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Realising the Educational Potential of Mass Higher Education

Paul Ashwin, Margaret Blackie, Jennifer Case,
Jan McArthur, Nicole Pitterson, Reneé Smit,
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Bloomsbury Higher Education Research

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In memory of Claire Callender: a brilliant, thoughtful, and deeply humane friend and colleague who was a strong supporter of the two projects that underpinned this book.

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Series Editor's Foreword

Realising the Educational Potential of Mass Higher Education is published as part of the Bloomsbury Higher Education Research book series. This series brings to the public, government and universities across the world the ideas and research evidence generated by researchers from the ESRC Centre for Global Higher Education,[1] which was supported by £6.4 million in three successive ESRC awards from November 2015 to May 2024 and continues as an ESRC Legacy Centre in 2024–9. CGHE's founding director was Simon Marginson (2015–24), and its present director is David Mills. CGHE continues an active webinar and globally networked research programme in the Legacy Centre phase, which is supported by a small additional ESRC grant of £100,000.

The ESRC decision to fund CGHE constituted recognition of the growing importance of higher education and the associated research, in social, economic, cultural and political life. In 2022, there were more than 260 million enrolled tertiary students and more than three million new research papers entered the main bibliometric collections, Web of Science and Scopus. The creation of CGHE was also a recognition of the importance of the cross-border and global dimension. Globalisation – global integration and convergence – is a contested and uneven process, but it continues to roll out. A quarter of all published research papers involve joint authorship across national borders. Almost seven million students worldwide cross borders for education of a year or more. Global movements of students, academics and researchers, knowledge, information and money help to shape not only nations but the international order itself. Worldwide capacity in higher education and research is becoming more plural. Whereas until the early 2000s Anglophone and Western European universities, together with Japan, were dominant at the world level, rising universities and science in China, the rest of East Asia and Singapore are now reshaping flows of knowledge and higher education. The European Higher Education and Research

1 ESRC refers to the UK Economic and Social Research Council. Part of the 2015–20 ESRC funding that supported the first phase of Centre for Global Higher Education's research was sourced from the then Higher Education Funding Council for England (HEFCE). Research England, one of HEFCE's successor bodies, provided financial support in 2020–3 in CGHE's second award phase.

Areas are flourishing. Latin America, South East Asia, India, Central Asia and the Arab nations have a growing global importance. The trajectories of education and research in sub-Saharan Africa are crucial to state-building and community development.

Perennial research questions about higher education continue. How can scarce public budgets provide for the public role of higher education institutions, for a socially equitable system of individual access and for research excellence, all at the same time? What is the role for and limits of family financing and tuition loan systems, or should higher education be provided on a universal taxpayer-funded basis, free of charge? What is the potential contribution of private institutions, including for-profit colleges? In national systems, what are the best balances between research-intensive and primarily teaching institutions, and between academic and vocational education? What are the potentials for online delivery and artificial intelligence in extending access and knowledge? What is happening in graduate labour markets, where returns to degrees are becoming more dispersed between families with differing levels of income, different kinds universities and different fields of study? Can larger education systems provide better social mobility and income equality? How does the internationalisation of universities contribute to national policy and local societies? Does mobile international education expand opportunity or further stratify societies? What are the implications of populist tensions between national and global goals, for higher education and research? And what can national systems of higher education and science learn from each other, and how can they build stronger common ground and cooperate more effectively?

CGHE has taken the investigation of some of these questions forward. During its full award period, the centre was a partnership of researchers from fifteen UK and international universities, the world's largest concentration of expertise in relation to higher education and its social contributions. It employed over twenty people as postdocs and in junior researcher posts, and carried out fifteen discrete research projects in the first funding phase 2015–20, continuing eight of these into the 2020–4 phase, along with two new projects. In the 2015–24 period, CGHE's researchers generated 110 CGHE Working Papers; 35 CGHE Policy Briefings, short CGHE Research Findings and longer CGHE Research Reports; and 1,090 discrete publications in the academic and policy-related literatures, including books and journal papers.

