as 21 years of age is that as is often the case for people who are born intersex, her parents had agreed to medical intervention to ‘normalise’ her, at least outwardly, as a woman. The advice provided to her parents is an example of the power regularly exercised by the medical profession in persuading the parents of intersex people that they are ‘other’ and must be made to fit the (social) construct of the biological sex binary. In fact, as the Australian Government Health Direct website notes approximately 1.7% of the population are intersex, about the same number of people who are born with red hair.

But the challenge to the notion of gender as being socially constructed is not just from the perspective of the flaws in arguments about biology determining sex. Socially constructed gender assumes a structural determinism that is hard to hold onto in the face of dynamic and changing cultural contexts (Connell, 2009, p. 95). It leaves no room for agency, nor any possibility for challenge. It suggests that individuals acquire fixed traits and cannot explain why, within the categories of women and men, there are variations in expression of that gender. As Connell suggests it leaves no room for pleasure, resistance, or difficulty in becoming gendered.

This leads to the development of a definition of gender that sees it as relational. Thus, gender is "something that we do and are done by not something that we are" (Mendick, 2006, p. 10). This moves far away from the idea that there is some inner expression of gender identity behind the way we appear in the world. Rather that identity is "performatively constituted" in the everyday doing and being of a person in the world (Butler, 2006, p. 34). In this view, people are not socialised into gendered ways of being, but rather there is a process of "subjectification" in which a person moves through a dynamic world of patterns of gender relations, taking up particular discourses of that gendered context (Davies, 1993; cited in Mendick, 2006, p. 17). This definition does not deny the regulatory power of gender discourses, but contrary to the gender socialisation view, acknowledges the possibility of agency, change, and resistance; to do and be otherwise (Mendick, 2006, p. 22).

Gender in this view is a system that operates across the macro level of cultural beliefs, the interactional level of practices in both every day and organisational contexts, and through individuals who conjure, perform, and experience selves and identities. At the level of cultural beliefs, gender systems operate to reinforce binary and hierarchical beliefs about men and women. For instance, the STEM disciplines are associated with men and with greater status value while women are associated with lesser value social, caring or nurturing knowledge areas. Faulkner describes these as a valuing of "masculine instrumentalism and feminine expressiveness" (Faulkner, 2000; Ridgeway & Correll, 2004). This is not to say that this is a deterministic structuring of possibilities, rather, as Mendick notes with regard to mathematics, it constrains the possibilities of being a woman and a mathematician, but in illuminating this tension, we open up the opportunity for change (Mendick, 2006, p. 17).

3.2.2 Illuminating the "doing and done by" of gender in a context: gender regimes

If we take on the definition of gender as "doing and done by", then it is something that is complex, dynamic, interactional, and situational. This is not to say that in a context we can ignore macro-structural influences but rather to suggest that to "see" gender patterns requires consideration of cultural, social, and individual regulatory forces that are coming together in a particular time and place. Connell (2006) has articulated a useful analytical framework for investigating the gender patterns in operation in organisations, which she terms gender regimes. In this section, I argue that this framework can be modified to provide a means to interrogate the gender regimes in operation in an engineering education context.

Connell distinguishes four dimensions of gender relations in her formulation of gender regimes (Connell, 2006). They are (1) the gendered division of labour, (2) gendered relations of power, (3) emotions and human relations, and (4) gender culture and symbolism. Taken together they provide a lens through which to view gender patterns in context. The use of the word “regime” to describe the distinguishing features of gender patterns, has similarities to its use by Trowler in analysing practices in academic departments through Teaching and Learning Regimes (Trowler, 2008, p. 52). Regimes in both cases imply an open system of practices that, while habitual and possibly tacit, are nonetheless dynamic with the possibility to change. An analysis of gender regimes is not an uncovering of the way things are for now and forever but it does serve to highlight current tensions and inequities.

Gender regimes are identified by dimensions that constitute their parts but are not separate categories. Connell suggests the dimensions are “tools for thinking”, that is, they perform as analytical lenses to bring to the foreground one aspect of a complex social practice in context. As such they are always interweaved together, intersecting in ways that are dynamic and provide constraints and opportunities for change within individual agency, social practices and cultural beliefs, in a similar way to the “moments” in Trowler’s Teaching and Learning Regimes (Connell, 2009, p. 85; Trowler, 2008, p. 55).

In discussing each of the dimensions in turn, while I draw on Connell’s original descriptions, I articulate analytical approaches that connect to the context of curriculum decisions and academic contexts in engineering. Further I will connect these dimensions to the ideas of Bernstein’s regulative discourse, suggesting a form of gendered regulation that can be discerned in operation within an educational system. The theoretical frames of Connell and Bernstein have in common that they recognise that there are both powerful regulatory forces in operation and that there is contestation and resistance, opening the possibilities for change.

3.2.2.1 Gendered divisions of labour

In contemporary Australia, as in most countries in the Global North, the gender profile of those who undertake particular types of work is highly skewed. For instance, engineering is dominated by men, nursing by women (Briggs, 2023; Cortis et al., 2023). In the sphere of domestic work, statistics continue to be reported that show that women undertake the bulk of domestic and caring labour in the home (Baxter et al., 2023). These large-scale divisions manifest in the higher numbers of men enrolled in engineering degrees. In this study, the gendered divisions of labour manifest as the student 'labour' within an educational system. In this study, I am interested in what roles are recurrently taken up by women students, and which by men students in the conduct of their learning. Within engineering education, one of the sites where divisions of labour can be observed is within team-based project work.

Gender patterns around the gendered division of labour can be seen in engineering education, through the ways in which project-based work is set up within curricular structures and implemented within pedagogic practices to produce gendered work divisions available to students. Beddoes and Panther in their study of engineering professors' perspectives and practices around gender and teamwork, note that the engineering academics they interviewed viewed as positive the experience of women students taking up roles in team projects as organisers and project managers. This is despite these tasks being associated with less valuable aspects of engineering work (Beddoes & Panther, 2018). Meadows and Sekaquaptewa analysed the presentations of over 1100 engineering students in 246 teams who presented the outcomes of their team-based projects to find that men overwhelmingly took up the role of “technical” expert, with women much more likely to take on a “non-technical” role (Meadows & Sekaquaptewa, 2013). This should not be seen as a horizontal division of labour, however, given the valorisation of the “technical” aspects of engineering practice that are consistently shown to be operating within engineering (Faulkner, 2000; Mills et al., 2013; Trevelyan, 2010). In this study, I show the ways in which academic perceptions of gender reveal gendered divisions of the roles undertaken in team-based projects, and in classroom interactions.

3.2.2.2 Gender relations of power

Power operates to privilege some individuals and groups, and to oppress others. Gendered power relations can be revealed, through an analysis of the pedagogic discourse and the ways in which it legitimates certain disciplinary knowledge practices, both in terms of the valorisation of particular knowledge and in the regulation of legitimate knowers. The operation of power within an educational system can be made visible through three mechanisms (Trowler, 2008, p. 98). Firstly, educational systems can foster access to outcomes by individuals and groups that are in their interests to the detriment of others’ interests. This connects to the gendered division of labour discussed in the previous section. For example, within laboratory settings in engineering, women often take on the role of note taker or sit back while men take active roles in using equipment giving them a greater access to planned learning opportunities (Hosaka, 2014).

Secondly, power operates through the inclusion or exclusion of certain disciplinary knowledge practices. As I noted earlier, for regional modes of knowledge, choices are made about which singular knowledge areas are to be regionalised and which aspects of that knowledge mode are to be incorporated in the curriculum (Bernstein, 2000, p. 9). In engineering, this comes to have a gendered pattern by virtue of the cultural beliefs operating to associate the natural and physical sciences, and mathematics with men and masculinities. Finally, power works to provide differential access to the capacity to think or imagine beyond the current state. Berstein noted that pedagogic discourse could act to provide differential access to “the unthinkable class of knowledge” by which he meant specialised knowledge discourses (either hierarchical or horizontal).

Power does not only operate through knowledge. The production and maintenance of a lack of knowledge can support a discourse that uses ignorance as a form of power to resist change. Mills, et al in their study of engineering workplaces noted that “the production of ignorance helps to obscure the sexual politics, not knowing its relevance to the situation of women engineers is an effective strategy to maintain the status quo” (Mills et al., 2013, p. 76). In this study, I show how academic perceptions of engineering knowledge, of gender, and in the production of ignorance operate to gender the possibilities of legitimate engineering student identities.

3.2.2.3 Emotions and human relations

The experiencing of emotions and their connection to human personal relationships are often viewed as being relevant only to a private and individual realm. Connell argues that to the contrary they strongly influence social interactional contexts such as organisations or educational systems (Connell, 2006; 2009, p. 81). Emotions and human relations are then an important dimension of gender regimes. Emotions may induce belonging or a sense of solidarity with others, in a positive sense or they may bring about prejudice, discomfort, or disdain when they are negative.

In connecting emotions with human personal relations, Connell highlights sexuality and attraction as components of the emotional gender patterns that operate within a context (Connell, 2006; 2009, p. 81). The connection of emotions to sexuality and attraction is linked to contemporary cultural beliefs that are based in a heteronormative gender order. This is the cultural belief that there are two genders and the "normal" way for the world to operate is for sexual attraction to work between people of different genders (Holmes, 2007, p. 21). Universities as educational systems are not immune from the implications of a heteronormative gender order.

In this study, I consider two ways to in which emotions and human relations are evident within an engineering education context. The first is via an interrogation of pedagogic practices within a classroom context and what they reveal about the emotional relations in operation amongst students and between students and academics. The second is via the pedagogic discourses evident within curricula structures, and whether the idea of emotions is connected to engineering as a disciplinary knowledge practice.

Recent curricular development in engineering has brought emotions and human relations to the fore in the growing body of research related to empathy in engineering education and practice. Empathy, in contrast to other engineering science knowledge areas, specifically focuses on engaging with the emotions of oneself and other people. For example, Walther et al have developed a model of empathy in engineering, which they argue should be a "core skill, practice orientation and professional way of being" (Walther et al., 2017). They argue that empathy is teachable, suggesting specific forms of pedagogic discourse and pedagogic practices. In this study, the presence or absence of content related to empathy or emotions will be used as an indicator of the nature of the gender regime in operation.

While there has been a long history of researching the gendered relations within engineering, focusing on women, there is much less research on the experiences of sexually diverse students. Cech and Waidzunas in a rare sociological study of lesbian, gay, and bisexual (LGB) engineering students uncovered "an oppressive climate" of heteronormativity. This was not only an experience of classroom interactions, in which the students ended up actively hiding their LGB identity, but also related to curricula positioning around competence. Discussions of diverse sexuality were seen as not relevant to engineering, per se, but rather as a social and private matter (Cech & Waidzunas, 2011).

To uncover the way that emotions and human relations illuminate gender regimes in operation in an educational context in this study, I describe both the pedagogic discourse and pedagogic practices that make in/visible the role of emotions in engineering practice and acknowledge the diversity of a student cohort, through explicitly being aware of the potential negative impacts of heteronormativity. This diversity is not just about women and men, but also about the presence of non-binary and transgender people within our classrooms along with people of diverse sexual orientations.

3.2.2.4 Gender culture and symbolism

Within a context, gender patterns are influenced by cultural beliefs about what gender is and the ways in which people come to be positioned on the basis of an assumed gender identity. An analysis of gender culture and symbolism seeks to uncover the hegemonic gender beliefs in action (Ridgeway & Correll, 2004). This involves the way in which gender itself is understood, symbolised, and represented in practices and material objects. This could include images, physical arrangements, written texts, policies, and social interactional arrangements. For instance, in her study of public service agencies, Connell found that gender neutrality was confirmed through culture and symbolism as “a degendering strategy”. In this case a commitment to equal opportunity as a means to ensure gender equity was enacted as an explicit rejection of affirmative action (Connell, 2006). The risk in a degendering strategy is that it creates a façade of equality that may mask the injustices and power relations that are actually operating. Gender does not cease to be “done” within a culture of gender neutrality.

To see the traces of gender culture and symbolism within an engineering education context is to interrogate not just the ways in which the gender dichotomy appears but also to look for examples of gender neutrality. In this study I interrogate the pedagogic discourse and practices for traces of gender culture, looking for manifestations of gender symbolism. Trowler suggests that “discursive repertoires” are forms of social practices that can (re)produce cultural meanings in a teaching and learning context (Trowler, 2008, p. 75). Analysing the representation of disciplinary knowledge practices within textbooks or in curricular choices, for example, can reveal gender culture and symbolism in pedagogic discourse and pedagogic practices.

In the engineering context there is a longstanding history of association between the discipline and masculinity. This creates a hierarchical dualism of masculine/ feminine. It is accompanied by a series of binary tensions within engineering, grounded in other dualist oppositions such as technical/social, rational/emotional, and technology-focused/people-focused, which have become inextricably linked to the hierarchical dualism of masculine/feminine (Faulkner, 2000; Holth, 2014). An outcome of these dualist notions in cultural beliefs about engineering is that woman and engineer symbolically appear as opposites. Faulkner suggests that this creates experiences of gender in/authenticity, such that, as Holth suggests “female engineer is a deviation, both professionally and as a woman” (Faulkner, 2015; Holth, 2014). In this study, I analyse the ways academic perceptions of engineering knowledge and of gender perpetuate these dualisms, reinforcing the legitimation of engineering identities that continue to be gendered.

3.2.3 Gender regimes in engineering curriculum and practices

Drawing together the explication of the pedagogic device in 3.1 and gender regimes in 3.2, I now summarise the analytical possibilities of gender regimes in an engineering education context that I use to discuss my findings. In this study I show how academic perceptions of engineering knowledge and of gender, make visible gender regimes through:

- Gender division of labour, that is revealed in the design and implementation of team-based project work in engineering curriculum, particularly in terms of the negotiation around roles within the team context that may be gendered.
- Gender relations of power are illuminated through recontextualising rules and pedagogic discourse, via both the choices of which disciplinary knowledge practices are legitimated and through the production and maintenance of ignorance. Cultural beliefs about knowledge and gender are intertwined.
- Emotion and human relations are interrogated through two interacting considerations. The first is regulative discourse and the ways it fosters a sense of belonging or exclusion for people of diverse genders and sexual orientations, and thus legitimates heteronormativity. The second is the disciplinary knowledge practices that connect engineering to emotions and human relations, through curriculum incorporation of content such as empathy and human centred design.
- Gender culture and symbolism is revealed through analysis of the "discursive repertoires" evidenced in pedagogic practices and textual productions, which reinforce gender differences and highlight prevailing beliefs about gender and engineering.

Thus, Bernstein's framing of pedagogic discourse and pedagogic practices, within the pedagogic device are viewed through the lens of Connell's gender regimes. Together these illuminate the tensions and struggles that may still ultimately result in the gendering of legitimate student identities, produced through curricula decisions by engineering educators. These are not the decisions of individuals but are practices framed by global, institutional, and local contexts, looking towards both research and the field of practice. Illuminating these tensions and the ways in which cultural, social, and individual regulation come together, I provide the opportunity to question the status quo and imagine a way that it could be different.

3.3 Knowledge relations and social relations in engineering curriculum: analytic possibilities

I conclude this chapter by articulating a framework that integrates pedagogic discourse and gender regimes into an overarching analytical approach. I understand curriculum as a form of disciplinary knowledge practice, which can be viewed from two perspectives. Bernstein referred to these as instructional discourse and regulative discourse, what I term *knowledge relations* and *social relations*. The perspectives of the engineering academic community in a local context reveal details of these relations in operation, which have a gendered dimension.

Knowledge relations, the selection, sequencing, and pacing of content within curriculum, is characterised by a knowledge mode as either a singular, region or generic mode. The gendered dimension of knowledge relations reveals the ways in which particular knowledge modes are connected to gender, that is, seen as masculine or feminine. In engineering education, of particular importance are the choices that are made in regionalisation regarding which singulars. We can interrogate knowledge relations for assumptions of gender neutrality, a degendering strategy. Finally, in knowledge relations the presence or absence of emotions and human-centred knowledge reveals a gendered dimension.

Social relations, the regulation of order, interactional relations, and identity within curriculum, reveals characteristics of the accepted roles of teacher and student in interaction. Further it illuminates the legitimate identities for teachers, students, and for knowledgeable members of the disciplinary community. In the context of this study, it reveals what counts as “authentic” engineering practice and who is an “authentic” engineer. The gendered dimension of social relations can be found by looking for the presence or absence of hegemonic gender beliefs, the reinforcement of dualist, hierarchical binaries around man and woman. The production of ignorance is not a rejection of this binary but rather obscures its impact. Finally, where heteronormativity is present within social relations, it challenges the possibilities for inclusion of students of diverse genders and sexual orientations.

As I discuss in the next chapter explaining research methodology, by investigating the perceptions of engineering academics around gender and knowledge in engineering, we can illuminate aspects of the knowledge relations and social relations in curriculum, with consequences for gender patterns in operation and the engineering student identities made available to students.

Chapter 4: Methodology and Methods

The purpose of this research is to explore the perceptions of academics of gender and of engineering knowledge in relation to their teaching practices and to connect this to the implications for gendered disciplinary knowledge practices in curriculum. The perceptions of academics reveal aspects of the “discursive repertoires” that operate in disciplinary knowledge practices within a context (Trowler, 2008, pp. 75-76). In this chapter I describe the methodology that guided my study. I give a detailed account of the methods that I used to answer my research questions.

Feminism informed my methodology and forms an important background to my study, even though my focus is not on the voices of women. Having learned, worked, and taught within the engineering profession for over thirty years, my positioning within my research context and the broader field of engineering education cannot be untangled from this study. This project is insider research, and I begin this chapter by articulating a personal positioning from which the study emerged. I go on to exploring the implications for using an interview method in my own institution as a sociological approach to interpretive research methodology (Clegg & Stevenson, 2013).

The later parts of the chapter explain the methods used to generate my research data and analyse it. A key component of the ongoing work of generation and analysis was a systematic approach to reflexive journalling. Because of the sensitivity of generating and reporting data from my own professional work context, I conclude the chapter with an explanation of the ways in which I will represent participant data in later chapters to ensure I sensitively maintain my ethical commitments to colleagues.

4.1 Researcher and methodological positioning

In this section I explore my personal positioning within this research study and the methodological positioning that leads on from that. I show how my history as an engineer, an educator, a woman, and a social science researcher has caused me to confront decisions about my research design, methodology, and methods. I do so because my research has emerged and developed from a personal quest to make sense of my experiences across that history.

4.1.1 My personal positioning

Introductory research texts in the social sciences often frame a hierarchy of research decisions that begin with ontology and end with methods (see for example Crotty, 1998). When I was a young woman studying engineering at university, my first glimpses of research within my discipline gave me no exposure at all to the meaning of ontology or epistemology. I was educated in a discipline which at that time as far as I could see largely took for granted that describing research design involved articulating in detail the experimental approach to be used within a scientific method. Even now when I talk with colleagues in engineering about research in engineering education, I am questioned about the validity of research studies that do not involve large numbers of students, under tightly controlled conditions, and with a calculated statistical validity to outcomes, as though there is no other way to know the world of engineering education.

I begin my discussion on positionality by raising ontology and epistemology because it is one of the joys of my continuing development as a researcher to be able to find personal value and meaning in articulating an ontological and epistemological positioning, rather than leaving these as assumed and unexplored. Ontologically, I am a realist. I have no doubt that reality exists outside our minds. While I am in awe of the wonderful outcomes that my scientist and engineer colleagues achieve through scientific research, I began my engagement with social science because of a feeling of dissatisfaction and frustration which emerged for me when the objectivist epistemology that underpins their work is applied to studying humans and the social world, as though it can be transplanted from physics, for example, without question. For me working within higher education, it is particularly problematic to assume that I can make sense of what is happening for students and for academics by using positivist, objectivist research methodologies.