Outputs from CGHE's affiliated researchers are continuing, with several longer-term CGHE projects producing substantial publication lists in the first year of the Legacy Centre, including those focused on student learning in STEM, research in higher education and the public good role of higher education. Information about CGHE's publications, webinars and other continuing activities can be found at https://www.researchcghe.org/. *Realising the Educational Potential of Mass Higher Education* is the thirteenth monograph in the Bloomsbury Higher Education Research series and the fourth to be published in six months, all of them available on an Open Access basis. More information on the Bloomsbury Higher Education Research series can be found at https://www.bloomsbury.com/uk/series/bloomsbury-higher-education-research/

Simon Marginson
Professor of Higher Education, University of Oxford
Director, ESRC Centre for Global Higher Education 2015–24
Editor, Bloomsbury Higher Education Research series

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This book could not have happened without the Pedagogic Quality and Inequality Project, a longitudinal study tracking students through their undergraduate degrees in Sociology in the UK. The research in this book seeks to extend that work by looking internationally at chemistry and chemical engineering and following the participants beyond graduation. We hugely appreciate the work that Monica McLean and Andrea Abbas did in the sociology project and their generosity in allowing us to build on that work.

Dee Daglish was the heartbeat of the study, providing kindness, support and love throughout our work together. Thank you, Dee, for your outstanding work. We would also like to thank Janja Komljenovic, Jasmine Matope, Johnson Carroll, Kevin Krost and Indhira Hasbun for their important contributions to the project.

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Why Focus on Realising the Educational Potential of Mass Higher Education?

This book is an investigation of the educational potential of mass higher education. We are writing at an inauspicious time for mass higher education. In many countries, there appears to be a turn away from higher education and a feeling that it has not lived up to its promises or its potential. In this chapter, we focus on this contentious context and argue that this sense of disappointment stems from a misunderstanding of the potential of mass higher education, which has led policy makers and university leaders to focus on the wrong aspects of the education offered through higher education. We argue that higher education needs to be released from this impoverished vision in order to refocus on its core purpose of providing access to powerful knowledge, through which students can change the ways they engage with the world and change their understanding of themselves. This argument is based on a seven-year longitudinal study of people who studied chemical engineering and chemistry in England, South Africa and the United States.

In this chapter, we first explain what we mean by the educational potential of mass higher education and why we focus on it. We situate our study in the context of a contemporary disillusionment within mass higher education in marketised higher education systems. We outline our theoretical framework and explain the focus and the design of the study that underpins the arguments in this book. We then set out the structure of the rest of the book.

The central question addressed in this book

The title of this book is tightly packed with words that signify what we are trying to achieve: 'realising', 'potential', 'educational' and 'mass higher education', and it is important to briefly consider what we mean by these terms.

We use the term 'mass higher education' in a particular way. As we will discuss later in this chapter, this way of thinking about higher education is often, and rightly, linked back to the work of Martin Trow (1970, 1973). However, too often the element of Trow's work that is foregrounded is the percentages of the population of the relevant age engaging in higher education at which the shift from elite to mass (15 per cent) and mass to universal (50 per cent) higher education takes place (Scott 2019). The more important aspect of Trow's work was characterising the changes in higher education systems as they transitioned between these different phases. We focus on mass higher education because it is at this stage that higher education is considered open to anyone who is qualified, and there is an increase in the variety of forms of higher education in order to meet the needs of a greater variety of students. Our intention is to focus on education that is open to all rather than elite higher education that identifies the so-called brightest and the best. The position we take is that the societal benefits of higher education are best realised when it nurtures talent in every student rather than only acting as a selection and sorting machine (see Ashwin 2020 for a fuller argument for this position).

'Realising' the potential of mass higher education is about how we develop an understanding of the potential of mass higher education and also about how we achieve that potential. 'Potential' is about the possible power of mass higher education, but also about the conditions that are necessary for that potential to be achieved.

'Educational' signals that we are focused on the education that is offered through mass higher education. Many important discussions of mass higher education tend to focus more on questions of systems of higher education and the relationships between students, institutions and the state within these systems rather than foregrounding the educational role of such systems (for example, Trow 1973; Scott 1995, 2021; Cantwell et al. 2018). Discussions of systems are just as important as questions of education. However, we argue that it is important to consider the *kind* of education provided by mass higher education, which tends to be obscured, or at least taken for granted, in system-level debates.

Taken as a whole, the central question of the book is how to understand and achieve the educational power of mass higher education so that all students can benefit from it, and what is needed to make this a reality. As such, this is an (overly?) ambitious book. Based on our study of participants who studied chemistry and chemical engineering, we were able to develop a detailed, evidence-based argument for what makes an educationally rich mass higher education. Clearly, this goes way beyond our data. However, we put the findings in relation to the extensive body of research on undergraduate education in higher education. Across our research team, we have been engaged in contributing to and synthesising to this body of knowledge over more than twenty-five years (for example, Ashwin 2009, 2020; Blackie et al. 2010; Smit 2012; Case 2013; McArthur 2013, 2020; Ashwin et al. 2015b, 2020; Case et al. 2018; McLean et al. 2018; Pitterson et al. 2018).

Debates over the nature of mass higher education

As higher education has grown around the world, it has become one of the central institutions in human society. From 2000 to 2022, global enrolment in higher education, defined as tertiary education, rose from 19 to 42 per cent of young people (UNESCO 2024). Marginson (2018a) argued that this expansion in global higher education was shaped by three broad trends that combined in distinct ways in different national settings. These are: (i) massification, (ii) intensification of competition and marketisation, and (iii) a partial global convergence and integration of national systems through processes tied to globalisation. Marginson (2018a) observes that whilst massification is the most universal of these trends, much less is written about it than is written about competition, marketisation or globalisation.

Trow's account of mass higher education

As we highlighted earlier, most of what is written about mass higher education is, to some extent, shaped by the work of Martin Trow (1970, 1973). Trow (1973) wrote from the perspective of the United States as the first mass system of higher education (Cantwell 2018) and positioned mass higher education as part of a triptych of elite-mass-universal higher education (Scott 2021). Trow (1973) was clear that the ideal types of elite, mass and universal higher education can coexist. As we will discuss further in Chapter 2, his major contribution was to show that these different types of higher education have different functions and different forms. Elite higher education is about forming the minds and characters of the ruling class through a specialised academic education that is centred on building personal relationships between scholars and students. Mass higher education is intended to produce a broader range of graduates through more modular and flexible education experiences and is grounded in much larger and more impersonal group settings. Universal higher education is far less structured and is positioned as being just another experience in modern society, rather than a qualitatively different educational experience. In universal systems, educational relationships are much more at a distance than in elite and mass systems.

Trow (1973) was a strong advocate for the growth of higher education, who regarded diversity of institutional types, missions and educational purposes as key to this expansion. Throughout his career, Trow was critical of those in British higher education who wanted to maintain a high and uniform quality of undergraduate degrees across the system, seeing this as a barrier to the expansion of the benefits of higher education to a greater number of people and as being based on a naïve belief in the possibility of a single academic standard (Trow 1969, 1998; Burrage 2010).

As Scott (2019) argued, Trow was a strong believer in elite higher education and the opportunities to flourish afforded to individuals by elite institutions, which he felt could never be replicated by mass institutions. The problem with Trow's position was that it profoundly underappreciated the ways in which expanding access through a differentiated system of higher education, whilst initially reducing inequalities, can quickly serve to entrench social, economic and educational inequalities (Cantwell & Marginson 2018; Espinoza et al. 2024; TASO 2024). Trow appeared to completely miss that access to elite institutions within a massified system tends to favour people who are more socially and economically privileged (Marginson 2018b). In this way, the promise of mass higher education to reduce inequality is undermined. This inconvenient truth is presently playing into a widespread populist discontent with higher education, undermining the higher education project as a whole, as higher education is seen on the wrong side of history and as part of an entrenched middle-class elite (Scott 2021).

Contemporary disillusionment with mass higher education in marketised systems

As higher education systems have grown, they have tended to become increasingly marketised (Jungblut & Vukasovic 2018; Marginson 2018a). Not all higher education systems have become equally marketised and, as Jungblut and Vukasovic (2018) show, marketisation has taken different forms in different countries. In countries where marketisation has been informed by the logic of neoliberalism, there has been an increasing sense of disillusionment with mass higher education (Marginson 2016; Busch 2017; Walker 2018; Mintz

2021; Cantwell et al. 2022; Waghid 2022; Bradbury 2023). For example, in the United States, as the private costs of higher education have risen and graduate outcomes have become more uncertain, there has been an increasing sense that higher education has broken its promises (Slaughter 2017), leading to a crisis of confidence in higher education (Brown 2024). The Covid-19 global pandemic intensified this sense of crisis across marketised higher education systems, putting financial pressure on institutions, as well raising questions about the forms of education they offer and whether they are properly preparing students for further employment (Bebbington 2021; Goedegebuure & Meek 2021; Treve 2021; Molla & Cuthbert 2023; Tomlinson et al. 2023).