I was assigned as female at birth and continue to identify as a woman. That has meant that much of my professional life within engineering I have been in the minority. While at high school I studied the most advanced mathematics available, physics, and chemistry. I cannot recall at the time ever being alert to how few women were in my classes. But when I went to university I have a vivid memory of walking into an Orientation week welcome and suddenly realising that women were only about 10% of the class of over 300 people. Since that day in 1987, my status as representative of a marginalised minority has been a constant companion in my professional thinking and interactions. I acknowledge that I am particularly privileged as a white, heterosexual, middle class woman and there are others for whom gender is only one aspect of their intersectional marginalisation.

Being a woman in engineering, as I have aged my sense of who I am as an engineer and what it means to be engaged in the engineering profession has moved considerably. Early on, while recognising there were few women, I was confused as to why that should be the case. Growing up as I did with two parents who were schoolteachers and one sibling, also a woman, I was never in any doubt as to my capacity to do anything I wanted to. Mathematics was an early passion, and my parents encouraged me in that passion. Once I was alerted to the lack of women in engineering, I thought only that more needed to be done to convince others that maths was fun and engineering an exciting opportunity to apply that maths in the real world. But as I aged, I began more and more to notice frustrating behaviours – young women being ignored or left out of hands-on activities, rooms full of professional men who would assume I was the administrative assistant, and colleagues who made broad statements about the “girls” in our classes which did not accord with my personal interactions with young women nor my memories of how I was as a student.

All this history leads to my positioning in this research study. In trying to make sense of my experiences, I came to see that humans and the social world cannot be easily explained (in my view) through a scientific method grounded in an objectivist epistemology. The world is real but it is impossible for a rational observer to ‘see’ experiences such as the daily micro-aggressions that in many cases young women experience as normal in an engineering classroom. I looked for explanations of the ways that the habitual and every day in my own context is not just enacting a culture but also constructing it (Trowler, 1998, p. 2). In short, I came to see that the explanations that made most sense of what I experienced where those that took a middle path, acknowledging the agency and uniqueness of individuals as well as the structural contexts that enable and constrain that agency, operating at a range of social levels.

I am a feminist. This, too, informs the approach of my study. I have held roles as a Women in Engineering Coordinator in the mid 1990s and am now the Chair of the Women in Engineering Queensland Committee for my professional association, Engineers Australia. I have watched, over the years that I have been a part of women in engineering activities the ways in which, time and again, the same strategies have been tried and failed to 'attract and retain' more women in the profession. As I have shown in the literature review in Chapter 2 this failure is not due to the lack of investigation of experiences of women from high school, higher education, and into the workforce. What was missing for me was an explanation for the contribution of academics in continuing to enact and construct local cultures that contribute to the lack of women in engineering. One of the key influences that academics have is on the curriculum and on the disciplinary knowledge practices that operate (Ashwin, 2021).

4.1.2 Study Methodology

Leading on from my personal positioning and my research questions, the methodology for this study draws on interpretivist theoretical perspectives. My insider status in the research context opens up the opportunity for the "fine-grained, usually immersive" practice-focused ethnographies (Trowler, 2014b) that take place when one is immersed at the (meso) local level of my faculty. The methodology then must provide a means to interrogate the "discursive repertoires" in the disciplinary knowledge practices of my research site (Trowler, 2008, pp. 75-76). These disciplinary knowledge practices are a form of encultured professional knowledge (Blackler, 1995), which is located in the shared meaning systems of academics, in this case about gender and about engineering knowledge.

As an insider, my daily work is constantly embedded in these social practices, providing both opportunity and challenge to my research. I have explicitly separated a discussion of methodology from method for this reason. As Clegg and Stevenson (2013) note in their critical discussion on interviews in higher education research, there is a risk in insider research which claims to be based on interviews that there is tacit, "richly ethnographic data" which is being drawn upon even if the researcher does not acknowledge it. To make a claim that this study is a practice-focused ethnography is to highlight the entanglement of context in my study. There is no beginning to my "fieldwork" and while I continue to work in this context, no clear end. Tied up within the study are my own personal commitments and values, and a desire to bring about change.

There is also a methodological corollary around the process of analysis and interpretation of interview transcripts. In choosing to interview my colleagues, I attempted to move into a different mode of conversation, by formalising into a research interview. However the "interpretive context" is one in which this formalisation was simply a break in what is an ongoing conversation (Clegg & Stevenson, 2013). To address this, I have documented ongoing observations and created reflexive journal entries as a way to "scrutinise the ethnographic elements" of my study (Clegg & Stevenson, 2013).

In analysing the interview data I have drawn on the features of discourse analysis described by Potter and Wetherall (1994) who suggest that discourse analysis as a form of interrogating social practices is concerned with "action, construction and variability" (Potter & Wetherall, 1994). In that sense, I am interested in not just the shared meanings that are constructed through disciplinary knowledge practices, but also the ways in which they vary and are differentiated.

4.2 Methods

Following on from the methodological positioning that I explained in the previous section, in this part of the chapter I will articulate the details of the methods I used in this study to answer my research questions. Beginning with a brief overview of the details of the research setting, I will then discuss the participants, the interview data generation, approach to analysis, and reflexive journalling. I conclude this section with a discussion of the limitations of this approach.

4.2.1 Research setting and context

As I noted earlier in this chapter, this project is insider research and is thus positioned within the institution that I work. In this section I will explain the type of institution and the organisational arrangements of the engineering schools which offer engineering education. I also provide some context for engineering education in Australian higher education institutions, particularly the context of external professional accreditation.

My institution is young by international standards, having only been established in 1989 as a university, drawing together various predecessor colleges and institutes. It prides itself on being a technology university and has a firm focus on employability as an outcome of its educational offerings. At the same time, it seeks to accelerate research growth in both fundamental and applied fields of research. There is strong central control within the educational function of the university. A central learning and teaching governance and development function has carriage of university wide policies and procedures, which are colloquially discussed as being particularly bureaucratic.

It has five faculties, made up of several schools each. The faculty in which my study is situated offers degree programs in engineering as well as other disciplines aligned to the built environment and architecture. The teaching of undergraduate and postgraduate degrees in engineering is shared across three schools that cover different disciplines of engineering. My role in this faculty is as the Associate Dean, Learning and Teaching. My work spans across the schools of the faculty in the areas of curriculum development, governance and accreditation, teaching quality, and student experience. I undertake this role with a focus both within the faculty and through connecting with the Associate Deans, Learning and Teaching from other faculties.

In Australia degrees that lead to the outcome of Professional Engineer are externally accredited by a professional association, Engineers Australia. The accrediting process includes five-yearly visits from a panel made up of both academics and industry representatives. Accreditation includes processes such as mapping of curriculum, review of assessment design and grading, meeting with groups of teaching academics and students, and touring the facilities of the university including laboratory spaces. The external professional accreditation is aligned to an international agreement, the Washington Accord, which leads to the portability of graduates' degrees in over 20 countries including the United States, United Kingdom, Canada, Japan, and South Africa. Engineers Australia accreditation is governed by a formal policy statement: the Accreditation Management System (Engineers Australia, 2019). The accreditation for qualifications leading to recognition as a graduate Professional Engineer is aligned to the Engineers Australia Stage 1 Competency Standard for Professional Engineer (Engineers Australia, 2013).

As well as maintaining the systems for international accreditation, Engineers Australia is a national association with professional membership and recognition beyond graduation through Fellowship and Chartered status. It provides a professional community with local committees for both disciplines of engineering (such as the Civil Engineering College) and for other cohorts such as engineering students, young engineers, and women in engineering. While there is encouragement for academics to become members and to achieve chartered or fellowship status with Engineers Australia, it is not a requirement of the accreditation process.

The undergraduate engineering degree program offered in my faculty is a Bachelor of Engineering (Honours), a four-year embedded honours degree designed to meet the requirements of the Australian Qualifications Framework Level 8 (Australian Qualifications Framework Council, 2013). This is the standard for Australian engineering degrees accredited by Engineers Australia to achieve Washington Accord status for a Professional Engineer. The degree structure includes foundational core units undertaken by all engineering disciplines as well as a defined group of units that achieve a named major, such as Civil Engineering or Mechanical Engineering. There are nine majors shared across the three engineering Schools. There are also various double degrees offered with the Bachelor of Engineering (Honours) which involve five or more years of study and the award of two qualifications at the end.

4.2.2 Participants

To understand the discourses operating within the academic community that teaches engineering in my institution, I purposefully sought out academics from across the disciplines, schools, levels, and roles within my faculty. A degree program at my institution is known as a Course and in the case of the engineering course, it is made up of Study Areas or majors which represent the different disciplines of engineering on offer. There are leadership roles for Course and Study Area Coordinators.

My participants consisted of 15 colleagues who spanned the disciplines offered in our undergraduate engineering course. They came from a range of academic levels (from Lecturer to Professor) and all but one were ongoing or contracted full time academics. Thus, they are education and research academics, some of whom were also Course or Study Area Coordinators. While I did not explicitly collect information on their current role balance, in my institution academics are most often working between 20 and 60% in education, between 20 and 60% in research, and have a 20% allocation to a service, leadership, and engagement activity, which includes Course and Study Area Coordination. Of the participants three were women and twelve were men. The ethnic background of those I interviewed included people from South Asia, China, Europe, the USA, and Australia. Some of those from Australia had studied as undergraduates at my institution. My analysis makes no attempt to make claims about the influence of gender or ethnicity on responses generated through interviews, but it may be inferred that there are likely intersectional influences from participants answers. This mix is reflective of the mix of academics within my faculty.

As well as any course or study area leadership role, each of my participants have been Unit Coordinators, responsible for the offering of a unit of study within the Bachelor of Engineering (Honours) degree. Cohort sizes in units in engineering vary from over 1000 students in first year, foundational units through to approximately 40 students in the advanced classes for smaller majors. The responsibility of a Unit Coordinator thus varies across the detailed design of content, assessment, learning resources, online learning experiences within the institutional Learning Management System, and on campus learning experiences. Alongside this they may manage a teaching team in larger units along with student queries and the administration of marking, grade finalisation, and reporting. Each semester, student evaluation feedback is sought for each unit of study, incorporating questions related to the unit and to those teaching within a unit. There is an expectation that unit coordinators will engage in a range of quality assurance processes, as members of a team of coordinators teaching in a study area/major and degree and through reviewing the student evaluation feedback.

I describe these functions to provide a picture of the activities that academics at my institution engage in as part of the educational aspects of their role. With each of my participants I have an existing collegial relationship. I encounter them in governance meetings, in management meetings, in activities to prepare for professional external accreditation, and in reporting and collaborative documentation for either university or external curriculum approval. I have led academic development workshops and seminars for the academics within the faculty including those who are my study participants.

I have formal positional power over curriculum within my role, which means that my participants have all engaged with me in requesting approvals for unit, study area, or course curriculum changes. On the flip side I also advocate for and represent curriculum development proposals from my faculty within the governance processes beyond faculty level, sometimes sitting alongside these colleagues in meetings with academics and leaders from other faculties and the centre of the university. I have been a member of the teaching team in units that some of my colleagues' coordinate, particularly undertaking lectures and assessment design. For some I also collaborate on engineering education research and collaborate as part of volunteer roles with professional associations.

Outside these formal interactions, I maintain an open and collegial relationship with most of them. Some of my participants catch up for coffee, we seek out advice from each other about educational challenges and attend conferences or dinners together. We see each other as we go about our roles on campus and interact in ways that mostly focus on work, but sometimes include small personal and social conversations. I note this about my interactions with participants to show that, although this study reports on semi-structured interviews, those interviews come within a relationship where there is already a rapport, a context in which initial awkwardness due to formality quickly fell away and became a continuation of conversation, albeit a more focused one around a topic that we may not have otherwise discussed.

4.2.3 Interview Data Generation

I generated data from my participants using semi-structured interviews. The interview protocol is reproduced in Appendix 1 – Interview Protocol. Following confirmation of ethical approval for the study interviews (via the Faculty of Arts and Social Sciences and Management School Research Ethics Committee, Lancaster University), I purposefully approached colleagues via personal interactions or email to ask if they would be willing to take part in my study. I chose participants to ensure that I had a mix of academic levels, engineering disciplinary background, year level of teaching, and experience as an educator. I also chose those with whom I had some form of relationship through our work. I shared with them the Participant Information Sheet and asked for their consent via the participant consent form (see Appendix 2 – Participant Information Sheet and Consent Form). As noted in the protocol, interviews were structured to begin with broad questions about what participants taught and what view of professional engineering informed their teaching. Questions then moved on to ask participants about gender, about pedagogy and about their perceptions of student responses based on gender. Finally, participants were asked to reflect on why a lack of gender diversity remained within engineering and what they had considered about responsibilities for addressing that challenge.

All interviews were conducted online, via Zoom, and recorded. At the start of each interview, I reminded participants that I would be recording and transcribing the interviews. Interviews lasted between 30 minutes and just over an hour, with an average length of 45 minutes. The Zoom platform has an automated transcription system. I took the text output from this system and then reviewed the sound myself to correct numerous errors. In this transcription, I only recorded the words spoken and did not attempt to log pauses. I attempted as much as possible to keep all words spoken in the original audio including repeated words. There was only one interview where some audio was obscured. The transcripts were then entered into Nvivo, for the purposes of analysis. The process of correcting the transcription caused me to engage with participant responses in some depth, forming the first step in my analysis.

4.2.4 Reflections on the Interview process

As I noted above, all those that I interviewed were colleagues, who I work with in the course of my academic work and theirs. In early interviews, I felt quite stilted in commencing the conversation with colleagues due to the artificial nature of the conversation and the recording on Zoom. In listening back to the transcripts, I can hear the way in which I deliberately formalised my voice in the early parts of the interview. However, as each interview progressed and as I undertook more interviews, I became more relaxed into the context. My participants mostly seemed also to be relaxed which somewhat surprised me in the initial stages, but on reflection, I suspect that they were all aware of my keen interest in both engineering education research and in the lack of women in engineering. This is something that I have spoken about in other contexts, including in faculty meetings and Town Hall events. I felt that they could not foresee any difficult conversations, as they too consider themselves to be committed to developing both the engineering profession and gender diversity.

I deliberately chose early questions that would be easy for my participants to answer about what they taught and their approach to teaching. These are conversations that we have had before in curriculum development workshops or processes around course governance. Some lapsed into informality quickly, using phrases such as “well you know me, Karen” or reminding me of other times when we had spoken about pedagogy or curriculum design. Some adopted quite a reflective approach to my questions but others expressed surprise or took some time to consider what their answers might be. In the questions about gender, I had wondered if some might be nervous to respond to me or unsure about talking about their thoughts and perceptions. I found that most began their responses with phrases that indicated a sense that they were “on side” with changing towards greater gender diversity. I had wondered if I would encounter some views that were openly misogynist or sexist and prepared myself to address these calmly. As it transpired, no-one was so outwardly negative in this way but almost all (including the women) reflected a view of gender as being binary and somewhat deterministic, as I show in the analysis in Chapter 5.

Most interviews felt as though they went quickly for me, and I had to deliberately hold myself back from jumping in too quickly in the conversation, given my familiarity with the participants. I tried to stick to the questioning I planned but found that in some cases it was more fruitful to follow a line of conversation that jumped around a little and then go back to probe other questions. I also found several of my participants had ‘prepared’ for the interview, in that they had read the participant information sheet and guessed at what I might want to discuss. Others felt ill-prepared due to not having “done any research”, a topic I return to in my analysis in Chapter 5. Some participants also drew from their experiences beyond being in academia, particularly relating to their own children or their own journey in engineering education, even reflecting on childhood or school experiences. Overall, the experience of generating data through interviews was one that I found enjoyable. To have the time to talk deeply about a topic with individuals is rare in the course of our daily work and there were occasions of amusement alongside the serious discussions.

4.2.5 Interview Analysis

In seeking to uncover the variation and extent of academic perceptions through interview data, I analysed the interviews as a pooled set. I was not seeking to ascribe a category to individuals but rather to identify themes and categories across the participants. Analysis of the interview transcripts was a two-stage process. In the first step I read and re-read the interviews to look for interpretive theming of the overall text. I had no preconceived structure other than identifying the concepts of interest: gender, students, engineering knowledge, learning, teaching. I highlighted quotes from the interviews that linked to these broad themes and then read the collection of quotes across those themes looking for links, similarities, variations, and contradictions. My first categories are listed in Table 1.

Table 4.1 Initial thematic categories

Broad Category	**Sub-category**
Gender	Not relevant Determinant of ways of acting, agency or capability Determinant of experiences
Engineering	Maths, science, computation, simulation with one right answer. Technical knowledge, fundamental theory. Design/problem solving focused on application of technical knowledge, calculations. Design focused on systems thinking, stakeholders, clients. Human centred practice, incorporating ethical commitments and responsibilities including sustainability. Not a trade! Hard work, on site, long hours.

Broad Category	Sub-category
Engineering education	Content, domain of knowledge to be imparted. Teaching choices – traditional, lectures, tutorials, laboratory/practical classes. Teaching choices – active, student centred, videos, demonstrations. Student experience, including group work. Student engagement, presence, enthusiasm.
Context	Narratives and stories. History. Pathways, past experiences. Marketing. Culture.

I then engaged in a process of reading and re-reading again with a view to developing relationships between the themes, highlighting variation and similarities, always recording quotes that were of interest. During this time as I was reviewing the words of my colleagues, I engaged in a process of reflexivity by recording my thoughts within a research journal. I asked myself questions and explored multiple pathways before converging towards the categories that form my results in Chapters 5 and 6. I recorded my methodological and analytical decisions alongside personal reflections. As a sole researcher I sought to use this as a tool to provide trustworthiness in my research outcomes (Nowell et al., 2017).

I engaged with a trusted colleague, a retired education academic and friend, explaining my thinking and testing my ideas. After interviewing all my participants, I asked my colleague to use the interview protocol and to interview me as a way of capturing my own beliefs, values, and reflections. This was not included in my analysis but provided another avenue for reflexivity. I spent time with my supervisor discussing my ideas, always sharing quotes from my participants. Neither my colleague nor my supervisor knew any of my participants. This articulation of ideas out loud to others was a key part of converging to my research results and the model created within this thesis.

There are also limitations to my method and approach. While I explicitly engaged others in my thinking, they were not engaged in confirming my interpretations and findings through systematic review of the full interview transcripts. My study is constrained to my own context and I can make no claim to generalisability. The data on which I have drawn is limited to the interview transcripts and my own reflexive notes. To further explore this framework, I could have looked at the curricular artefacts that academics created or observed their teaching and learning practice. However, I leave these for future investigation and present my analysis with a recognition of that limitation. Nonetheless it makes an original contribution to the investigation of one aspect of gendered disciplinary knowledge practices in engineering education, that is, academic perceptions of gender and of engineering knowledge in relation to the curriculum.

4.2.6 Representation within this study text

In this final section of the chapter, I outline the ways in which I have represented my participants in the next chapters. Because they are colleagues, when I report on their interviews, I have allocated them a number so that they are not identifiable. Thus, quotes are attributed to P1 through to P15. Within quotes I have removed obvious identifiers of their engineering discipline and do not differentiate their gender, ethnicity, or academic level. This coupled with the pooling of data for the purposes of analysis protects the identification of individuals and is in alignment with my overall methodological positioning. That is, my interest is not in ascribing perceptions to individuals but rather to uncover the habitual and encultured practices that are shared amongst a local disciplinary community.