These economic questions about higher education have been further amplified by concerns from both sides of the political spectrum about marketised mass higher education. On the political left there is a sense of the betrayal of the promise of higher education with lower quality education offered to students, a loss of autonomy for the academic profession and higher education institutions being turned into businesses focused on prestige and money rather than the stewardship of knowledge (for example, Fleming 2021; Secret Lecturer 2024). From the right, a prominent charge is that higher education has been taken over by a left-wing elite (Ellis 2021) and that it does not provide anything of educational value to students that could not be gained from the internet (Caplan 2018). Outside of these overtly political positions, there are those who campaign against so many young people going to university and being left with a lifetime of debt (Wiltshire 2024).

Whilst coming from different directions, what these perspectives have in common is a concern that, in the move to mass higher education, educational rigour has been lost. The charge is that, as higher education is marketised and a greater variety of students are given access to it, there are more and more students who are not interested in learning studying in educational institutions that are not focused on educating them. A key part of this sense of disillusionment is that mass higher education is perceived as offering low-quality education, whilst burdening newer generations with terrifying debt (Mettler 2014; Marginson 2016).

In understanding this disillusionment with mass higher education, we must also recognise that many of these complaints are not new (Macfarlane 2024). The idea of the 'disengagement compact', in which academic staff give students good grades for low-quality work provided students give positive ratings of their low-quality teaching, has been around since the 1990s (Kuh 1991). Indeed, concerns about the quality of students are found in the earliest forms of writing in now dead languages (Jordan & Fink 2023). In the 1930s, Eells (1934, p. 399), writing about critics of higher education in the United States, wrote:

> *As for the students, the fact is that in the opinion of these critics not more than a quarter of the undergraduates have first-rate minds. Not more than half of them are capable of receiving any real intellectual benefit from a college education. The other half simply are not educable; they can neither see, nor hear, nor think; they have no disposition to work, nor capacity for sustained effort. Only a small minority think of anything beyond athletics, fraternities, and social trivialities; education as applied to their training is a travesty on the word. Half of the Seniors are semi-illiterates; anyone can graduate if he is not absolutely a fool.*

In the 1960s, Sanford (1962, p. 10) was critical of the education offered by US higher education institutions: '*A close look at the college-educated people in the United States is enough to dispel any notion that our institutions of higher education are doing a good job of liberal education*'. Sanford (1967) later wrote a book on the failure of higher education institutions in the United States. Such criticism was not limited to the United States. Writing in the 1940s, Moberly (1949, p. 174) described students in the UK as '*fundamentally uneducated*'.

These kinds of criticisms tend to resurface at moments of crisis. In relation to more recent crises of higher education, Macfarlane (2024) traces four overlapping crises, starting with a massification crisis, then shifting to a marketisation crisis, followed by a restitution crisis focused on addressing those excluded from higher education and a geopolitical crisis related to wars, political repression, the climate and nature emergency and Covid-19. It is important to note that these crises are emerging at a moment when higher education is socially pervasive, with the vast majority of young people in nearly all countries at least aspiring to participate. This suggests that the current disillusionment with mass higher education may be more a result of its success in growing than its failures (Scott 1997; Brint 2018).

The position taken on mass higher education in this book is strongly informed by, and in agreement with, Scott's (2021) seminal work surveying the origins of the current crisis of mass higher education and proposing a way forward. His stance is that the disillusionment with mass higher education arises from a failure to recognise its achievements, how it works and the conditions that it needs to thrive. In a similar vein, Watson (2014) developed a Hippocratic Oath for higher education that, amongst other things, highlighted the importance of higher education telling the truth, being careful with the truth, keeping its promises and guarding its treasure. In this book, we hope to contribute to helping higher education to honour this oath by making a case for what is needed to realise the educational potential of mass higher education.

The educational purposes of mass higher education

We have argued so far that what is needed is a stronger sense of the educational purposes of mass higher education. Questions over the educational purposes of higher education are always related to the concerns at a particular moment in time and geographical location (Ashwin 2022). For example, Moberly's (1949) concerns arose from an anxiety over the fragmentation of knowledge and the loss of a synoptic and Christian view of the intellectual world which, he was clear, British higher education should provide. In more pluralistic societies, this is not something that would be considered to constitute a crisis. So, what are the purposes of mass higher education in a system that is focused on expanding access to a wider range of students and is founded on bodies of knowledge that are increasingly diverse and contested (Marginson 2022)? We explore three such purposes: education for employment, education for personal development and education for engagement with knowledge.