4.2.7 Secondary data and analysis

Alongside the interview data generation, I collected secondary data that reflected the influence on disciplinary knowledge practices in curriculum of the engineering profession. Bernstein refers to this as the "external field of practice" and recognises the role of professional bodies in "setting standards of practice" and accreditation (Bernstein, 2000, p. 55). In the case of this study, the secondary data of interest came from Engineers Australia, the professional body that accredits engineering programs in Australia. I also looked toward the Board of Professional Engineers, Queensland (BPEQ), "an independent statutory body" established under legislation: *Professional Engineers Act 2002 (Qld)* ***(***Board of Professional Engineers of Queensland, 2013***)***. While graduates cannot be recognised as Professional Engineers under the Act until they have undertaken some years of experience, it is nonetheless an important part of the career pathway for engineering graduates. I analysed a range of policy texts, including standards and reports from Engineers Australia and definitional notes from BPEQ as a way of looking further into the "official recontextualising discourse" that is another contributing factor in the pedagogic discourses developed in this context (Singh, 2002).

My analysis took the form of a discourse analysis of the texts in relation to their context and with a particular view to apprehending their approach to (re)producing gendered disciplinary knowledge practices within the engineering profession. Policy reconstruction of this kind can serve to illuminate the “relationship between agency (or individual responses) and structure” in educational practices (Fanghanel, 2007). Placing this analysis alongside that of the participant interviews provided a richer picture of the disciplinary knowledge practices in operation within this context.

4.3 Conclusion

In this chapter I have framed my methodological positioning alongside a detailed description of methods, data generation, participants, and analysis approach. Through this articulation I have framed my analysis as insider research, with a purposeful approach to reflexivity designed to ensure that the research outcomes can make an original contribution to research in this domain. In the next two chapters I share detailed analysis of the participant research interviews, drawing together those outcomes into a descriptive framework in Chapter 7, before providing recommendations for changing practices in Chapter 8.

Chapter 5: Ways of perceiving gender and engineering education

This is the first of two chapters in which I present the findings of my analysis of interview transcripts and of policy documents that inform engineering curriculum. In this chapter, I begin with the presentation of categories of perception that emerge from interview transcripts showing the way academic participants think about gender and engineering as it relates to their teaching.

Some of these perceptions also result in beliefs about students, and these are outlined in the second section of this chapter. In the final part of the chapter, I contrast this with an analysis of a policy document from the professional accrediting body, Engineers Australia reporting on women in engineering. My purpose in exploring these perceptions is to answer one of my research questions: *What are academics' perceptions of gender and engineering education?* In Chapter 7, I consider the implications of these perceptions for the contribution of educators to pedagogic discourses and gender regimes. These structure the identity positions that can be negotiated by students.

5.1 Categories of perception: gender and engineering education

While I have approached this study with an understanding of gender as "something that we do and are done by not something that we are" (Mendick, 2006, p. 10) this is not the everyday way in which people often think about gender. In this first section of my research findings, I explore the range of ways that participants in my study perceive of gender, within the context of their teaching in engineering. These perceptions are connected to their perceptions of what engineering is, as it relates to their teaching, which I will explore in Chapter 6.

Analysis of the pooled interview transcripts revealed five categories for understanding gender and engineering education. Individuals are not aligned to categories, rather participants often moved between categories in their interviews. The categories are:

1. Gender as not relevant in engineering education as everyone is unique.
2. Gender as not relevant in engineering education as engineering is neutral regarding gender.
3. Gender determines how people behave and what capabilities they have in engineering.
4. Gender determines people's self-concept as engineering students and engineers.
5. Gender is a mediator of experiences in study, work, and the world as an engineer.

These categories are not about gender in general but specifically about gender as it relates to engineering and engineering education. The following sections explore these categories and provides examples from transcripts to illustrate the category.

5.1.1 Category 1: Gender is not relevant as everyone is unique.

> *"I don't think so, I think, yeah, a mixture. I think it's very individual."* (P11)

While the appearance of this perception was isolated to one of the participants, I have included it here for completeness to reflect the full range of categories of perceptions. This perception was a response to a question about whether the participant thought that there were differences in the ways in which women and men in engineering experienced teaching and learning.

This perception aligned with seeing individuals as overseeing their own choices, exercising agency in the ways they navigated engineering study which were unique to themselves. In this category, the context of engineering was also not relevant, since the focus is on people being unique, regardless of context. As P11 noted:

"*It's all about the individual quality state process.*"

Responses in both this category and Category 2 reflect a position that gender is understood to have no relevance to experiences in engineering education.

5.1.2 Category 2: Gender as not relevant because engineering is neutral.

"I don't think there's a difference in gender. I think you have to be a type of person who - to want to do engineering, which is that sort of thirst for wanting to know how things work, wanting to know how the world works." (P3)

In contrast to Category 1, this category was prevalent in participant accounts. It was associated with the idea that engineers are a particular type of person and that these characteristics are what attracted students to study engineering in the first place. These characteristics included being "*really good analytical thinkers"* (P7) and having an interest in science and mathematics.

"I think engineering is attractive to a certain type of person, a person that is perhaps interested in scientific methods and science, and maths and these kind of things more generally with the more sort of pragmatic view towards their career, and where their studies, can take - where their studies in science can take them to be successful." (P13)

It coincided with a view of engineering as being about engineering science, “technical” knowledge, and that those who study it are attracted to and have a strength in this area. As I will show in section 5.2, this contrasts with the ways in which participants spoke at other times about the different choice pathways that men and women take into engineering. This category aligns to a view of individual agency in determining pathways into and through engineering. Responses within this category obscure the views of participants on the nature of gender, since it is quite literally seen as not relevant to the discussion.

Responses in this category occurred alongside a reluctance of participants to comment or answer questions about their perceptions of whether gender made a difference in engineering, often justified by having “*not done any proper studies on this”* (P4). In contrast, participants were confident of the engineering knowledge that was relevant to their teaching context.

5.1.3 Category 3: Gender as determining capabilities and behaviour.

“I think certainly my experience going through an engineering degree as well, it's very anecdotal, but I would say that the maths ability of the girls tended to be better on average than the men.” (P11)

In this category of perceptions, participants noted the differences they had observed in the behaviours of women and men in their classes and explained them in terms of their different capabilities. This was not confined to only commenting on strengths but also on areas where men were lacking, although participants rarely suggested a lack of capability in women. The nature of these differences will be explored further in section 5.2.

In describing different behaviours, responses in this category started to include descriptions of engineering as incorporating both “technical” and “non-technical” aspects, an expanded view of what engineering is. The context for responses in this category was both broad descriptions of women and men as students as well as the roles they undertook, particularly in project-based assessment. There were some responses in this category that suggested that the social environment of the classroom influenced the way these gendered behaviours emerged. For example, P5 in describing a group assessment project where students must take on different roles in the team, suggested that the men negotiated taking on roles that were more focused on engineering calculations as they were *“very sciencey or tech oriented”*, whereas the women were more likely to take on the role of project manager, coordinating the work of the group. P5 suggested student groups negotiated this role distribution with shared assumptions about which students had strengths aligned to roles.

Like Category 2, participants were guarded in being definitive around the differences in women and men due to a perceived lack of having done or seen empirical research:

“You know I don’t have stats on that. But it’s my perception through my lens of bias, isn’t it?” (P5)

They nonetheless stated observations of various behaviours and capabilities that they saw in women students that were different to men students. Most participants shared responses within this category despite coming from very different disciplines within engineering, from medical engineering where there are roughly equal numbers of women and men through to electrical engineering where the percentage of women is less than ten.

I interpreted these responses as reflecting a fixed view of gender. Women were seen as distinctly different to men in their capabilities and behaviour. When prompted about whether participants had experienced any people who were non-binary or who did not fit into the categories of woman or man, most suggested they were aware of such people existing (in the world) without having ever experienced this within their own classroom environments.

This category is closely aligned to the next, and in section 5.2 I will explore more of the details of the positioning of women and men in these perceptions.

5.1.4 Category 4: Gender as determining self-concept.

"*Probably not. I would say, I know a lot of students speak about, you know, imposter syndrome or feeling …. and that generally tends to be female students.*" (P1)

I have used the term "self-concept" in this category description, not to link it to its meaning within psychology but rather the more everyday meaning of how one thinks or feels about oneself, what motivations, interests, and concerns determine choices and actions.

In this category, participants speculate on the differences in the way men and women in engineering feel about their strengths and interests. While linked to the previous category, I have separated out this category as it goes beyond statements of the observation of behaviours to ascribing to students different motivations, interests, and concerns. I show in later chapters how this can lead academics to suggest solutions to the “problem” of women in engineering which seek to align to the self-concept assumed of women.

As in Category 3, engineering is viewed as incorporating both “technical” and “non-technical” aspects. This category includes the potential for engineering to make a difference in the world. This purpose is seen to align with a different self-concept in terms of values and motivations. For example, P7 suggests that women are naturally “*altruistic, more people oriented”* whereas P12 says “*the men are probably a little bit more interested in getting the degree and maybe making money”*.

In this category, participants are more likely to give responses that mention macro socio-cultural contexts rather than linking these views to the local social context of the classroom. They suggest that women and girls see themselves as being more caring and aligned to humanitarian commitments. “Doing” gender may not be such a fixed concept aligned to identity but may be influenced by social relations within engineering. Ways of being a woman or man within engineering shift over time. P2, for example, notes that in the early years of the engineering degree “*often there are groups of female students, you know moving together*”. They note that this is because of a perceived discomfort in being in such small numbers within the cohort. P6 notes that in the final years this has changed, explaining that:

> *“ … so a lot of that gendered - gender stress for want of a better - I can’t think of a better way of it - engendered-ness issues, a lot of it just goes away not completely, but it, to a certain extent becomes mostly, a non-issue, I think.”* (P6)

Nonetheless, there is a sense in these responses that individuals are exercising choice in navigating a pathway through engineering study which aligns with their self-concept and that this is different dependant on their gender. This is not seen as a negative but rather an opportunity for individuals to follow their interests.

5.1.5 Category 5: Gender mediates experiences of engineering and engineering education.

"I think, women are more likely to receive either some form of assault or unkind behaviour potentially from male colleagues and even sometimes female colleagues as well." (P10)

This final category was rare but is included to create a complete picture of the possible perceptions that were revealed. In this category participants suggested that rather than observing differences between men and women related to behaviours or self-concept, they noted that those who presented as man or woman were treated differently by both academics and other students. Mention was made of the implications for women, for example, in "*the way they fit in with their team members"* (P2) and whether they would be accepted within the classroom culture.

Men participants reflected also on their own "*position of privilege*" (P8) recognising that their views were perhaps accepted or carried weight due to aligning to the dominant gender. Others noted that women experienced challenges due to their smaller numbers. For example, P10 suggested that when walking into a large lecture theatre, it could be daunting as a new student, "*but can you imagine if I was female walking in the door, seeing all the faces and then seeing, I can only see five female students in the whole room."*

These responses were more likely to be connected in participant responses to macro socio-cultural influences, linked to the experiences of girls and boys, and women and men in everyday contexts where stereotypes mitigate what is perceived as being acceptable and constrained individual agency:

"I feel like it's down to the culture that we live in, unfortunately, and I think, even from such an early age, you know you have even kids toys you've got the segregation between even something like Lego which I feel like everyone can enjoy. But then you have like the Lego and then the Lego Friends, which is you know the pink and the purple and there's a horse and you know, like I don't know why that needs to be that separation. So I feel like some of its just implicit and ingrained and then you know you go through school and then by the time you get to high school and you're starting to think about your career that's just the biases from society." (P10)

Some of the participants had worked in engineering industry prior to returning to academia and articulated the experiences of women engineers who had to "*justify why you're there, and what your role is, that you're not the secretary, that you're not the cleaner that you're an engineer."* (P11). There was recognition that this resulted in many more negative experiences for women that constrained their choices or made them feel at the very least uncomfortable and in the extreme case, be subjected to harassment and discrimination.

In this category, gender is not defined as a fixed characteristic of people but rather as something that other people infer and as a mediator of experiences. In a similar way, participants did not directly discuss the nature of engineering when describing mediating experiences but they were more likely to connect to the world beyond the classroom, either in terms of a macro context or the experiences of engineering practice. However, mention was made of external perceptions of engineering as being aligned with men and masculinity:

"What do high schoolers see coming into the profession? Their understanding of what engineering is and perceiving that as a gendered profession - there's still effort to be put in there, that people see that engineering is a job for males and females, but somehow they still think that the job involves - I don't know somehow making stuff and that's a male thing to do?" (P6)

5.1.6 Summary: Perceptions of Gender and Engineering Education

The five categories reflect variations in the ways that participants thought about:

- Knowledge, engineering knowledge, and whether engineering knowledge is thought to exist separately to the people who become engineers, whether engineering is thought of as being primarily "technical" knowledge (that is engineering science) or whether it could be seen to encompass more. Further, the purpose or outcome of engineering shifts from an instrumental view of technical problem solving through to making a difference in the world.
- Explanations of the social world, which range across a spectrum from agentic explanations, through recognising the influence of the local social context or further to a recognition of macro socio-cultural influences.
- Gender as a fixed characteristic of identity and with a fixed binary classification, gender as fixed but with variation within genders as well as between them, through to gender as being a social and relational construct, dynamically generated and performed within practices, and changing over time.

In summary, the interview transcripts revealed variations in the ways in which academics conceived of gender in relation to engineering education and connected to the professional context. These categories of perception have implications for both the decisions that academics make about learning, teaching and assessment, and the ways that they might act to change the gender balance within engineering. Given that in the first four categories gender was either seen as not relevant or largely fixed, these perceptions lead to considering solutions that focus on either fixing women or presenting a picture of engineering that will promote engineering to the perceived capabilities and interests of women. In the next section I explore the ways that women and men have been positioned differently in engineering in participant interviews.

5.2 Women and Men as Student Engineers

In section 5.1, I showed two categories of perception about gender and engineering education that were linked to having a fixed view of gender identity. In these categories gender is seen as being a determinant of behaviours and capabilities (Category 3) and self-concept in terms of motivations, interests, and concerns (Category 4). In this section I will explore in more detail the ways in which those fixed views translated into perceptions about women and men and explore the distinctive binaries that emerged.

5.2.1 Women are capable and social, but not always confident.

"I haven't paid attention too much to it. I haven't overly focused on it. I would say that I've noticed the female students do a lot better in the project management side. When they are in those groups. I do, I have noticed that, but I haven't sort of taken any statistics of it. It's just generally when they - because part of the milestone assessments, we asked them to provide their project management documents. And

often when I mark those documents, they're you know, nicely detailed, well organised, and yeah, and that tends to, I believe, when there's more female teams or teams with females in it that comes across." (P3)

The quote above from P3 was typical across several participant responses in a hesitance to speak categorically, accompanied by statements of belief about women in their classes. Throughout most interviews, participants commented that women students were organisers, project managers, and effective communicators. In project work women were perceived as being naturally good at organising their teammates and being comfortable in social situations. While project management is an identified knowledge area in engineering, P5 suggested that for students sometimes "*I think that role is somewhat seen as a secretarial role. You know that person is maybe taking the minutes"*.

Participants also believed that women were more likely to be academically capable than men. P13 who teaches in one of the engineering disciplines that has a higher proportion of women noted that even within that context, "*of my very high performing students, I would say that women are disproportionately represented, highly represented, I mean*". Women were also seen to be more effective and capable at seeking help or drawing on resources to support their study. P8 noted that women "*made better use of the resources available to them"*.

Within an assessment task, P5 incorporated a requirement for journalling of critical reflections on the progress of the project and the way students' project team was functioning. P5 suggested that this task, which requires engagement with personal feelings and motivations, is something that women are more comfortable with and take "*quite seriously"*. Women "*are much more likely to identify a problem and talk* *about it"*. Men, on the other hand, were much more likely to suggest "*there are no problems in our group and everything's great and why are you making me do this?".*

Alongside these strengths and capabilities of women, participants often mentioned differences in the self-concept of women students. Most suggested that women seeking help more was likely a result of lower confidence in their capability but P6 believed that women were nonetheless confident in their choice to enter engineering.

> *"In engineering, I think, often for a female to have entered engineering in the first place, they often fall into the more confident category to start with. It doesn't necessarily mean that they're - they have more intrinsic understanding of the area. That may not always be true. But they're generally sort of a bit more confident to tackle something because they're doing something that is not traditionally seen as a female-focused profession."* (P6)

This idea of women making a conscious choice to enter engineering was consistently mentioned across the interviews.

Despite making this conscious choice, some participants also noted that experiences within engineering education might lead to women being more likely to experience imposter syndrome. P14 wondered if this was connected to the propensity of women to ask more questions and seek out help. They suggested that there were likely men who had similar questions or concerns but who were less likely to be seeking out resources and asking questions in the same way.

Women were described as more caring, empathetic, and attracted to the more altruistic or humanitarian side of engineering. This was postulated by several participants as the reason why there were more women studying medical engineering:

"I think there's potential for those sorts of differences in and you know, perhaps a reason also why, you find, you know, many more women in medical engineering and disciplines like that compared to others, because they're driven more by wanting to do things that are - beneficial is not the right word, you know, because building a bridge is also beneficial to society, but it's somehow a very direct impact on people's health and wellbeing that seems to attract." (P5)

This notion is echoed in a slightly different form in an Engineers Australia report on Women in Engineering, which suggests women are "more likely to be influenced by desires for fulfilling work, making a difference, and a career that aligns with their hobbies, interests, and personality" (Romanis, 2022).

In summary, when gender is seen as a fixed part of identity, women are seen as capable, organised, and good communicators and as having a greater alignment to values of altruism and humanitarian impact. These are characteristics of self-concept and competencies that are valued in engineering but are firmly connected to the "non-technical" aspects of engineering and to the Engineers Australia competency domain of Professional and Personal attributes. These will be discussed further in Chapter 6.

5.2.2 Men are confident, independent, and comfortable.

"Yeah. I'm just thinking whether communication is another thing where I tend to see a lot of our female students, particularly higher performing in, than the average you know and maybe that has to do with, you know, the sorts of individuals that come to

engineering. In males are typically, your very sciencey or tech orientated, you know. It's maybe the little bit clichéd, you know, back room engineer, who's, you know, happy to do the calculations and the tech or whatnot, but not so happy out in front, giving the presentation" (P5)

In contrast to the way in which women are seen, men in engineering are perceived as having a wide range of capabilities but almost always focused on the "technical" aspects of engineering. As in this quote from P5 these are more often presented as engineering skills, not generic skills, even if they are those of a "*back room"*. This association between men and science, technology, and engineering is suggested as a reason why "*it is much easier for men to fall into engineering"* (P12). In contrast to the over-representation of women in high-performing and academically capable students, there is according to P12 a "*long tail"* of men who continue along regardless because they are comfortable in the context of engineering education.