The educational purpose of mass higher education as preparing students for employment

In marketised higher education systems, the dominant policy response to the question of the educational purposes of mass higher education tends to be framed in terms of employment outcomes (for example, Biesta 2011; OECD 2017; Fryer 2022, 2024; Scott 2022; Molla & Cuthbert 2023; Schleicher 2024). This dominance is connected to the strong influence human capital theory has had on higher education policies (Olssen & Peters 2005; Brown et al. 2020; Lauder & Mayhew 2020; Wheelahan & Moodie 2024). This theory positions education as an investment in which the human capital gained, usually understood as skills, leads to higher future earnings for the individual and economic growth for the society (Becker 1964; in relation to higher education, see Marginson 2019). There are five issues with positioning the educational purposes of mass higher education primarily in terms of employment outcomes.

First, employment outcomes are not simply outcomes of students' education. They are shaped by many factors which are not directly related to the quality of their higher education, including students' backgrounds and social networks, the prestige of the institutions they studied at, students' geographical locations and the state of the economy (Chetty et al. 2017; Clotfelter 2017; Friedman & Laurison 2019; Wildschut et al. 2020; Fryer 2022).

Second, despite this, it places the responsibility for employment on the student and the education they engage with, rather than taking into account factors such as the state and structure of the labour market. Higher education is seen as wasted if the 'investment' does not 'pay off' in terms of a highly paid job, which is seen to result in 'overeducation' (Jackson 2021) and 'overqualification' (OECD 2024). Unlike earlier approaches to employability (for example, Knight & Yorke 2004), there is no sense that employers have a responsibility to consider how working environments might need to change in order to make the most effective use of graduates' capabilities. Similarly, governments are no longer seen as responsible for building education institutions and their role is simply to regulate and assure the quality of qualifications (Allais 2012, 2014; Jungblut & Vukasovic 2018), the meanings of which are expected to be transparent to the labour market (Allais 2012, 2014). In this way, higher education is positioned as an instrument of economic policy rather than as an educational institution (Biesta 2022).

Third, thinking of mass higher education in terms of employment outcomes presents a distorted view of both the knowledge that students engage within their degrees and the kind of relationship that students develop with that knowledge. In presenting this knowledge as a form of capital that is 'banked' (Brown et al. 2020), it 'flattens' knowledge by removing it from its structure and turning collective bodies of knowledge into fragments that can be used wherever they are needed (Bernstein 2000; Allais 2012, 2014; Wheelahan & Moodie 2024). Through the flattening of knowledge, it also positions students outside of knowledge, obscuring the ways in which students' relationships to knowledge differ across subjects (Ashwin 2020) and viewing students as instrumental consumers who are primarily focused on gaining credentials rather than engaging personally with collective bodies of knowledge (for example see Brooks 2018; Gunn 2023).

Fourth, when the educational purposes of mass higher education are positioned in terms of preparing for graduates for employment, there is great pressure from policy makers to characterise this education in terms of generic employability skills unconnected to the bodies of knowledge that students have studied (Ashwin et al. 2015a). These generic skills, such as problem solving or personal initiative, are essentially empty because they have had all the situational and abstract knowledge removed (Ashwin 2020; Wheelahan et al. 2022). This removal of knowledge undermines the potential of education because it is engagement with the structure of particular bodies of knowledge that enables students and graduates to make use of their new understanding across a variety of contexts (Bernstein 2000; Allais 2014; Ashwin 2020).

Finally, the development of dynamic relationships to knowledge structures involves intense engagement to achieve, requiring relatively expensive and inflexible traditional three- or four-year undergraduate degrees. In contrast, the emptiness of generic employability skills suggests that they can be generated almost instantaneously. In this way, despite their educational emptiness, the focus on producing generic employability skills raises urgent policy questions about whether students might not be much more cheaply and accessibly prepared for employment through the stacking of micro-credentials (Wheelahan & Moody 2022, 2024; Ljungqvist & Sonesson 2023).

Despite the capacity of a focus on generic employability to render mass higher education educationally empty, higher education institutions have tended to respond to such policy demands by redefining what they do in terms of preparing students for employment. For example, UniversitiesUK defines itself as the collective voice of universities in the UK. Its 2024 'blueprint for change' argued:

> *If our aim is to get more people into better jobs, to fuel sustainable economic growth and remain internationally competitive, we will require strong, place-based networks that reduce local competition, duplication and complexity.*
>
> (UUK 2024, p. 29)

Similarly, individual higher education institutions have responded to the demand for generating employability by developing a range of generic graduate attributes, which express students' employability in terms of skills such as problem-solving or communication, without taking account of different forms of disciplinary or professional knowledge (for example see Wong et al. 2022; Baron & McCormack 2024).

The educational purpose of mass higher education as the personal development of students

An alternative approach to the disillusionment with mass higher education is to re-emphasise its contribution to the personal development of students. For example, Fischman and Gardner (2022) argued that the educational purpose of higher education is to create or amplify students' intellectual capital. They focus on the ways in which graduates think and propose the notion of Higher Education

Capital (HEDCAP) which *'denotes the ability to attend, analyse, reflect, connect and communicate on issues of importance and interest'* (pp. 79–80). Their approach is built upon the work of Perry (1999) on stages of intellectual development and also echoes the approach put forward by Sanford (1962, 1967).

In each of these cases, the development of the person is separated from the discipline. In other words, the approach to dealing with the diversity of knowledge and students is to focus on the way in which higher education transforms students' abilities to generalise and synthesise. As Sanford (1967, p. 4) argued:

> *We can provide adaptable intellectual tools, teach ways of approaching problems that are so general and so fundamental that they will serve in a greater diversity of situations, and develop in students the flexibility which will enable them to go on learning and to maintain a stable sense of themselves through a succession of changing roles.*

A key weakness of this approach is that it remains unclear why students' engagement with different subjects would lead to the development of the same abilities. Indeed, it suffers from the same weakness as the notion of generic skills in that just because we can describe capabilities generically, such as problem-solving skills, it does not mean that learning to problem solve in mathematics prepares students to solve problems in philosophy (Ashwin 2020). The starting point of this book is that any move to foreground generic outcomes of undergraduate degrees in the face of the disillusionment with higher education is a step in the wrong direction. This is because the disillusionment with mass higher education comes from a sense that it has not delivered on its promises. If we are to address this, then we need to ensure that any claim we make about the outcomes of mass higher education is based on a clear notion of why the education offered is expected to lead to these outcomes. The claims made about both employability and generic academic dispositions are unconvincing because it is not clear why a diverse range of degrees based on a diverse range and combinations of subjects would be expected to lead to broadly similar outcomes. For this reason, we argue that the power of mass higher education needs to be rooted in the distinctive subjects that students study.

The educational purpose of mass higher education as bringing students into relationship with particular bodies of knowledge

Considering the relationship students form with particular bodies of knowledge throughout their degree, and beyond, leads to the final way of addressing the diversity of knowledge and students in mass higher education. This is to argue that what mass higher education does educationally is to introduce students to particular bodies of knowledge that support them to engage with the world. Through the variety of subjects that different students engage with, societies are offered graduates with diverse ways of engaging with the world (for example, see Bowden and Marton 1998; Wald & Harland 2019; Ashwin 2020). As with the previous approaches discussed, this idea is not new. For example, Habermas (1987) asked how the idea of a 'university' could be justified given the increasing diversity of bodies of knowledge that cannot be brought together into a single system. He argued that it could be founded on the collective pursuit and argument over particular forms of knowledge.

The central argument in this book then, is that, in order to understand the educational potential of mass higher education, we need to deepen our understanding of how students develop new ways of thinking and doing through an interrogation of their engagement with their degree programmes. This involves examining the ways of seeing, knowing and making sense of the world that are developed as students grapple with particular bodies of knowledge over the course of their degrees (McCune & Hounsell 2005; Anderson and Hounsell 2007; McCune et al. 2023).

How does this book seek to contribute to debates about the educational potential of mass higher education?

This book aims to contribute to debates about the educational potential of mass higher education by examining how students engaged with their undergraduate degrees in Chemistry or Chemical Engineering in two English, two South African and two US universities and how they benefitted from their education after they had graduated. In these three countries, it examines the positioning of higher education, how the knowledge of chemistry and the bodies of knowledge relating to chemical engineering were transformed into curricula and the ways in which students engaged with this knowledge and made use of it, as graduates, after they had completed their studies.