At the same time, men are seen to navigate a path through their education that lets them take up more "technical" roles rather than being more "social". In contrast to women students who are organised and ask questions, P3 notes that in their group project:

"*male students kind of just play it by ear. And that doesn't really work with a design type of unit, where if you don't manage your time properly - you can't leave it to the last minute. If you leave it to the last minute things are not gonna work."*

In the project-based task set by P5 each student must take on a different engineering role within the team. P5 notes that men almost always take up the role of concept developer, which is seen as being the inventor or creator of ideas, in contrast to women taking up the role of project manager. Each role within the team is supposed to lead a particular area of work but "*the idea of the role is not that you go away and do all of the work associated with that role independently, but rather you harness the rest of your team to help you complete that role*". However, P5 notes that the men who take on concept development often "*push their own ideas":*

"And I think a lot more males are comfortable to sit back within their domain and you know, "allocate me my task and I'll do those and deliver them back but forcing me to talk and interact with everybody" is more towards outside their comfort zone."

P3 also suggests that "*male students overestimate their abilities, and I think the female students underestimate their abilities"*. For P3 this is a positive attribute of the women because it means they get on top of things early but it also suggests that men will maintain the confidence in their choice of engineering and likely success despite any small setbacks. P7 suggests that this confidence results in "*some push back from some of the males, …. and you could see that in some of the bravado of the male groups"* which occurs when students first encounter topics related to the need to move beyond "technical" knowledge and, in this case, to discuss the benefits of diversity in engineering teams.

Men are ascribed as having different motivations in entering engineering. P12 suggests men are driven by having a good career and making money rather than the more altruistic motives of women, who want to make a difference in the world.

5.2.3 Implications of the binaries: woman/man

Drawing together the findings presented in this section, I have explored a field of binaries that underpin perceptions about gender and engineering education. They include:

- Woman/Man
- Professional skills/Engineering knowledge
- Caring/Career
- Collaborative/Independent

I explore further binaries in Chapter 6 regarding engineering knowledge. Together these binaries influence the spaces for women to feel as though they belong within engineering education.

5.3 Gender and engineering: perspectives from the profession

In this section I explore findings from the analysis of a policy document produced by the professional association Engineers Australia. I show the ways it aligns to the perceptions about gender illuminated in the previous sections. As well as the body that accredits curriculum at universities, Engineers Australia is "the national body for engineering", supporting "the engineering profession in every capacity" (Engineers Australia, 2024).

In 2021, Engineers Australia commissioned an external market research company to report on "Women in Engineering". The subtitle of the subsequent report is "*Identifying avenues for increasing female participation in engineering, by understanding the motivators and barriers around entry and progression" (*Romanis, 2022). The report seeks to provide a framework for action for the profession to "cause" more women to choose engineering as a career. While not explicitly explored within the report, the assumptions that can be read from this document are that gender is a fixed binary – women and men are different in ways that can be measured and quantified. The difference between women and men that is evident in the document is in alignment with Category 4 of the perceptions seen in the interview transcripts: that gender determines interests, motivations, and self-concept. This is particularly clear in the first section of the report regarding entry into engineering. This incorporates reporting on a survey of women and men in engineering and women in non-engineering 'benchmark' fields. The primary conclusion is that women and girls are "driven" to choose careers that are "impactful", "fulfilling", and "exciting", adjectives that are not associated with engineering. Thus, the report concludes, to attract more girls and women to engineering "we can determine what perceptions need to shift, to better align engineering with the motivators that matter".

In the final section of the report, which explored experiences of women and men in engineering, explanations for why women leave the profession are reported as being about a lack of equal opportunity, experiencing bullying, and an overall negative workplace culture. While this might suggest a shifting perception of gender toward Category 5 (gender determining experiences), one of the proposed actions to mitigate these experiences is to "empower women to progress their careers and to navigate the challenges faced in the workplace", that is, to place the onus onto women to enhance their self-concept and 'power' through their careers. The call to action seems to be that we must 'dress up' engineering and bolster women's confidence and self-concept to shift the dial on the numbers of women in engineering.

This report alongside findings regarding perceptions of gender and engineering education, highlight a more complete picture of the so-called “double bind” (Saavedra, Araújo, Manuel de Oliveira, et al., 2014) that emerges from these perceptions of gender and of engineering, which provide constrained ways for people to be both a woman and an engineer.

5.4 Gender and Engineering Summary

In this chapter, I have shown the categories of perceptions of gender and engineering education that are operating within my research context. I showed the way women and men are perceived as different within two of those categories and connected this with the assumptions that seem to underpin a call to action to increase the number of women engineers from Engineers Australia, the national association of professional engineers in Australia. In the next chapter I will present the findings around perceptions of the nature of engineering knowledge and the purposes and outcomes of an engineering education and compare and contrast these with policy documents that inform curriculum in engineering.

Chapter 6: What is engineering knowledge?

In this chapter I explore the perceptions that participants have of engineering knowledge and of the purposes and outcomes of an engineering education. Exploring these perceptions accesses the way in which academics recontextualise the field of engineering within their curricula decision making and begins to illuminate the pedagogic discourse within this context (Bernstein, 1990). Alongside these perceptions of academics, I contrast the views of engineering knowledge and practice that are presented within the "official recontextualising field" (Singh, 2002) of the regulating professional association, Engineers Australia and the legislative body of my state: the Board of Professional Engineers, Queensland.

6.1 Perceptions of engineering knowledge

Analysis of the pooled interview transcripts revealed a set of five nested concepts in participant perceptions of engineering knowledge. Categories build from a core, with each subsequent category incorporating earlier concepts and expanding them. These concepts can be further grouped with the three at the core reflecting a view of engineering as being about "technical" knowledge. The five categories are:

1. **Engineering is science**, particularly physics and chemistry, and mathematics.
2. **Engineering is engineering science**, an application of fundamental sciences through abstraction of the real world requiring application of analysis, modelling, and simulation.
3. **Engineering knowledge is concerned with material engineering systems**, involving a complex material world where components of systems may be

described by different fields of engineering science but are brought together into a material, physical system. An example is an industrial robot or a building.

4. **Engineering knowledge is about relational engineering systems** and involves both a material and a social world. The social world incorporates clients and stakeholders as well as other people in the engineering team. In this view relationships with people matter to engineering.
5. **Engineering knowledge is concerned with moral engineering systems**. The social and material worlds that engineers operate within must incorporate moral accountability through ethics, sustainability, regulation and law, and financial accountability. In this view, being an engineer both carries a heavy responsibility but also has the potential to impact on the world.

The first three of these categories together form a picture of what is often described as the “technical” aspects of engineering or the “engineering knowledge” with the outer two layers often placed in binary opposition as “non-technical” or “professional skills”. As I show in the documentary analysis presented in later sections, this is reinforced within much of the official discourse around the profession both in Australia but also around the world.

The categories of engineering knowledge that emerged are represented in Figure 1. In the following sections quotations from interview transcripts will be used to illustrate the categories.

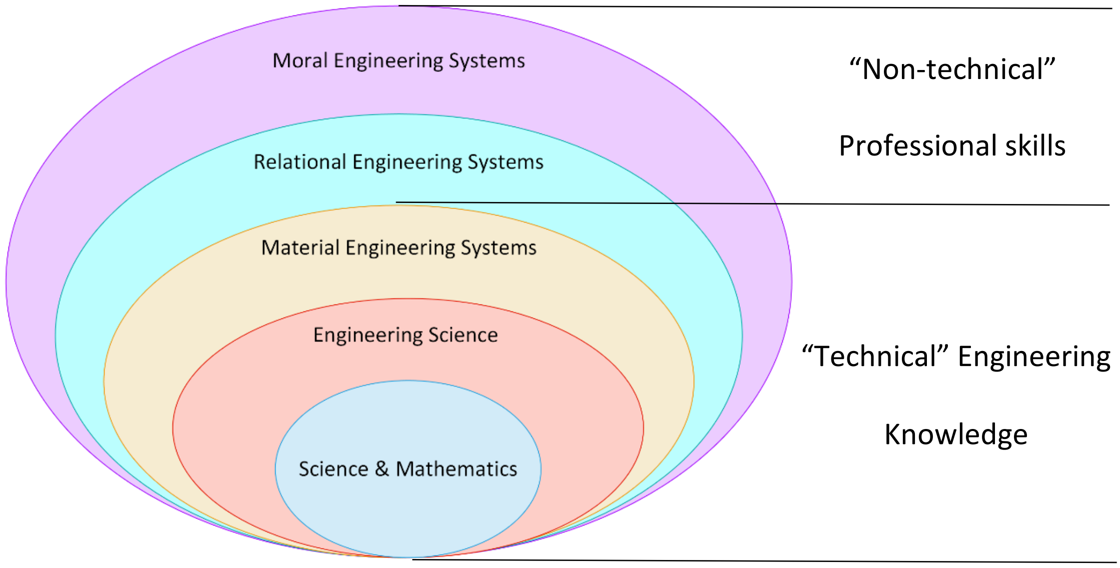

Figure 6.1 Describing engineering knowledge through nested categories of perception. The three central categories come together to be described as "technical" engineering knowledge with the outer two layers contributing the addition of the "non-technical" or professional skills to a view of engineering knowledge.

6.1.1 Engineering is science and mathematics.

"I'm going to teach you a bunch of maths, because it's really hard to learn the maths on the job, but it's super useful when you know it well, and it gives you an intuition that you would not have otherwise." (P8)

While none of the participants claimed that engineering is the same as science and mathematics, there were often responses that emphasised that fundamental knowledge of physics, chemistry, and mathematics is core to engineering knowledge. As inferred in the quote from P8 above, this was often stated with an understanding that in "industry" or engineering practice this knowledge would rarely be drawn upon in this fundamental form but was a necessary part of engineering curriculum. Participants emphasised that without this fundamental knowledge students would not be able to progress into other areas of engineering knowledge and would not be fully prepared to enter the profession. Engineering is a "*profession that relies on the fundamentals of math and sciences.*" (P2).

In this category, the focus of curriculum is on the pure abstraction of fundamental scientific concepts and mathematical formulations and relies on extracting the object of study out of the real world, with little mention or concern for the context. In all cases where the curriculum focuses on physics, chemistry, and mathematics in this way, the purpose or outcomes that engineering might have in the real world are not considered.

While this has been identified as a separate knowledge area, the boundary between fundamental science and the next category, engineering science, is not clear cut. For both the emphasis in participant responses was on "content" in the curriculum and on the requirement for this knowledge to appear early in the sequence of university study of engineering.

6.1.2 Engineering is engineering science applying analysis, modelling, and simulation to the real world.

"Yeah, there's a lot more theory on embedded systems, just learning content of what a sensor does, what a microcontroller does …… So there's a lot of just your basic or not basic, but a lot of just your engineering skills in the knowledge …." (P3)

In this category engineering science is related to fundamental science and mathematics but extends Category 1 in that it is applied to the analysis, modelling, or simulation of parts of real material objects. Participants described this as the knowledge that "*students need to have"* (P15) and connected it to the "content" of the curriculum. As curriculum moves into engineering sciences, participants also recognised the role of physical demonstrations or practical, laboratory experiences to support students understanding of this knowledge. For example, P12 talked about their subject as being primarily fundamental engineering science but attempted to "*get the students to understand that all this maths and application,* [engineering science] *is a model of a system, a real system"* by devising simple experiments in the laboratory.

While this is a category that begins the move into the real world, it still involves considerable abstraction. The physical or computational models that academics described using were often considerably simplified to remove real world complexity. An example of this kind of abstraction from my own teaching is shown in Figure 6.2 below, which is an image from class notes used to teach Engineering Mechanics. The sketch is an idealised drawing of a beam with loads on it and identifies some of the physical quantities of interest, including the slope of the beam. Any mechanical or civil engineer will recognise this kind of image but how it relates to a real beam such as those within house trusses or as part of a bridge deck is often absent from the texts and images used to teach engineering science and not easily inferred by recourse to the image alone.

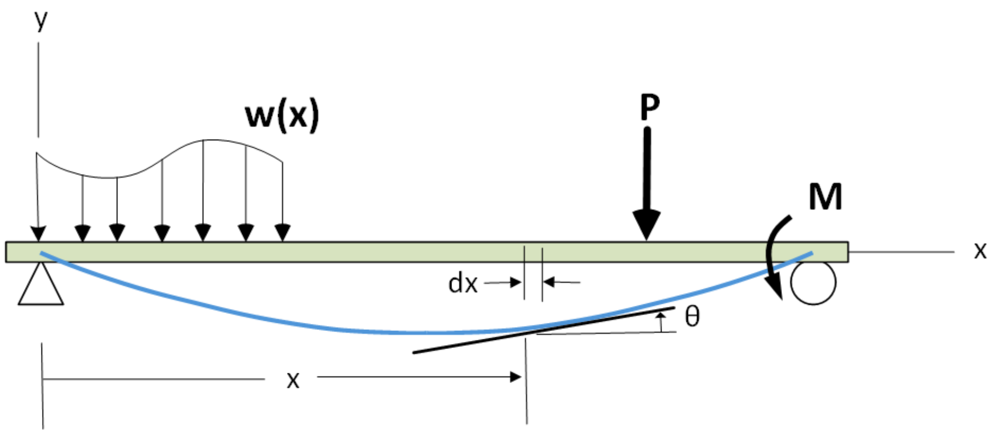

Figure 6.2 A loaded beam. This is an image used in the teaching of engineering mechanics, an engineering science.

In talking about engineering knowledge as engineering science participants similarly focused in on curriculum that was abstracted from the real world, separating out the object of study, and focused on material objects separate from people or society. Even when academics attempted to connect engineering science with "*something you might see as an engineer*" (P12), they found it somewhat challenging to do. As P12 noted "*it's not really required, because this is basically, this is how we do analysis on a very simplistic level.*" This knowledge area was almost always perceived as requiring early sequencing in curriculum, a necessary pre-cursor to any more complex knowledge engagement.

6.1.3 Engineering is about material engineering systems.

> *"We assign, or they have to choose a part of the product, a subsystem that we define. So, we say, this is the challenge, you have to build us a* [engineering system] *to do this and there's 4 parts of this* [engineering system] *that you need to build, and the milestones have set criteria that they have to meet for each different subsystem."*
>
> (P3)

This is the final category that falls within “technical” engineering knowledge. When participants described engineering in this way, it was almost always as part of a shift from fundamentals of science and engineering science into what is often considered a defining feature of engineering: engineering design. As I explore later in this chapter, the Engineers Australia Stage 1 Competency Standard for Professional Engineer identifies three areas of competency:

(1) Knowledge and skill base

(2) Engineering application ability

(3) Professional and personal attributes (Engineers Australia, 2013)

It is in (2) Engineering application ability that engineering design comes to the fore, as the distinctive engineering problem solving approach. Participants in this study described engineering of this kind as being able to take a complex material system and to break it down into its component parts, applying the relevant engineering science to each so that it could be designed to meet a technical functional requirement. P7 recognised this view of engineering knowledge as dominating in curriculum, while also problematising it as a limited view:

> *“It's all about the technical aspects and you've got to come up with the most innovative design, or the cheapest use of materials, and or the least amount of materials in a structure or something, when that's one part of the engineering solution.”*

This form of systems thinking in engineering was not always related to design in the form of creation of something new, however. P8, for example, suggested that overwhelmingly graduates were more likely to be working with existing systems and that applying this thinking to the maintenance or renewal of systems was more important in the curriculum. At the same time, the focus on maintenance or design of systems was in terms of its material functioning without mention of interaction with people or society.

In this category participants brought in real world systems into their teaching but removed a considerable amount of the context by focusing on technical functional requirements rather than any impacts on people, users, or social systems.

This category continued the connection to "content" in the curriculum. While being introduced in early years, sequencing of content in this domain often followed the fundamental science and engineering science knowledge. The implication from participant perceptions is that students must understand the building blocks before they can bring them together into a systems view of real-world complexity.

6.1.4 Engineering is about relational engineering systems, involving both material and social worlds.

"*When I say for humans, I meant that the design is inherently a human process. So, when we're creating methodologies to build things that's a process for humans. It's about how humans interact and carry out an activity - But in that context I wasn't meaning it in terms of the end users, I was meaning in terms of the engineers involved in the process.*" (P14)

Interview responses that were part of this category began to note that engineering involved relationships and interactions with people. These social interactions were with two different groups of people: others in the engineering team, as P14 describes in the quote above, and with stakeholders or users of material engineering systems.

P11 recognised that working engineers spent a lot of their time in interactions with others suggesting that:

> *"Yeah, I think there's a lot of project management. I think that's where a lot of engineers focus in reality, sits. So that means that there's a lot of managing people and collaborating with people to make projects actually happen."*

P9, on the other hand, talked about the impact of a designed system on end users and that being a consideration for engineers: *"They're kind of very conscious what they have used and what implications that those inputs and the parameters that make to the outcome* [for people].*"* P9 also suggested that engineers must pay attention to the technical detail around the "*products they deliver"* to ensure that they are rigorous and valid and highlighted a separation of the "technical" engineering knowledge which is then delivered to human users.

Other responses reflected a placing of people at the centre of engineering design from the beginning rather than just delivering a "technical" outcome. P10, for example, was focused on considering users or people from the beginning and described engineering as having "*the person at the centre"*. P7 described engineers as "*providing solutions for clients that, so they understand who their clients are"*.

The introduction of a relational or social element to engineering knowledge in curriculum was often mentioned in relation to group projects where students must interact in a team to complete a task. In describing this focus within curriculum, participants started to move away from any mention of "content" or any fundamental knowledge that might support this aspect of engineering work. They spoke of this being core to being an engineer but being absent from much of the curriculum sequenced early in the degree. P3 used the idea of "*soft skills*", of working in a team and effectively communicating to motivate students around future job prospects. A connection to work and engineering practice is made by participants in this category but as P3's comment below suggests, it rarely involved dedicated teaching time or "content":

"I have a full lecture dedicated to communication - well, maybe an hour worth of content on communication skills." (P3)

This contrasts with the other content which is primarily "technical" and focused on the underpinning engineering science and engineering design related to material components and systems.

Thus, in moving outward from the "technical" core participants are less likely to talk about "content" or fundamental knowledge as being part of the learning required in this aspect of engineering curriculum. Rather it is assumed that this is a contextual element, that skills will be developed through the experiences of doing applied projects and ultimately connected with work as an engineer. While it may be mentioned in earlier years of the degree, it is more likely to come into focus and be expected in later years.

6.1.5 Engineering is about moral engineering systems.

"*So the way I see engineering is I see it as a service profession for addressing human needs, whatever those human needs are and those human needs have evolved over you know, thousands of years, so I see engineering as a creative, you know, profession that relies on the fundamentals of math and sciences too and to create and address and fulfill whatever that human need was in the first place. So, I* *see it as a profession that's really at the forefront of the population and see the service is just a technical service but really it's first you know, professional, the service of the population."* (P2)

P2's quote above encapsulates a complete picture of engineering across all the categories mentioned thus far but incorporating a moral accountability, which comes with being part of a profession. That accountability is articulated through a range of commitments as a professional, from aligning to the formal Engineers Australia Code of Ethics, through to addressing safety, sustainability, legal and regulatory obligations, and financial accountability. As P13 notes:

"Yeah, so, I mean, we have to closely follow - we have to accept. We're - how do I say? - clearly obligated to follow rules and regulations, to make sure that we do things in a safe and sustainable way. And although that does apply to professionals in general, within the engineering profession, the standards that we have are very clearly articulated, and the bar is actually set a lot higher."

Participants talked about this more complete picture of engineering in "industry" or in practice in relation to the curriculum in units of study that are later in the degree. Responses suggested that early in the degree, in the first or second years of study (out of four), it is challenging to engage students in seeing this bigger picture of engineering. As P10 notes, "*For the first year I found it a bit more challenging because we had quite a bit of the kind of fundamental* [engineering science] *theory to get through"*. In their interview, P10 focused on the moral aspect of being an engineering professional through contextual stories, particularly related to assessment.

As in Category 4, little mention is made of "content" or of explicit teaching of any fundamental knowledge about these concepts. P15, in a similar fashion to P3's approach to communication, gave one "*specific lecture dedicated to teaching the student about the ethics in engineering."*

P5 described creating a group project in their design subject in which some of the roles that students must take on relate to quality, risk management, regulatory accountability, and project management. They note that much of the rest of the curriculum can convey to the students that *"we do a lot of mathematics"* but that this is unlikely to be what working engineers spend their time on. P5 notes that one of the reasons this is important to them is that "*not all engineers are necessarily mathematical, you know, highly competent and that this unit should afford the opportunity that those other sorts of engineers or types, start to see themselves, and where they fit in with this."*

This category, alongside Category 4, was presented by participants almost in a binary opposition to the earlier categories. Responses moved from the "technical" to the "non-technical". This category is characterised by an emphasis on the real world of working as an engineer. Participants suggested this category is contextual rather than core and suggested a lack of inclusion of too much by way of "content" or fundamental knowledge required to address it within the curriculum. I return to this concept in Chapter 7.

6.1.6 Summary: perceptions of engineering knowledge

In describing engineering knowledge within curriculum, participants varied across four dimensions in their perceptions:

- Varying levels of abstraction from pure abstraction, for example, when using mathematical descriptions through to the real material world, the social world and onto rich descriptions of operating in “industry” or in engineering practice where the material, relational, and moral all come together.
- Varying in the scale of focus of engineering practice as shown in curriculum, from separating out the object of study and looking at a micro level, through placing the object of study as a macro phenomenon within a social and global context.
- Varying in the impact and outcome of engineering and engineering education from the creation or maintenance of material objects through to solving human problems and on to changing the world for the better.
- Changing from a focus on “content” to “context” and arguing for a sequencing of knowledge areas within the curriculum from early to final years of the degree, as the perception of engineering became more complex, contextual, and closer to engineering practice.

Across the interview transcripts I have identified a nested suite of perceptions of engineering knowledge that informed participant decisions about their approach to learning, teaching, and assessment in engineering. These perceptions illuminate some of the ways in which “disciplinary knowledge practices are situated in teaching-learning interactions” (Ashwin, 2009). The perceptions reflect several binaries that emerge in the ways academics perceive engineering knowledge:

- Technical/Non-technical
- Abstract/Real
- Theory/Practice

- Knowledge/Skills
- Content/Context
- Taught/Experienced

In the next section, I show the variation in participants perceptions of the purposes and outcomes of engineering education before contrasting with the Engineers Australia policy document that articulates required knowledge areas in engineering curriculum.

6.2 Purpose and outcome of engineering education: from personal development to public good

In section 6.1, I presented a set of nested categories for describing engineering knowledge and suggested that as perceptions moved further outward in these categories, the perceived purposes and outcomes of engineering education changed. In this section, I explore more of the detail around the range of purposes and outcomes that participants associated with engineering and were revealed in the interview transcripts. My argument for exploring these in detail is that in historic and contemporary narratives about women and engineering one of the key areas that is consistently posited to increase the number of women is to shift the perception of the nature of engineering towards a more compelling story of impact and outcome. In the Engineers Australia "Women in Engineering" report (Romanis, 2022) this is captured succinctly in the Executive Summary:

> "Engineering lacks positive perceptions: it is mainly seen as male-dominated and challenging. It is not perceived as impactful or fulfilling – which are important considerations for many women and girls."

There are four outcomes that I identified within participant responses. These cover a spectrum within two purposes:

- **Personal development purpose** that incorporates possible outcomes of:
    - Technical competence
    - Open-mindedness and the capacity for critical thinking
- **Public good purpose** that incorporates possible outcomes of:
    - Humanistic, client and user centred engineering
    - Saving society and the environment

I use the term "Public good purpose" in the sense of that argued for by Walker and McLean (2013) and explored with regard to engineering by Case and Marshall (2016) who suggest that from this perspective a key question is "how science and engineering graduates might use their knowledge, skills and capabilities as professionals to make good lives for themselves, while also contributing to sustainable human development as a public good."

In Figure 3, I represent the spectrum. I explore each point along the spectrum in turn with examples from interview transcripts.

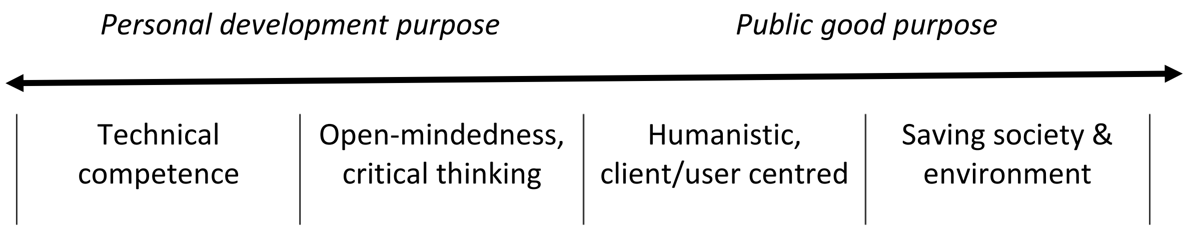

Figure 6.3 The spectrum of purposes and outcomes of engineering education

6.2.1 Personal development purpose: technical competence and open-mindedness

"You need sort of maybe [to] *think mathematically, apply computationally. That's sort of what distinguishes engineering or my style of engineering like* [engineering discipline]*, more the theoretical style of engineering. Yes, it's very mathematics based, but it's also towards, driven by applications. So, what you then need to do to be successful in the more research type of engineering is to abstract the world in a way so that you can use your tools and then move back to the real world and see how it goes."* (P4)

When asked what type of engineer they saw emerging from the education they provide, some participants prioritised technical competence as P4 does, that is the skilled application of engineering science to real-world material outcomes. These responses focused on analysis, computation, and using technology and simulation to undertake rigorous and defensible calculations.

For some this was seen as the skill of thoroughly applying existing methodologies, as technical competence, but for others this was expanded to include the capability to explain why particular techniques were applicable. As P3 suggested, "*I feel like the engineers we grad, I'd like to say we graduate, are more resilient to solving open world problems"*, although the "open world" P3 referred to was an unseen technical and material system. Terms used to describe the kinds of capabilities graduates should develop included inquisitiveness, reasoning, attention to detail, critical thinking, and asking why.

In these responses, participants were focused on the personal development of graduates as highly capable individuals, with little reference to their impact outside doing “high quality” work.

6.2.2 Public good focus: human-centred engineering and saving the world

“I think, one of the things that I’m more aware of now, is that - trying to be more aware that as engineers, that as a profession, it's - you can either say we built, you know we design things we build things, right? But you can just as equally frame that as we solve problems. We solve the world's problems. We solve society's problems. We make society a better place.” (P6)

As in P6’s description, when participants articulated the idea that engineering could change the world, they often place this in contrast to the more “traditional” view of engineering as “*just maths that you do”* (P10). Several responses made mention of disciplines within engineering that have a greater alignment to this kind of purpose such as medical engineering or humanitarian engineering. While still emphasising the idea that engineers must be thorough and rigorous in their calculations and analysis, participants who talked about this greater purpose and impact suggested that this must be done in a way that assured safety and sustainability. As P14 suggests, engineers “*are much more likely to be working on systems that kill people if they’re not engineered correctly”*.

While individual personal development was still important within these responses, this development was seen to have a purpose beyond the individual. For some this purpose was humanistic, the consideration of close users and stakeholders within projects. For others, the purpose and outcome were bigger than the one project and was focused on saving the world, particularly as we face a climate crisis. This purpose and outcome were sometimes associated with the idea of engineering knowledge as incorporating moral accountability not just “technical” knowledge.

These purposes and outcomes are echoed in a policy statement from Engineers Australia regarding their position on climate change:

> “Engineers Australia recognises the scale and urgency of the challenges presented by climate change, the disruptions it causes, and the pivotal role of engineering in enabling a socially just transition to a sustainable society.” (Engineers Australia, 2021)

While this would seem to connect to a view of engineering knowledge as encompassing relational and moral considerations, it was not always the case that respondents spoke about the two together when describing the knowledge within curriculum. As I noted in 6.1.5, making the connection to these larger purposes and outcomes can be challenging, given it is seen as different and separate from the “technical” engineering knowledge that is required, particularly early in the degree programme.

However, participants did make mention of these purposes when talking about the ways in which marketing of engineering could be enhanced to attract more women to study engineering.

6.3 Official discourses on the profession

> "While the outcomes of engineering have physical forms, the work of Professional Engineers is predominantly intellectual in nature." (from Stage 1 Competency Standard for Professional Engineer, (Engineers Australia, 2013))

In this section, I will explore two policy documents that may be said to represent the "official recontextualising field" (Singh, 2002) of the engineering profession. I include this exploration because as a professional discipline, a "region" according to Bernstein's (2000) theoretical framework, what counts as engineering knowledge is strongly influenced by regulating policy like that produced by the professional accrediting authority, Engineers Australia. In my state of Queensland, engineering work is even more strongly regulated through legislative requirements.

In this section, I highlight the contrast and alignment between the view of engineering knowledge encapsulated within these policy documents and the categories of perception of participants. Bernstein (2000) suggests one of the characteristics of regionalised knowledge domains such as engineering is that they look in two directions: towards both the "field of production" and the "field of practice". The recontextualization of knowledge within curriculum is mediated by both.

The two policy documents I will investigate are:

- "A guide to the elements of a Professional Engineering Service": a Practice Note resource published by the Board of Professional Engineers of Queensland (BPEQ), "an independent statutory body" established under legislation: *Professional Engineers Act 2002* (Qld) (Board of Professional Engineers of Queensland, 2013)

- "Engineers Australia Stage 1 Competency Standard for Professional Engineer" (Engineers Australia, 2013): a statement which is used in the processes of professional accreditation of degree programmes within Australia. It is aligned to a statement from the International Engineering Alliance (IEA Graduate Attributes and Professional Competencies, (International Engineering Alliance, 2021)), which recognises Australian qualified graduates within the Washington Accord, "an international agreement between bodies responsible for accrediting engineering degree programmes".

Both documents make statements about what engineering is, which shape the curriculum within universities.

The BPEQ Practice Note is a definitional document supposed to support clients or stakeholders to have clarity on what constitutes an "engineering service" for the purposes of the legislation as a means of "protecting the public". The definitions incorporated in this Practice Note are somewhat circular (e.g. "Engineering Principles are the principles of engineering") but the definition of Engineering is of relevance to this study both in terms of what is included as well as what it is silent about. BPEQ suggests:

> "**Engineering** is the science of design, construction, maintenance and operation of structures, machines, systems and processes according to scientific and mathematical principals [sic]." (bold in original)

This definition emphasises science and mathematics and their application to the creation of material systems. It is a definition that captures the inner three categories of perceptions that I have described from analysis of interview transcripts, the "technical" knowledge of engineering. What is not clear is what counts as "science" in this context and the "scientific principles" that are to be relied upon. The implication is that this means the natural and physical sciences since it applies to structures and machines but it is unclear if this could incorporate the social sciences, particularly as "processes" may involve the organisation of people as well as physical systems.

The "Engineers Australia Stage 1 Competency Standard for Professional Engineer" is the primary policy document used by universities in Australia to inform curriculum in accredited degrees (Engineers Australia, 2013). It is one of the ways degree programmes are confirmed as fulfilling the requirements for professional accreditation.

The Competency Standard consists of a preamble role description of "the mature, professional engineer" followed by an explanation of the competencies that "**must be demonstrated** at the point of entry to practice" (bold in original). As mentioned earlier in this chapter, the Competency Standard incorporates three domains of competency and is made up of 16 elements of competency that fall under those three domains. The preamble includes the statement that begins this section as well as suggesting that Professional Engineers ensure that "technical and non-technical considerations are properly integrated." One of the uses of this Competency Standard as part of the Engineers Australia Accreditation process is a requirement to map curriculum from degree programmes to these elements. All those I interviewed had been involved in this process as part of their academic teaching role.

Mapping is a complex task, because the Elements of Competency are not distinct and independent, and they include a range of confusing language. For example, the listing of each domain's competency elements begins with a bolded group of words that conveys emphasis on the category of competency incorporated. In the domain of Knowledge and Skill Base there are Elements of Competency that call for:

- Comprehensive, theory based understanding,
- Conceptual understanding,
- In-depth understanding,
- Discernment of knowledge,
- Knowledge, and
- Understanding.

These words are all bolded, and are related to different knowledge areas from "numerical analysis" to "sustainable engineering practice" but the nuances of meaning between each is not clear. The Elements of Competency are supported by Indicators of Attainment, which "<u>should not be interpreted</u> as discrete sub-elements of competency" (underlining in original) but nonetheless are often relied upon as being a complete list of what is required in the processes for mapping of curriculum.

Reading only the Competency domains and Elements of Competency might lead to an assumption that the first two domains: Knowledge and Skill Base and Engineering Application Ability, are aligned to the "technical" engineering knowledge from my interview analysis, the inner three layers of the model of engineering knowledge.

However, a deeper reading shows that within the Indicators of Attainment is a suggestion that there may be Knowledge and Skill Base associated with the Relational and Moral Engineering Systems categories, which in this policy are expressed as “contextual factors”. Specifically, element 1.5 includes the following two indicators:

“(b) **Identifies and understands** the interactions between engineering systems and people in the social, cultural, environmental, commercial, legal and political contexts in which they operate, including both the positive role of engineering in sustainable development and the potentially adverse impacts of engineering activity in the engineering discipline.

(d) **Is aware of** the founding principles of human factors relevant to the engineering discipline.”

These Competency Standards are currently being reviewed following an update to the IEA Graduate Attributes and Professional Competencies that inform them (International Engineering Alliance, 2021). The update by IEA included a new statement of the first area in the “Knowledge and Attitude Profile for Professional Engineers”, which now suggests that a Washington Accord programme provides: “A systematic, theory-based understanding of the **natural sciences** applicable to the discipline and awareness of relevant **social sciences**” (bold in original).

Taken together, this reading of the Engineers Australia and IEA statements opens the possibility that it is not just the natural and physical sciences that underpin engineering. The social sciences might also form an important fundamental knowledge input into engineering curriculum. This suggests that it could require more than the development of “non-technical” skills learned through experience. I will take up this point further in Chapter 7 as I draw together the outcomes of Chapters 5 and 6 to illuminate the interaction of pedagogic discourses (Bernstein, 2000) and gender regimes (Connell, 2006) which work together to close off ways to be a woman and an engineer.

6.4 Summary: Engineering Knowledge in the curriculum

This chapter has developed a view of the “knowledge-as-curriculum” (Ashwin, 2014) in engineering as perceived by my participants and within the policy documents of Engineers Australia. I have done so to begin the process of illuminating the pedagogic discourses in operation in my research context.

Drawing together the analysis presented in this chapter, I have further explored a field of binaries that seem to underpin thinking about engineering curriculum:

- Professional skills/Engineering knowledge
- Relational and Moral/Technical
- Human/Material
- Public good/Personal development
- Society/Individual

In the next chapter, I will draw together the analysis from chapters 5 and 6 and place it within a theoretical framework around pedagogic discourses and gender regimes, showing how the binaries around gender and around engineering curriculum work together to influence the spaces for women to feel as though they belong within the engineering context.

Chapter 7: Binaries in tension: Disciplinary knowledge practices in curriculum and Gender Regimes

In this chapter, I discuss the findings of Chapters 5 and 6 to illuminate aspects of the disciplinary knowledge practices in curriculum and gender regimes in operation within my research context. I show the gendered knowledge and social relations that are demonstrated through interrogation of perceptions of gender and perceptions of engineering knowledge. This has consequences for the legitimate identities made available to students within this context.

In the first section of this chapter, I connect the findings from Chapter 5 and 6 to the theoretical framing of disciplinary knowledge practices in curriculum and pedagogic practices as examined in Chapter 3. Academics are key agents within curriculum and their perceptions reveal aspects of the knowledge and social relations in operation in pedagogical interactions. Through exploration of a series of binaries in tension, this chapter presents an analysis of the "macro and micro structuring of knowledge" that is illuminated within the perceptions presented in Chapters 5 and 6 (Singh, 2002).

In the second section of this chapter, these binaries in tension are brought together into an analysis of the gender regimes: gendered knowledge and social relations. The binary in tension of masculine versus feminine as 'authentic' engineer is inextricably linked to these disciplinary knowledge practice binaries. The structuring of engineering knowledge in curriculum is also a structuring of (gendered) legitimate student engineers.

7.1 Pedagogic discourse: social and knowledge relations in curriculum

In the first section of this chapter, I discuss the findings of the last two chapters and connect them to theoretical framing of disciplinary knowledge practices as examined in Chapter 3. Participant perceptions of what counts as engineering knowledge reveal some of the rules of recontextualisation operating in my research context. As I noted in Chapter 3, the curriculum is not just a simple reflection of research nor the field of practice. Rather it reflects a site of contest and tension where global, institutional, local, and individual interests are negotiated.

7.1.1 Which singulars? Taught content versus experienced context

The findings of Chapter 6 reveal several binaries in tension. Across the categories represented in Figure 6.1 and the descriptions of each category, tensions are revealed in the formation of the curriculum. Disciplinary knowledge practices in curriculum reflect choices about what is explicitly taught and what is assumed to be learned through experience, what appears as content and what is left only as context, and which disciplinary knowledge practices from either research or practice are drawn into curriculum.

My findings show that participants clearly make a distinction between teaching and content, and experience and context. P7 for example expresses the view that most educators are "transfixed" by content, which is explicitly related to "foundational material":

"Yeah, so, as engineering educators, right, this might be a bit out there, but I think sometimes we've got to let go of the content, certainly, in the classroom. People are

still transfixed on: they have to learn this, this and this and this. You know, all this foundational material."

In contrast, P10 discussed framing assessment with the use of context, using narrative to wrap around a technical problem, to address the broader knowledge areas required of an engineer. This context is separate from the taught content of the unit of study:

> *"The assessment would always have a story around it, you know, Sam the* [engineering discipline] *engineer is designing* [a component] *and we've got* [an engineering system] *and then you know, think about efficiency and the context around that, for example".*

Engineering disciplinary knowledge practices in curriculum reflect decisions about knowledge relations and social relations. In noting shifts in the nature of disciplinary knowledge, Bernstein (2000) articulated that disciplines could be categorised dependant on the strength of their classification as either singulars, regions, or generic modes of knowledge. In the perceptions of engineering knowledge that are revealed in the current study, there is a shift from the inner perceptions which are aligned to singulars in the natural and physical sciences and mathematics to the outer layers where the regionalisation of knowledge begins to appear as the focus becomes more on engineering as a practice. This is shown in the nested categories of perception in Figure 6.1.

The shift in engineering disciplinary knowledge practices from singulars in the inner core to a region in the outer layers is in alignment with the shift from "technical" to "non-technical" knowledge. But there are tensions in the accounts of knowledge within these perceptions between the "technical" and the "non-technical" reflecting tensions in the choices to be made about which disciplinary knowledge practices are drawn on to create regionalised engineering knowledge.