In this study, we were interested in exploring how students changed through their engagement with knowledge in chemistry and in chemical engineering. To track this, we needed to follow them over an extended period and examine systematically how their understanding of the world and their selves changed. With the notable exception of the work that informed the design of the current study (McLean et al. 2018), this kind of examination is not common in higher education research. Longitudinal research has, however, examined students' accounts of particular concepts (for example see Dahlgren 1989; Trumper 1998), epistemological development (for example see Baxter Magolda 1992, 2004), conceptions of learning (for example van Rossum and Hamer 2010) and learning patterns (for example see Donche et al. 2010; Neilsen 2013; Richardson 2013). There have been very few longitudinal studies that have examined how students' understanding of chemistry or chemical engineering develops over time, and these have tended to focus on school children (for example, see Øyehaug and Holt 2013). Mathias (1980) followed a small group of science students, including chemistry students, through their undergraduate course. However, this study examined how students approached their studies rather than their understanding of chemistry.

This book draws on data from a longitudinal study that tracked participants for up to seven years from their first undergraduate year of study to up to four years after graduation, depending on the length of their degree and the time it took them to complete it. The methodology of this study owes a considerable debt to a previous study examining sociology (see McLean et al. 2018). Appendix 1 provides a fuller outline of the methodology of the study underpinning this book.

Why focus on chemistry and chemical engineering?

We focused on undergraduate degrees in chemistry and undergraduate degrees in chemical engineering for four key reasons. First, a great deal of research on students' experiences of their undergraduate education, and how they draw on their education after graduation, does not focus on particular subjects. Instead, it tends to involve students and/or graduates from a variety of disciplines and subjects. This means that this kind of inquiry is not designed to offer an in-depth examination of the role that students' and graduates' engagement with particular bodies of knowledge plays in the outcomes of their education. Second, the limited amount of research that has focused on the transformation of knowledge into curriculum and student understanding in particular subject areas has tended to focus on what Bernstein (2000) termed 'horizontal' knowledge structures, more commonly found in the arts, humanities and social sciences, rather than 'hierarchical' knowledge structures more commonly found in the natural and applied sciences (although, see Yates et al. 2016 for an exception focusing on physics as well as history). For example, the McLean et al. (2018) study focused on sociology.

Third, we were interested in exploring the differences in the way knowledge, curriculum and student understanding were produced, in Bernstein's (2000) terms, in the 'singular' form of chemistry and a 'regional' form of chemical engineering. Fourth, there are interesting similarities and differences between chemistry and chemical engineering. They are both STEM programmes that are seen as good routes into prosperity for individual students and for driving economic development nationally. Engineers and scientists are more likely than students from other subjects to be fact-oriented (Lonka et al. 2021), and students studying STEM subjects are more likely to adopt consumerist perspectives on their education than students from other subjects (Bunce et al. 2017). However, they differ in the economic returns: chemical engineering is one of the subject areas with the highest salaries for graduates (Quadlin et al. 2023), whereas chemistry graduates have been found to have lower salary returns than students with other STEM subject backgrounds (Britton et al. 2022). This combination of factors suggests that students studying chemistry and chemical engineering can be expected to be most influenced by instrumental reasons for studying their degrees. Therefore, if we found that their engagement with knowledge played a significant role in what they gained from higher education, then this would suggest that this is likely in other subjects where students tend to be less instrumental.

Why focus on England, South Africa and the United States?

In examining the educational potential of mass higher education, these three countries offer illuminating contexts to examine marketised mass higher education (Czerniewicz et al. 2023; Durán Del Fierro 2023) and reflect the instrumental view of education that is argued to have become embedded in the Anglosphere (Lauder & Mayhew 2020). All involve students paying tuition fees which are argued to lead to the development of student consumerism (Plamper et al. 2023). However, higher education in South Africa is at a different stage of massification and, in response to its apartheid history, is much more explicitly positioned in policy as having a role in transforming society than in England or the United States (Boughey & McKenna 2021).

Theoretical framework: The pedagogic device

The design of this study was informed by the view of knowledge and curriculum captured in Bernstein's (2000) notion of the 'pedagogic device'. The focus of

Bernstein's (1990, 2000) research was on how knowledge, power and control come together through the 'voice' of education. Bernstein (1990, 2000) argued that many education theories were aiming to show how discourses of education reproduce relations of social class, gender and racial inequality. This means these theories focused on aspects that are external to education, which is seen as a 'carrier' of other discourses, '*only a voice through which others speak*' while its '*own voice is absent*' (Bernstein 1990, p. 166). Rather than analysing *relations to* pedagogic communication, Bernstein's (1990, 2000) focus was on analysing *relations within* pedagogic communication by developing an understanding of the voice of pedagogic discourse (Ashwin 2009; Barrett 2024).