The singular disciplines of science and mathematics, the "technical" disciplines, are associated with content and with the active teaching of that content mostly through traditional teaching approaches such as lectures and with traditional assessment regimes incorporating exams and problem solving tasks. P8 who describes themselves as teaching "a bunch of maths" describes their teaching approach as traditional and technical, using lectures, exams, and problem solving in contrast to other units that might use larger, more integrative team-based projects:

> *"But I'm very old school. I would be even older school if I could and I think maybe we'll get some support for this … higher percentage of exams and more of them in the era of Chat GPT, but I like, for my units it works, okay. The problem solving task where I permit some group work and I encourage group work in a way that's important for learning. And then I use the exam to make sure, to individualise that, let's say. So, it's pretty traditional. But for my units, it works. They're not design units in that they're usually some kind of very technical skills that we're trying to impart. So, problem solving task and exams work well for that, maybe a little project in there as well".*

It is the singulars of natural and physical sciences and mathematics that are drawn upon as regionalised knowledge practices within Category 2 Engineering Science and Category 3 Material Engineering Systems. In contrast, the outer layers of engineering practice knowledge shown in Figure 6.1 are associated, not with content, but rather with context alone and are rarely explicitly mentioned in terms of teaching. The singular knowledge modes that might inform these areas is unclear, although they do look towards the field of practice, albeit through a transformation process of recontextualisation.

In the outer layers of the model presented in Figure 6.1, topic areas within subjects begin to change to incorporate knowledge areas such as communication, sustainability, and ethics that are not core to the natural and physical sciences or mathematics. However, the possibility of the singulars of social science and humanities informing the disciplinary knowledge practices of engineering remains largely invisible in the perceptions offered by my participants despite there being potential connections to these disciplinary knowledge practices in content on communication and ethics, for example. Instead, these knowledge practices look like generic mode knowledge. Ashwin notes that "such modes are empty because they simply refer to themselves and are focused on responding to the changing demands of technology, organizations and the market" (Ashwin, 2009). These knowledge modes are not forms of specialised knowledge because they foreground only the context. In that sense the knowledge is not transferable beyond that context. In professions, such as engineering, regionalised knowledge is specialised even as it is "accrued from specific contexts" and may even contribute to the development of new knowledge through applied research (Young & Muller, 2015, p. 208).

The binaries in tension in disciplinary knowledge practices, between content and context, between taught and experienced, and between the physical sciences and the social sciences and humanities creates problematic knowledge relations within curriculum. As studies of engineering practice have shown (for example Faulkner, 2015; Trevelyan, 2010) there is a disconnect between the view of engineering knowledge practices developed in university education where it is focused on purely "technical" knowledge practices rather than reflecting the more complete heterogeneous, socio-technical knowledge practices that exist in the field of practice.

I see this tension also in practices around who counts as a legitimate educator in engineering degree programmes. My insider experience in the research context of my study is that when there are areas of content and explicit teaching of knowledge from the invisible singulars or as a generic mode (for example technical communication or team collaboration), this teaching is almost always undertaken by an educator who is not an engineering academic. In common with the engineering education communities of which I am a part, there are those who are engineers (by virtue of graduation from an engineering undergraduate degree) and engineering academics with responsibility for teaching the "technical" content, and then there are others, often in roles such as those aligned to learning development or student academic support, who step in to do teaching with a "non-technical" focus as a guest within the classroom. In the case of my context, several of these educators have PhDs in either social sciences or areas of applied social science but they are not employed as academic staff and rather occupy roles as "third space professionals" (Whitchurch, 2008).

7.1.2 Tracing engineering knowledge: theory in the academy versus practice in industry

The knowledge relations, which are manifest in aspects of curriculum such as selection and sequencing of knowledge areas shows a shift from the early years of the degree programme which are largely grounded in theory within the academy through to engineering practice in the world. Participants who teach in the early years of the degree discuss the challenge in relating content to practice. P12 even notes, "*Everything I teach is a hundred plus years old*", referring to the curricula focus on physical sciences and engineering sciences.

While regionalised knowledge looks towards both singulars and the field of practice, in my context there is an uneasy integration of knowledge from theory in singulars progressed through the academy and practice knowledge embedded within industry. The history of engineering education in the Global North has reflected this struggle between the academy and industry (Case, 2015). In Australia, alongside the US and the UK, this struggle has come to be mediated and regulated by professional bodies through professional accreditation. The perceptions of engineering knowledge that are shown in Figure 6.1 in Chapter 6 reflect that this struggle continues to make visible the connection of engineering knowledge almost exclusively to the singulars of the natural and physical sciences and mathematics. As Winberg et al noted in their review of research on employability in engineering education, "None of the studies surveyed dispute that the basic and engineering sciences form the epistemological core of the engineering curriculum" (Winberg et al., 2020).

Engaging in this research study has caused me to reflect on my own undergraduate engineering education, which is now over 30 years ago. P12's reference to their teaching being on a topic that is over 100 years old is not the least surprising when compared with my own undergraduate curriculum. The subject I teach in Engineering Mechanics is very similar in structure, content, and assessment to the one I studied as an undergraduate. I note that some of the textbooks that are recommended within my context are up to the 10th edition of a volume that was used in my own undergraduate study, albeit now accessed via an online format. And yet the practice of engineering over that 30-year period has been considerably transformed.

The transformation of engineering practice each month is exemplified by my monthly subscription to the professional magazine of Engineers Australia. The magazine includes advertisements targeted at practising professional engineers and a common advertisement is one for a computer package that automates a mathematical technique known as Finite Element Analysis or FEA. I learned Finite Element Analysis in my final years of an engineering degree sitting in a classroom and hand-writing my notes and at a time when to implement it you had to write your own programming code. Now, however, engineers engage with fully developed software solutions that implement FEA for them. The biggest challenge is not how to implement the technical solution but rather how to engage stakeholders in accepting the designed solution. But my experience of 10 years as an Associate Dean, Learning and Teaching confirms that my institution's degree structures have changed very little to reflect this. The recontextualisation of the field of practice into curriculum is no less contested than the choice of singulars.

Curriculum structures that have not substantially altered for decades have further implications for who is positioned as a legitimate engineering educator within university engineering education beyond those discussed in section 7.1.1. In their 2021 review of engineering education, the Australian Council of Engineering Deans (ACED) called for Schools of Engineering to "provide greater opportunity for industry-based engineering personnel to participate in engineering education" including "engineering practitioners as part of the staffing profile" (Illing, 2021). This call is in response to the current profile of engineering educators who are primarily drawn from research pathways, focused on the engineering sciences. The report further identified a need to shift the curriculum in engineering education towards "integrating human/social dimensions within technical contexts" to reflect practices in industry. Currently in my research context the input of professional engineers in industry, the "engineering practitioners" mentioned above, happens only via formal committee structures such as Industry Advisory Groups. This industry input is a requirement of both the institutional policy around curriculum development and review and of the Engineers Australia professional accreditation. The nature of the input is often constrained to the presentation of almost complete curriculum at a meeting with requests for questions and input.

Curriculum development work is primarily undertaken by a community of engineering academics. However, engineering academics have noted that their biggest challenge in shifting engineering education was in their confidence in integrating "human and social issues" into their teaching (Illing, 2021). Bernstein (2000) emphasises in the field of recontextualization that disciplinary knowledge practices are transformed into "virtual practices". They are not the same as discipline-as-research (Ashwin et al., 2012), nor are they the same as the field of practice. The findings of this study show that the virtual practices that are created foreground the "technical", with the "non-technical" or professional skills left only as context.

There is a tension and struggle, then, for engineering academics to reflect the field of practice within their teaching. The compromise is a curriculum with the singulars of natural and physical sciences and mathematics at its core with either third space professionals or professional engineers from industry undertaking the uneasy role of filling the gap, through either guest lectures or giving advice when invited to do so via committee. Disciplinary knowledge practices in curriculum then create a view of virtual practices that valorises the engineering sciences and theory developed in the academy.

Pedagogic practices largely incorporate visible, performance pedagogies, which recognise legitimate knowers as those who excel at the objective testing of knowledge. Alongside a focus on content in describing the teaching of core knowledge, most participants incorporated testing through exams into their teaching practice. This is still overwhelmingly a dominant assessment practice in engineering. Thus, in the contest between the academy and industry, the curriculum and pedagogic practises reveal that the academy dominates. Engineering science theory is valorised, and industry practice is left to the domain of professional skills.

7.1.3 “We solve society's problems. We make society a better place.”

A site of struggle and tension evident in the perceptions of my participants is the purpose and outcome of an engineering education, across a spectrum from technical competence to public good (expressed in the quote in the title by P6). Part of this tension and those mentioned earlier can be linked to shifting cultural beliefs around the disciplines that have come to be known collectively as STEM (Science, Technology, Engineering, Mathematics) and in particular the valorisation of STEM knowledge as being essential to life success in contemporary society, particularly as this relates to employment. An example of this can be found in the Australian Government Department of Education website, entitled, “Why is STEM important?”:

> As the world of work changes, we will need to change our skills to match. The gap between the knowledge generated in the education system and the skills

> demanded by employers and individuals is widening. Overcoming these limitations requires a priority focus on science, technology, engineering and mathematics (STEM), including the development of workplace skills in STEM. Future careers will also rely heavily on ‘21st century skills’ — for example, critical thinking, creativity, cultural awareness, collaboration and problem-solving. When done well, STEM education complements the development of 21st century skills. It’s predicted that future workers will spend more than twice as much time on job tasks requiring science, maths and critical thinking than today. (*Why is STEM important?*, 2023)

In this rendering of education, its purpose is to produce employable individuals and engineering is encompassed by the overarching disciplinary grouping that is STEM, which is grounded in “science, maths and critical thinking”. This firmly positions engineering against the humanities and social sciences disciplines that are not STEM. At the same time, this call to attract students to the STEM disciplines is failing. As Table 1 below shows, the percentage of Australian graduates in Engineering and Related Technologies is well below that of both Society and Culture and Management and Commerce and has remained relatively consistent over the 20-year period from 2001 to 2021 despite an increase in overall graduates.

Field of Education	% of total graduates in 2001 (total graduates = 191,872)	% of total graduates in 2021 (total graduates = 418,316)
Engineering and Related Technologies	5.6%	6.2%
Society and Culture	19.1%	18.0%
Management and Commerce	27.7%	27.6%

Table 7.1 Percentage of graduates in Australian Higher Education in 2001 and 2021, in three fields of education (Data Source: Australian Government, Department of Education, Higher Education Student Data https://www.education.gov.au/higher-education-statistics/student-data/selected-higher-education-statistics-2021-student-data)

A further tension around the purpose and outcome of an engineering education is the challenge for the profession regarding its potential contribution to sustainability and addressing the global crisis of climate change. Engineers Australia (EA) has as its primary Policy and Advocacy focus the fundamental role of engineering in addressing climate change. In a recent article within the EA professional magazine, Create, about a Climate Change conference EA's Chief Engineer, Jane McMaster is quoted: "Engineering as a profession is all about serving the community and serving people. I actually like to extend that a bit and say we're here for people and planet" (Sheedy, 2023).

It may be that an engineering curriculum could have focus on both technical competence and public good but as P2 suggests this is not always evident in the pedagogic practices:

"I think it's important that they're aware that their primary goal is to serve human needs and it's not just about human, I think all engineering is humanitarian engineering whether it's about supplying you know power, mobile phones whatever.

But, it is possible that sometimes, because of the nature of it, that human needs, sometimes are not always at the forefront of what they're doing. So, it's possible that, particularly as you know, student engineers and also probably as young, as early graduates, their understanding of the profession is more that it is of a technical nature and that's as far as like the purpose of what they're doing, it's sometime not exactly in their face. It's not like a doctor who sees their clients all the time or a psychologist etc, there is a bit of a system, you know and the young engineer that sometimes is a bit remote from that's the purpose of what they're doing, which is to serve humanity …"

This view that "all engineering is humanitarian engineering" was reflected in several participant interviews. I read this as a belief in the public good of technology and technical competence, rather than it being a choice between one or the other. Participants believe that through technology the engineering profession can save the world and if we emphasise this aspect of engineering, we will attract more students to study (particularly women). The challenge in this commitment is that, as the figures around graduates demonstrate this is not a connection that is widely made in everyday discourse, and it has not translated into more students nor shifted the gender balance.

7.1.4 A model of the disciplinary knowledge practices in curriculum

Drawing together these three binaries in tension reveals a model of the knowledge relations in disciplinary knowledge practices in curriculum which I illustrate in Figure 7.1 below. The model incorporates three areas of tension and contestation revealed in my findings. Firstly, there is a tension around which singulars are to be recontextualised, with natural and physical sciences and mathematics dominating. This is revealed through their dominance in perceptions about content. Singulars from humanities and social sciences, on the other hand, are only revealed as context or invisibly relegated to generic mode knowledge. Secondly, there is a tension between academy and industry, where the field of practice is less influential than research in engineering sciences. Finally, the outcomes of an engineering education are aligned along similar lines to the tensions in knowledge mode.

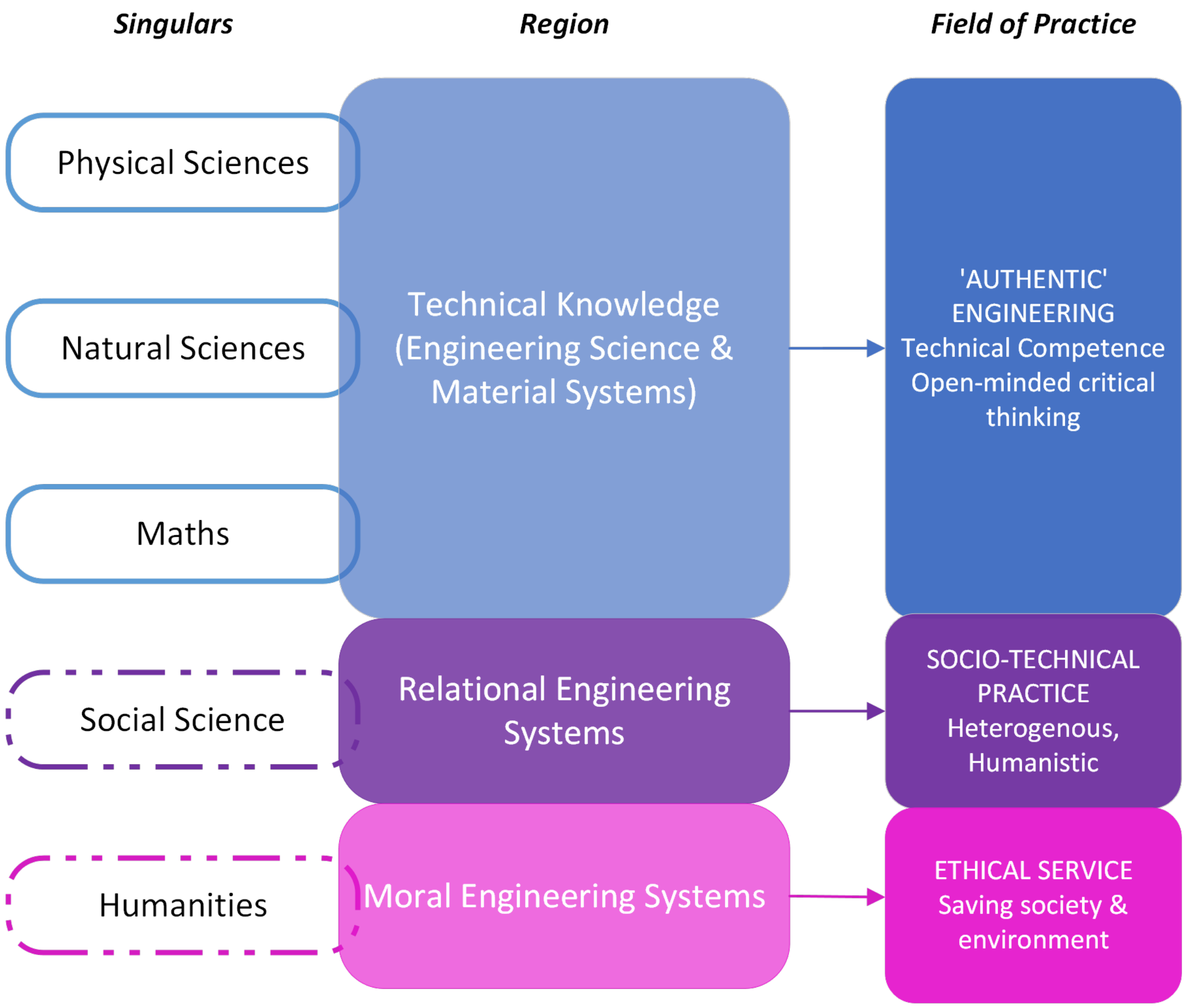

Figure 7.1 A model of the disciplinary knowledge practices that maps the singulars, regionalised knowledge, and field of practice evident in the current research context.

In the next section I explore the implications of these tensions for gender regimes, highlighting that the tensions articulated in the knowledge relations in curriculum are not just crises of knowledge but also have implications for (gendered) engineering student identities, reinforcing the double bind experienced by women in engineering.

7.2 Gender regimes in engineering education practices

In this section, I connect the participant perceptions revealed in Chapters 5 and 6 to their implications regarding the kinds of gendered legitimate student identities that are made available. In doing so I address the dimensions of gender regimes which I developed from Connell in Chapter 3 (Connell, 2006). This is by no means a full account of the gender regimes in operation but it does reflect the important role that academics play in creating knowledge relations and social relations, through (gendered) disciplinary knowledge practices. As Ashwin notes, contemporary accounts of university education often “fail to value the importance of teachers’ understanding of how to make this knowledge accessible to students” (Ashwin, 2021).

As I noted in Chapter 3, the dimensions of gender regimes do not exist as separate categories but are interweaved, providing overlapping analytical lenses through which to view gender systems and patterns. In this section, I will discuss each of the dimensions in turn but in an order that makes more sense for my findings: gender culture and symbolism, gender division of labour, emotions and human relations, and gender relations of power.

7.2.1 Gender culture and symbolism

The findings in Chapter 5 that illuminate perspectives of gender are the most obvious pointers to the way that gender culture and symbolism plays out in my research context. Through these perspectives, participants reveal the range of ways that gender symbolically frames knowledge and social relations. My findings reveal two groupings of perspective that I discuss in this section: Categories 1 and 2, which both suggest that gender is not relevant, a form of “degendering strategy” or gender neutrality (Connell, 2006); and Categories 3 and 4 where gender matters because women and men are seen to align to cultural stereotypes of femininity and masculinity respectively.

7.2.1.1 Gender is not relevant.

Holding a belief that gender is not relevant, particularly where this coincides with a belief in the gender neutrality of a discipline, leads to a tendency to focus gender diversity efforts on women as the problem. While the perception that gender is not relevant (Categories 1 and 2 from section 5.1.1 and 5.1.2) was not dominant, it is worth noting the impact of this discourse, particularly within a context where there are consistent efforts to increase gender diversity. My institution has an overt strategy to increase gender diversity through strategies such as scholarships for Women in Engineering and explicit support for student clubs for women.

Conefrey describes the two strategies that often follow from an assumption that science and engineering are gender neutral as the “compensatory” and the “search for undiscovered talent” approaches. Either women are assumed to not be entering the gender-neutral engineering or science discipline because they are not yet competent and thus there needs to be some compensatory activity to build up that competence. Alternatively, they are assumed to be competent but attracted to other areas, which results in a marketing solution, searching for and attracting the undiscovered talent (Conefrey, 2001).

The claims for gender neutrality often come alongside claims for meritocracy. Foor et al, using Conefrey’s cultural myths of science, showed the emotional and practical impacts of these myths in action for an engineering student with intersectional disadvantage (Foor et al., 2007). As Conefrey notes, myths of gender neutrality, value-free cultures, and meritocracy render the legitimated discourses in sciences and engineering invisible (Conefrey, 2001). As the rules for legitimate engagement in disciplinary knowledge practices remain tacit, those who are “doing” a gendered identity that is outside the hegemonic (masculine) identity are left feeling disconnected and excluded (Conefrey, 2001; Foor et al., 2007). In the current research context, beliefs about gender not being relevant can create an exclusionary culture.

7.2.1.2 Gender matters: men and women are different.

When hegemonic gender beliefs operate everyday social interactions reinforce cultural stereotypes about what it means to be a woman or a man. These perceptions are articulated in Category 3 and Category 4 of my findings regarding perceptions of gender. A recent development in addressing the lack of women in STEM disciplines at universities in Australia has been the enthusiastic take up of "unconscious bias" training to purportedly address this cultural stereotyping. It is a requirement within my institution for academics in my faculty and there are examples within engineering education of incorporating this training into curriculum for students (Isaac et al., 2023).

I contend that, despite an institutional context that commits to addressing gender equity, "unconscious bias" training as an approach is unlikely to achieve the desired outcomes, while hegemonic gender beliefs remain unchallenged. There have been critiques of unconscious bias training, including a systematic review of the evidence of its effectiveness from the UK Equality and Human Rights Commission, which found little or no evidence of impact (Atewologun et al., 2018). As Möller et al. (2023) note in their critique, much of the unconscious bias training that operates connects to a psychological definition of unconscious bias that frames it as "a problem located inside individual minds". It draws on a commonly held definition of unconscious bias that proposes it as an implicit cognitive effect which individuals just need to be alerted to for its impacts to be minimised (Greenwald & Banaji, 1995). I would add that this challenge is confounded when it does not engage with cultural beliefs around gender or other characteristics of identity presumed to be inherent to individuals such as race.

P14 recognised this challenge in highlighting the commonly offered marketing advice around making engineering more attractive to women by showing it as having an impact on the world and involving caring for "people and planet".

> *"We have these training courses about stereotyping and unconscious bias and whatnot. And you shouldn't think about a certain group as having certain properties or thinking in certain ways. Women will think this way or men will think this way but, somehow to kind of - for those different groups you have to stereotype, and you can't cater more effectively for them without thinking about, how might this group react better or worse, to a particular, you know thing that you do. So, you're sort of inherently forced to stereotype in order to cater for a more diverse group …"*

The perceptions about gender that are revealed in my study show that, while participants might understand the need to not behave in ways that assume people are a certain way because of their gender, they nonetheless believe those gender differences exist and are inherent to people's identity.

7.2.2 Gendered division of labour

The gendered division of labour was illustrated in the perceptions of my participants in categories of perception in which they differentiated between men and women. As I showed in Chapter 5, in Category 3 and 4, participants differentiated between women and men, particularly in the roles they undertook in team-based project assessment. The nature of these capabilities, motivations, and interests is both gendered and hierarchical. As I showed in Chapter 3 studies of engineering practice consistently demonstrate that capabilities associated with technical engineering knowledge are valorised to the extent that they render capabilities associated with the human and social dimensions as invisible or generic (Faulkner, 2000; Lagesen & Sørensen, 2009).

The higher value placed on technical engineering knowledge, associated with masculinity, is demonstrated in the greater value given to this knowledge in determining grades. In discussing their team-based project, I asked P3 about the grading for the engineering system that was the focus of the assessment. In particular, I was interested to understand if the assessment was focused on visible pedagogic practices, a performance pedagogy, since this would give an indication of the knowledge practices that were valorised. P3 suggested that, despite his contention that the organisation of women students was beneficial to a team, a passing grade required only that a functional system be created. There was no direct assessment or grading of organisation, only of the technical capabilities of the system:

> *"So, let's say, there's about 30 groups that go into the unit. Probably about 2 or 3 teams don't get a functioning* [engineering system] *to some degree. But there's a whole grading system. I would say there's about 3 that are on the fail level, and then there's a bunch more that hit the pass, and then there's all of above from that. But that's what I was saying, the system's not, the challenge is not too hard that they can try and slap together something. And it does work just doesn't get good grades".*

This is not an uncommon narrative, that while team-based projects are supposed to focus students beyond just the “technical” outcomes, when it comes to assessment, only the technical outcomes count.

Assessment focused on technical outcomes, placed alongside the perceptions of women and men that my participants revealed, suggest that the double bind continues to dominate gender relations in my context. This double bind means that, while women students are positioned as effective communicators, project managers, and organisers, those knowledge outcomes are not seen as a valuable part of the assessment.

7.2.3 Emotion and human relations

My findings show that emotions and human relations are largely absent from perceptions about gender and about engineering knowledge. As I suggest in Chapter 3, I expected that two aspects of engineering disciplinary knowledge practices would indicate this dimension of the gender regime. The first was through a recognition of the diversity of gender and sexual orientation within the student cohort. The second was via the inclusion of curriculum related to empathy, emotions, and human dimensions of engineering.

Only two of my participants made comments that could be connected to the place of sexuality in human relations within the pedagogic discourse. It was a limitation of my interviews that I did not ask specific questions related to sexuality or human relations. However, in reviewing interview transcripts, I noted one participant who made comments that reinforced the heteronormativity that underlies beliefs about women and men. A common informal narrative amongst the engineering academic community in my institution is that most of our students are entering university from high school and the young men, in particular, are often engaged in an overt heterosexual bravado. As P12 commented:

"And I think there's also the fact that you know the women are, like they're obvious! They're seen and seen to be women, and they're in a class where, you know, they might be 20, or 18 to 20 year old girls, women and along with that, you know, 5 to 6 boys, men of a similar age like it's hard to get around that. And University is a big mixer, and that is not a - not nothing".

P6, on the other hand, responded to a question about whether they were aware of people who identified outside the gender binary, by specifically talking about sexuality, and the ways in which human relations had changed since they had studied engineering:

"And it was perhaps you know people had an inkling but it just wasn't, at least in the circles I moved in we just left that well alone yeah. Whereas I think now it's accepted that there's going to be people who are straight, people who are gay, people who are something else altogether and that's fine, on the sexuality front. And then even beyond that now on the gender front there's an acceptance that there are people who identify as male, people who identify as female and then there's who knows what in between and that's okay.

I think, and I'll show my own biases here, I think, for a lot of us, so owning this ...

We find that a bit odd at times and go, don't get it, don't understand it, don't pretend to get it, even perhaps at times don't agree with it, but hey that's my personal view, I'm not going to let that affect someone else's opportunities or interactions here I'm *just going to let them come in and be a good engineer and be a good educator here, and do my best, and I wonder if a lot of students operate in the same mode now - same degree of acceptance, regardless of what they really think. Figuring, well at the end of the day, let's just accept one another and get on with life and make the most of life, yeah and supporting each other, which I think is a good thing".*

Both these comments speak to the separateness of social relations from knowledge relations in the beliefs of P6 and P12. In these accounts human sexual relations sit outside the engineering curriculum considerations. "Acceptance" in this view still reinforces a binary between the heterosexual "normal" as an opposite to "other".

Findings related to curriculum addressing empathy, emotions, and the human dimensions of engineering were present. In the area of knowledge relations in curriculum, the outer perceptions of engineering as relational and moral did begin to incorporate human-centred, ethical, and sustainability accountabilities. However, even in this domain, participants spoke of these areas in an instrumental way. Contrary to the empathy model proposed by Walther et al. (2017), there was very little discussion of emotions, aside from P5 who tentatively suggested that women might be over-represented in engineers who displayed empathy. P5 had introduced a journalling activity as a way of engaging students in thinking about personal feelings, a task which they commented was a much more comfortable undertaking for women students than men. I read this as an indicator that the curriculum in the context of my research study is largely silent on emotions in engineering, and as a consequence of the identities ascribed to women, likely to contribute to the double bind even further. "Technical" knowledge relations are what really count, and men are comfortable with that knowledge.

7.2.4 Gender relations of power

Gender relations of power are most revealed through my findings of perceptions of gender since these are connected to the social relations in disciplinary knowledge practices. Social relations (the regulative discourse) dominate knowledge relations (instructional discourse) meaning that in disciplinary knowledge practices in engineering, certain knowledge areas are not only valorised but also firmly associated with masculinity and a particular form of masculinity. Valorisation of “technical” knowledge and the relegation of “non-technical” knowledge to a generic mode, as professional skills and context, has powerful gendered impacts on students. It creates legitimate student identities that are not encompassing of femininity nor of the capabilities that are associated with women.

The professional skills that participants in my study ascribed to women are routinely described in the engineering education literature as being separate and distinct from engineering knowledge. Winberg et al. (2020) in their review of approaches to the development of employability in engineering call for recognition that professional skills are not generic while simultaneously maintaining them as separate to “disciplinary content”. Even as they suggest that there should be an integrated curriculum that incorporates professional skills, they maintain them as separate and distinct from the knowledge of engineering.

I would argue that rather than seeing professional skills as not engineering knowledge, we might create a curriculum in which we recognise singulars in social science and the humanities as being just as important as those from the natural and physical sciences and mathematics. This is in effect what Walther et al. (2017) call for in the introduction of empathy as a “core skill, practice orientation, and professional way of being". They flag within their presentation of a model of empathy that they have developed content which will be implemented into curriculum.

There are two arguments that could potentially be mounted against the idea of incorporating engineering social science and engineering humanities into the core of an engineering curriculum as knowledge areas. The first is that, given the perceptions that associate it with the strengths and capabilities of women, this simply reinforces cultural stereotypes about women. From my personal history, I would argue that this does not have to be the case. As I have grown older, I have reflected on the discomfort I felt when, once again, the suggestion for attracting more women to engineering is to show the way it is a caring, impactful, and altruistic profession. My discomfort and that of other women I know who remain in engineering is because our attraction to it stemmed from a deep interest in physics and mathematics, not in spite of it. Taking up a broader view of the underpinning knowledge in engineering is not about pandering to the stereotypes but rather about providing opportunities for all engineering students to engage in a curriculum that is truly authentic to the practice of engineering.

The second argument is that integrating knowledge across the apparent opposites of natural sciences and social sciences would be extremely difficult given their different knowledge structures. However, there are allied health curricula that comfortably achieve this. For instance, the study of chemistry alongside client care interactions in pharmacy or of biomechanics alongside social psychology and patient care ethics in physiotherapy. Thus, it is the combination of engineering knowledge as only engineering science alongside hegemonic beliefs about gender and women that creates unequal power relations.

Another unequal gender power relation is revealed in the findings that show the production of ignorance. As I noted in Chapter 5, many participants at some point in my interviews noted their reluctance to comment on gender due to a lack of knowledge, personal experience, or access to empirical evidence. In this way, participants are both reinforcing gender binaries and refusing to see them. The implications of this for women students are that it is unlikely that my participants see in classroom interactions or in their grading the ways in which gendered knowledge and social relations continue to create contested and uncomfortable conditions for women. Reflecting on my own personal history, I see this as an impossible choice – one cannot be a feminine engineer nor a masculine woman leaving women with an uneasy sense of their place within engineering.

Added to this production of ignorance about women and their experience of the gender power relations is a further lack of engagement with other forms of gender and sexual orientation diversity. Most participants either had nothing to say regarding encountering non-binary students or as P6 noted above spoke about them in a way that firmly placed them as an 'other' within the social relations of the educational context.

7.3 Gender regimes, knowledge relations and social relations in engineering curriculum

In concluding this chapter, I return to Figure 7.1 showing the knowledge relations in operation within my research context. Viewed through the lens of gender regimes, we see hierarchical binaries constantly reinforced, all of which reinforce the primary binary of masculine/feminine. This is shown in Figure 7.2. They are:

- Natural and physical sciences/social science and humanities
- Content/Context
- Technical/Non-technical
- Knowledge/Professional Skills
- Authentic engineering/Administration and organisational skills

In this picture of the knowledge relations and social relations in this engineering education context a woman who enjoys mathematics, is queer or is socially awkward does not fit the profile of an authentic engineering student nor of a woman engineering student. She does not see herself reflected in the curriculum nor do her engineering educators create an easy place for her to take up in the interactions with her mostly male student colleagues. Despite so much in our everyday lives being created and maintained by engineers, she may see no reflection of herself in the imaginary engineering practice of classroom experiences. There are possibilities, however, for those knowledge relations and social relations to be shifted. I take this up in the next chapter, discussing the implications and possibilities for change.

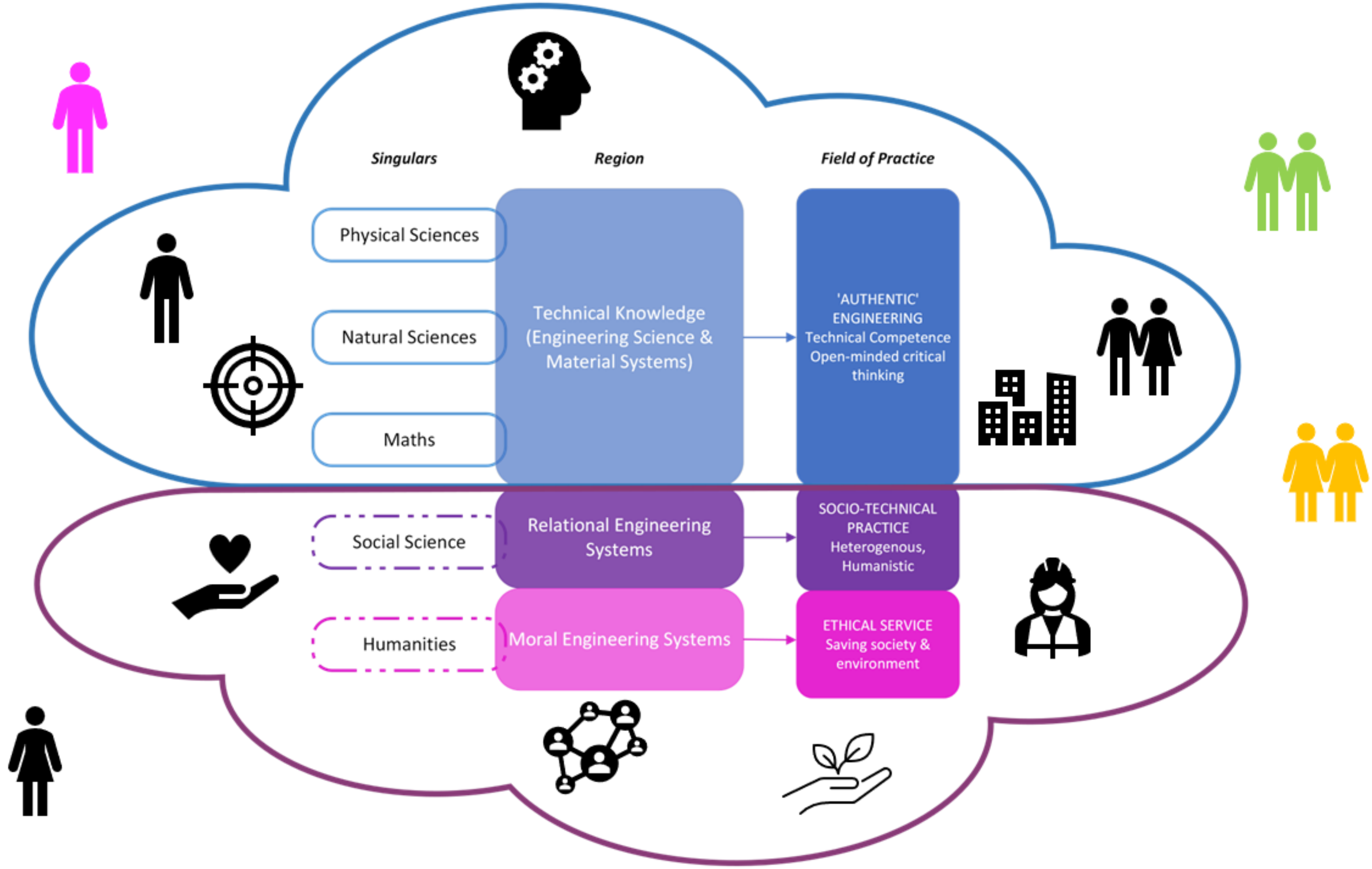

Figure 7.2 A model of the knowledge relations and social relations in curricular disciplinary knowledge practices.

Chapter 8: Study contributions, implications, and conclusion.

Having presented a model of gendered disciplinary knowledge practices, in this chapter I outline the contribution of my study to research in engineering education and discuss the implications for changing practices. I first outline what the research shows about the "doing" of gender in engineering curriculum before proposing actions and propositions for changing disciplinary knowledge practices towards a new virtual engineering practice that is more inclusive and aligned to achieving the potential of the engineering profession, as a public good as well as contributing to the development of an inclusive profession.

8.1 The "doing" of gender in engineering curriculum – contributions of the study.

The implications of the model presented in Chapter 7 are that disciplinary knowledge practices in the curriculum are "doing" gender in ways that are not conducive for women or gender diverse people to see themselves as 'authentic' engineers. By illuminating the contribution of academic perceptions to disciplinary knowledge practices in curriculum, I have highlighted the impact of academic decisions about the content, sequencing, assessment design, and teaching practices. These do not just contribute to the instructional discourse, the knowledge relations in engineering education. Rather they are also inextricably linked to the regulative discourse, the social relations that reflect systems of power and control that reinforce engineering knowledge as "technical" knowledge and as masculine.

This study has contributed to research in engineering education in three main areas. Firstly, the study has drawn together two theoretical frameworks: Bernstein's pedagogic discourse and Connell’s gender regimes, to create an analytical lens to interrogate gendered disciplinary knowledge practices in engineering education. This theoretical lens has been applied in this study via analysis of academic perceptions and discourse analysis of policy. Further applications of this analytical framework to the analysis of other aspects of engineering education such as pedagogic practices and student perceptions, particularly around assessment, would provide useful sites for interventions in engineering education aimed at addressing the challenge of gender diversity.

Secondly, the study has raised questions about the taken-for-granted assumption that the regionalised knowledge of engineering draws only on singular knowledge structures in the natural and physical sciences and mathematics. I question the view that “professional skills” should be viewed in opposition to “technical skills” and seen as generic mode knowledge or merely contextual. Instead, I suggest that a more critical conversation about “which singulars” contribute to engineering may lead to more complete picture of engineering knowledge as drawing also on engineering social science and engineering humanities. This would lead to a very different picture of the content required in an engineering curriculum and the assessment design and assessment practices.

Finally, I have shown how, at least within my context, engineering academic teams hold onto hegemonic beliefs about gender which have consequences for the women and non-binary students in their cohorts. Further, heteronormativity is a likely companion to these beliefs. These belief systems mean that attempts to change the student experience for women and non-binary people particularly in, for example, team-based projects are likely to start from flawed assumptions and to focus on strategies that simply reinforce unhelpful binaries. It is likely that these hegemonic beliefs about gender also influence the classroom climate and general discourses about engineering that exclude not just women and non-binary people but also men who do not align to a certain form of “techno-rational” masculinity.

By highlighting the critical role of academics, my study shows that paying attention only to attracting women into engineering study or providing extra supports to women as they study is unlikely to result in a substantial shift. This is not to say that Women in Engineering programs that focus in these areas are of no use but rather that they should be accompanied by frameworks for action within curriculum design and teaching practices in engineering as well as organisational environments that include professional engineers. What the study does point to are areas where there is a possibility of bringing about change, a change that focuses on creating a more inclusive curriculum and disciplinary knowledge practices that reflect a more realistic and inclusive view of engineering practice. In the next section I outline specific recommendations for changing practice.

8.2 Opportunities for change: curriculum, assessment, and teaching practices

Given that this study has focused on academic perceptions, the opportunities for change based on my research outcomes are focused on the design of curriculum, assessment, and the teaching practices of academic teams. In this section I identify four areas of intervention aimed in these areas:

1. Addressing hegemonic gender beliefs
2. Incorporating engineering social science and engineering humanities content into curriculum

3. Changing assessment practices, particularly grading criteria
4. Reviewing narratives about engineering within classroom practices, teaching texts, and images.

8.2.1 Challenge the binaries – disrupting hegemonic gender beliefs.

A common approach to addressing the perceived biases operating in engineering education and the engineering profession is to suggest the implementation of unconscious bias training. As I noted in Chapter 7 though, there is evidence to suggest that this does not have the impact that is expected. I would contend based on my research that the reason that unconscious bias training does not work is that it does not seek to challenge underpinning beliefs about gender. The premise of unconscious bias training is that it disrupts taken for granted assumptions about the nature of people of a particular gender. For example, it questions the stereotype of all women being assumed to be natural carers. The problem with this approach, however, is that it does not disrupt the first step in our thinking: that of assuming that gender objectively exists and that it is a binary. When one holds onto beliefs about gender that assume it to be an inherent characteristic of a person, unconscious bias training does not focus on disrupting the first step in thinking: that of identification of a person as having a gender, but rather focuses only on the second, i.e. the stereotypes that flow from identification. We can still be left with beliefs that there is a category of people in the world who are women. This is what leads to the circular arguments that one of my participants identified. That is, we can make engineering more attractive to women by making it seem more stereotypically feminine.

My first recommendation for action then is to shift an academic development focus from unconscious bias training to one that focuses on gender beliefs and their implications for engineering practice and engineering curriculum. Some of this work is currently developed within the training for becoming an LGBTIQA+ Ally in my institution but there are limited numbers of people in my faculty who have undertaken the training and it is not directly related to our educational practice. A next step would be to build from this to create development opportunities focused on the implications for engineering curriculum, particularly assessment. By development in this context, I do not mean to imply the creation of a one-off opportunity such as is often provided for unconscious bias training or indeed the Ally training mentioned above. Rather my aim is to disrupt the discursive repertoires that have developed over time within the social context of an academic teaching team (Trowler, 2008). I foresee this as a long-term project, requiring constant questioning and discussion within many curricular conversations. Nonetheless, I see this as being vital to support the other recommendations.

8.2.2 Bring explicit curricular focus to engineering social science and engineering humanities: content

Across my study, the binaries around technical and non-technical, knowledge and skills, and masculine and feminine are reinforced through another binary around content and experience. While the non-technical, professional skills are seen as being a strength of women but as not 'authentic' engineering, there continues to be an uneasy place for those who identify as both woman and engineer. For curriculum to authentically reflect knowledge and practice in engineering, there needs to be a recognition that the regionalised knowledge of engineering draws on more than the singulars within mathematics and physical sciences.

While claiming to be outcomes-based accreditation, Engineers Australia through their Accreditation Management System nonetheless suggests that programs “are expected to include” certain percentages of content, which they suggest are areas of “student effort” (see Figure 8.1 below) (Engineers Australia, 2019). This requirement is followed by the rather confusing advice that the proportions reflected in the table are not mutually exclusive and that “while some are principally related to content, others relate more to learning processes”. The analysis of my participant interviews showed that there is an understanding that content is associated with those areas that academics teach through scheduled in class activities such as lectures or tutorials and that content maintains high value as engineering knowledge. I contend that curriculum in engineering would more appropriately reflect both the ‘field of production’ and the field of external practice if it recognised that there is knowledge and content that can be drawn on from engineering social science and engineering humanities. The recognition that knowledge of social sciences might contribute to engineering is seen in the engineering education research around empathy that I highlighted in Chapter 7 (Walther et al., 2017).

This is particularly pertinent to address a contradiction that I see reflected in the scant provision of content on aspects of engineering practice that could be grounded in engineering social science knowledge such as stakeholder engagement or negotiating within an engineering design team. Often these are framed as knowledge-free or contextual skills that will be developed through experiences alone. In the case of there being content on these areas, academics will often invite in careers educators or third space professionals who link the need for this content to future career success by asking students to search for graduate engineering jobs and reviewing the position capabilities listed. These almost always include statements about effective communication or working in a team. A focus on the field of external practice might suggest this would translate into required content, but this is rarely the case.

Areas of content (student effort)	**Proportions of Learning by qualification**		
	Professional Engineer	*Engineering Technologist*	*Engineering Associate*
Underpinning mathematics, science, engineering principles, skills and tools appropriate to the discipline of study and qualification	*≥ 40%*	*≥ 40%*	*30%*
Engineering design and projects	*≈ 20%*	*≈ 20%*	*30%*
An engineering discipline specialisation	*≈ 20%*	*≈ 20%*	*15%*
Integrated exposure to professional engineering practice, including management and professional ethics (approximately 10%	*≈ 10%*	*≈ 10%*	*15%*
More of any of the above elements, or other elective studies	*≈ 10%*	*≈ 10%*	*10%*

Figure 8.1 Areas of content required in for an accredited programme according to Engineers Australia's Accreditation Management System (Engineers Australia, 2019)

The idea that engineering curriculum should broaden the underpinning knowledge of graduates is not new. In 1996, a national review of engineering education in Australia included the following statement:

> "The present emphasis placed on engineering science resulting in graduates with high technical capability, has often acted to limit their appreciation of the broader role of engineering professionals." (The Institution of Engineers Australia, 1996)

From this study, I suggest that we need to move beyond broad statements of required capabilities and cursory inclusion as generic or professional skills and realise in curriculum content that focuses on engineering social science and engineering humanities knowledge as being key to ensuring that engineering curriculum reflects engineering practice and that graduates can engage critically as professionals.

8.2.3 Change assessment practices to value a broader view of engineering knowledge

Curriculum content reflecting engineering social science and engineering humanities requires an accompanying shift in the approach to assessment and to grading. Currently in my context institutional assessment policy suggests that grading of assessment should be “standards-based” and that criteria and standards in the form of a rubric should be shared with students at the time of assessment release. A simple (but not easy) shift in reflecting a broader knowledge underpinning could be achieved by ensuring that all engineering project assessment included criteria that focus on engineering social science and engineering humanities and not just from a generic skills perspective. Currently a student who actively rejects the need to collaborate effectively with colleagues and isolates themselves in doing the technical aspects of a project is actively rewarded in their grade in most team projects. Academics in my study suggest that this is overwhelmingly likely to be a male student. Another student, who invests effort in managing engineering team processes and is left with the engineering technical writing or presentation tasks may well be left doubting their own technical and engineering capability and not actively rewarded through grades. My participants described this as being a role often undertaken by women.

One professional skill that has had considerable attention in engineering education research is teamwork. As noted in Chapter 2, team projects can be a site of active marginalisation of women. And yet, overwhelmingly the assessment of teamwork skills in engineering involves a process of peer review whereby students are asked to provide feedback on their peers within a team, in some cases without any active instruction focused on knowledge around the practice of working in a team. For example Pieterse and Thompson suggested that the learning of teamwork skills in their study was done “in an informal way” with an expectation that students would work as active members of their teams but that they “did not closely supervise them” (Pieterse & Thompson, 2010). I would argue that providing so little by way of learning experiences and content to develop knowledge of team processes and using only peer reflections to assess teamwork capabilities simply reinforces embedded biases and risks active marginalisation of women. Without some critical engagement with knowledge about how engineering teams operate, students are judging each other in peer review with no underpinning knowledge on which to base that judgement and a lack of critical engagement or reflection on their experiences beyond the everyday, biased stereotypes of engineering and of gender.

Studies often report on the experience of “high performing” students in teams who become “diligent isolates”, that is they explicitly seek to work alone on technical outcomes (Pieterse & Thompson, 2010). My argument regarding changing assessment practices is to suggest that if engineering is viewed as a regionalisation of more than the mathematical and physical sciences, then our content and assessment regimes ought to reflect that. That is, a “high performing” student ought to have succeeded not just in the technical knowledge and skills but also in team knowledge and skills. Barr and Clerck’s study of student perspectives on teams reports on gender bias in a manner that reflects current approaches to the design of assessment of engineering projects, i.e. that despite teamwork being important to engineers, it is not a requirement for academic success in engineering (Barr & De

Clerck, 2018). Their study, along with others, suggests that to remove the gender bias we should make sure that women get to exercise their technical capabilities too. The study does not suggest that an alternative is to reflect to men who act as “diligent isolates” that they are not actually effective engineers. This recommendation links to disciplinary knowledge practices in the field of reproduction seeking to question and reframe the evaluative rules of disciplinary knowledge practices in this domain. To achieve this requires a critical conversation with the academic teaching team and students to consider assessment design and grading practices that reform these rules.

8.2.4 Review the narratives about engineering that classroom practice, teaching texts, and image choices reveal

While the outcomes of this study may seem to suggest that there is a long way to go to change engineering disciplinary knowledge practices in curriculum, there is some cause for optimism, particularly as it relates to participant interview data. All my participants expressed a desire to increase the number of women in engineering and recognised that one of the challenges was in the everyday discourse around engineering and what engineers do. My final recommendation for action is to focus on the everyday experiences of engineering academics and engineering students that reinforce unhelpful stereotypes about engineering, alongside hegemonic gender beliefs. Textbooks, marketing materials, media images, and even current teaching and learning discourses into which engineering academics enter all work to create a narrative that reinforces certain taken-for-granted assumptions about engineering practice and about ways to increase the number of women.

Shifting this narrative is challenging. In reflecting on ways in which this might be achieved, I have looked to other sectors and other contexts for strategies that might be trialled within an engineering education context. One such evidenced based example comes from the University of Calgary project, “Shift: The Project to End Domestic Violence” and their report on frameworks for engaging male-oriented settings in gender equality and violence prevention (Dozois & Wells, 2020). They explore a key construct that is described as “flooding the system with signals”. This is a process of consistent signalling across interpersonal and individual behaviours, and local arrangements of discourses and practices supported by structural and systemic (institutional) policies, procedures and norms. At the individual level, this refers to building capacity for micro-interventions that prevent or counter micro-aggressions, for example.

In my context and via my role, I aim to shine a light on current ‘harmful’ signals that reinforce gendered inequality within curricular disciplinary knowledge practices. I can then seek to leverage local protocols and artefacts to try to shift those signals. For example, currently there is very little consideration given to the impact of the choice of images or textbooks in curriculum with a taken for granted assumption that this choice should be driven only by academic expertise. However, the development of a checklist or the incorporation of a key question in current academic peer review processes signals that more thought is required around the impact of that choice. This is not a recommendation that I can carry alone but I am optimistic that I can recruit others, both from my participants and a broader academic teaching team, to create opportunities for flooding our context with everyday conversations about gendered inequality. Indeed, I consider that without these small scale, everyday interventions larger scale projects run the risk of not disrupting current practices.

8.3 Conclusion: Changing from within

As a conclusion to this section of contributions and recommendations and the thesis, I note once again that the "problem" of women in engineering is not a new one and projects aimed at changing the situation have operated for many years with mixed success (Stonyer, 2001). The overriding theme of the recommendations I have made here is that the focus of change must traverse individuals (potential students, students, academics, professionals), the local context, the engineering education system, and broader socio-cultural norms. It must also start from a question about gender and what that means in a contemporary university engineering education context. I am optimistic that there is a growing community of educators and professionals, both within my own institution and more broadly who are willing to grapple with this complexity and to work towards change.

Through this thesis I have developed a framework to illuminate the gendered disciplinary knowledge practices in curriculum, from the perspective of academics in the teaching team at my institution. While I have shone a light on only one aspect of those disciplinary knowledge practices, it shows the complex ways in which experiences of gender and of engineering are intertwined in the engineering education systems that operate at my university.

One part of my academic role is to present to prospective students, generally those in high school who have come with their parents to hear me speak about what it is like to study at my institution and to begin on the career path towards the engineering profession. I find these events to be uplifting because as I often remark, the work of engineers is everywhere. Engineers create, construct, develop, and maintain so many systems that we interact with every day from transport systems to food production, from my laptop to my washing machine. And yet overwhelmingly the people who are creating, constructing, developing, and maintaining these systems represent a very narrow group of people.

The ubiquitous nature of engineering systems means that they should reflect and be created by a diverse and representative group from across society. I hope that my contributions in this thesis open new possibilities for creating more inclusive engineering curriculum, not by a simplistic re-rendering of what is already there but by a deeper engagement in thinking about the nature of engineering knowledge and starting from a different understanding of gender. I seek this, not just for women, but for the small but growing numbers of students who identify as non-binary or who represent diversity in sexual orientation and many other intersectional backgrounds. I often tell my students that engineering is about imagining a future that does not yet exist and then designing it to be a safe, reliable, and functional reality for the human beings it serves. I believe this project of inclusivity should be approached in exactly the same way.

Appendix 1 – Interview Protocol

In this study I am interested in the ways in which educators think about gender and the engineering profession and how they relate that to their teaching and learning in engineering.

I'd like to talk to you about your teaching more broadly and your views on what it is to be a professional engineer.

Then I will move on to a specific conversation about gender.

What subjects or units do you currently or generally teach?

When you are planning for and delivering that subject, what view of professional engineering or a Professional Engineer do you have in mind? *(Prompt with below if needed)*

- What can they do?
- What words would you use to describe a Professional Engineer?
- What are their characteristics?
- What distinctive ways of working and thinking do engineers do?
- What kinds of values are important?

What kind of engineer do you see emerging from the engineering education you provide?

Now, when you think of that view of a professional engineer and engineering, do you think some of those ways of thinking and working are gendered?

Which parts of engineering?

Are those characteristics particularly masculine or feminine? Why?

Can you give me some examples?

What teaching approaches/pedagogy do you use in teaching your subject?

Thinking about the student cohort you teach, do they differ in the way they receive the subject matter or the teaching approach, by gender?

Do men and women respond differently to your subject?

Do you notice that men and women have different experiences or behave differently in your classes?

Can you give me some examples?

[What characteristics do you see in a “good” student in your subject?]

Why do you think we continue to see low numbers of women studying engineering and staying in the profession?

What is distinctive about women who study engineering? Do they differ from other women?

What about men? Are they distinctive from other men?

What responsibilities do you think we have as educators to change that?

Appendix 2 – Participant Information Sheet and Consent Form

Participant information sheet

Gender and Engineering: Conceptions of Engineering Educators

For further information about how Lancaster University processes personal data for research purposes and your data rights please visit our webpage: www.lancaster.ac.uk/research/data-protection

I am a PhD student at Lancaster University, and I would like to invite you to take part in a research study about the ways in which engineering academics think about the profession of engineering and gender when they are teaching.

Please take time to read the following information carefully before you decide whether or not you wish to take part.

What is the study about?

This study aims to investigate the ways that engineering academics think about their profession and about gender when they are designing and delivering subjects of study.

Why have I been invited?

I have approached you because you are an engineering academic at an Australian university who is teaching engineering subjects in an undergraduate engineering degree.

I would be very grateful if you would agree to take part in this study.

What will I be asked to do if I take part?

If you decided to take part, this would involve being interviewed by me, using Zoom. I will ask you a series of questions related to your teaching, your views about the engineering profession and any ways in which you consider gender to influence both teaching practices and student experience. I will record the interview. You can indicate to me whether you prefer that recording to only be audio. I will then analyse the transcripts of all the interviews I conduct. You will be one of approximately 25 people interviewed.

What are the possible benefits from taking part?

If you take part in this study, you will contribute to a greater understanding of the ways academics think about gender in engineering and how that might influence decisions in teaching practice. This may help to explain ways we can change teaching practice to create more inclusive learning environments.

Do I have to take part?

No. It's completely up to you to decide whether or not you take part. Your participation is voluntary.

What if I change my mind?

If you change your mind, you are free to withdraw at any time during your participation in this study. If you want to withdraw, please let me know, and I will extract any ideas or information you contributed to the study and destroy them. However, it is difficult and often impossible to take out data from one specific participant when this has already been anonymised or pooled together with other people’s data. Therefore, you can only withdraw up to 2 weeks after taking part in the study.

What are the possible disadvantages and risks of taking part?

It is unlikely that there will be any major disadvantages to taking part. You will need to invest 60 to 90 minutes of your time in the interview.

Will my data be identifiable?

After the interview, only myself, the researcher conducting this study, and my supervisor will have access to the ideas you share with me.

I will keep all personal information about you (e.g. your name and other information about you that can identify you) confidential, that is I will not share it with others. I will remove any personal information from the written record of your contribution. All reasonable steps will be taken to protect the anonymity of the participants involved in this project

How will we use the information you have shared with us and what will happen to the results of the research study?

I will use the information you have shared with me for research purposes. This will include my PhD thesis and other publications, such as journal articles. I may also present the results of my study at academic conferences and in academic development activities within my own and other institutions (such as workshops to talk about teaching).

When writing up the findings from this study, I would like to reproduce some of the views and ideas you will share with me. I will only use anonymised quotes (e.g. from my interview with you), so that although I will use your exact words, all reasonable steps will be taken to protect your anonymity in our publications.

How my data will be stored

Your data will be stored in encrypted files (that is no-one other than me, the researcher will be able to access them) and on password-protected computers. I will store hard copies of any data securely in locked cabinets in my office. I will keep data that can identify you separately from non-personal information (e.g. your views on a specific topic). In accordance with University guidelines, I will keep the data securely for a minimum of ten years.

I will make the transcriptions of interviews available for future use by other researchers. I will exclude all personal data from archiving. I intend to archive the data via the Lancaster University Research Data Archive.

What if I have a question or concern?

If you have any queries or if you are unhappy with anything that happens concerning your participation in the study, please contact myself or my supervisor:

Karen Whelan, k.whelan@qut.edu.au

Supervisor: Carolyn Jackson, c.jackson2@lancaster.ac.uk

If you have any concerns or complaints that you wish to discuss with a person who is not directly involved in the research, you can also contact the Head of Department, Educational Research: Paul Ashwin, paul.ashwin@lancaster.ac.uk

Sources of support

This study has been reviewed and approved by the Faculty of Arts and Social Sciences, Lancaster University

Thank you for considering your participation in this project.

CONSENT FORM

Project Title: Gender and Engineering: Conceptions of Engineering Educators

Name of Researcher: Karen Whelan
Email: k.whelan@qut.edu.au
Please tick each box

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily	☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time during my participation in this study and within 2 weeks after I took part in the study, without giving any reason. If I withdraw within 2 weeks of taking part in the study my data will be removed.	☐
3. I understand that any information given by me may be used in future reports, academic articles, publications or presentations by the researcher/s, but my personal information will not be included, and all reasonable steps will be taken to protect the anonymity of the participants involved in this project.	☐
4. I understand that my anonymised data will be offered to Lancaster University research data archive (Pure) and will be made available to genuine research for re-use (secondary analysis)	☐
5. I understand that my name/my organisation's name will not appear in any reports, articles, or presentation without my consent.	☐
6. I understand that any interviews will be video and /or audio-recorded and transcribed and that data will be protected on encrypted devices and kept secure.	☐
7. I understand that data will be kept according to University guidelines for a minimum of 10 years after the end of the study.	☐
8. I agree to take part in the above study.	☐

Name of Participant ____________ Date ____________ Signature ____________

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

Signature of Researcher /person taking the consent__________________________

Date ___________ Day/month/year

One copy of this form will be given to the participant and the original kept in the files of the researcher at Lancaster University

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