Through the pedagogic device, Bernstein (1990, 2000) provided conceptual tools to analyse how disciplinary knowledge is produced and transformed into curriculum and how curriculum and educational interactions shape the consciousness of both academics and students. As Arnot and Reay (2004, p. 137) noted, '[Bernstein's theory] *is unique in formulating connections between the organisation and structuring of knowledge, the means by which it is transmitted and the ways in which acquisition is experienced*'. The pedagogic device highlights the ways in which knowledge is transformed as it moves from a research context, is recontextualised into higher education curricula and then into the classroom context, into the understandings that students develop of this knowledge. This transformative movement can be characterised in terms of 'knowledge-as-research', 'knowledge-as-curriculum' and 'knowledge-as-student-understanding' (Ashwin et al. 2012; Ashwin 2014).

Bernstein (2000) emphasised that the transformation of knowledge, as it moves between these forms, is not simply based on the logic of knowledge itself. Rather, these transformations are the sites of struggle in which different voices seek to impose particular versions of legitimate knowledge, curriculum and student understanding (Singh 2002; Ashwin 2009; Horrod 2023; Barratt 2024). Focusing on the relations between knowledge-as-research, knowledge-as-curriculum and knowledge-as-student-understanding offers a powerful way of understanding the transformative power of higher education because it brings into focus both the ways in which higher education changes students' understanding and identities, but also the potential of students to transform curricula and the knowledge with which they engage.

The pedagogic device consists of three sets of rules which determine the kinds of knowledge that are produced, who has access to these different kinds of knowledge and the different ways in which different groups in society are given access to particular kinds of knowledge. Maton and Muller (2007, p. 19) summarise the pedagogic device as follows:

> *… the ordered regulation and distribution of a society's worthwhile store of knowledge, ordered by a specifiable set of **distributive rules**; the transformation of this store into a pedagogic discourse, a form amenable to pedagogic transmission, ordered by a specifiable set of **recontextualising rules**; and the further transformation of this pedagogic discourse into a set of evaluative criteria to be attained, ordered by a specifiable set of **evaluative rules**.*
>
> (emphasis in the original)

Thus, as Singh (2002) argues, the pedagogic device brings together the contexts in which knowledge is produced (regulated by distributive rules), made ready for transmission through the recontextualising of that knowledge into curriculum (regulated by recontextualising rules), and is reproduced through educational practices (regulated by evaluative rules). Although school education, rather than higher education, was the principal focus of Bernstein's work, it is particularly interesting to look at higher education from the perspective of the pedagogic device because knowledge is produced, recontextualised and reproduced within the same institutions (Ashwin 2009).

In the field of knowledge production (knowledge-as-research), the distributive rules govern '*who may transmit what to whom, and under what conditions*' (Bernstein 1990, p. 183) and the distribution of knowledge to different social groups. Bernstein (2000) distinguished between everyday knowledge that is rooted to its context and has a horizontal discourse, and specialised knowledge, which has a vertical discourse with '*a coherent, explicit, and systematically principled structure*' (Bernstein 2000, p. 157). A further distinction within specialised knowledge relates to disciplines with hierarchical knowledge structures and those with horizontal knowledge structures. Hierarchical knowledge structures, such as those in the natural sciences, create general theories (high abstraction) that integrate knowledge at lower levels of abstraction. Horizontal knowledge structures, such as sociology, on the other hand, consist of collections of different 'languages' (Bernstein 2000).

The recontextualising field is focused on how knowledge is transformed into curricula (knowledge-as-curriculum). Bernstein (2000) examined three broad ways in which knowledge can be recontextualised. First, it can be recontextualised as singulars, in which disciplines maintain their unique 'voice' through stronger classification, as they are 'insulated' or separated from the discourses of other disciplines. Second, where classification is weaker, Bernstein

(2000, p. 9) argued, discourses are likely to be recontextualised as regions, which involve the recontextualisation of different singulars in relation to each other. Whereas singulars are 'pure' disciplines that are mainly focused on defining the problems generated by their own discourses, regions are more focused on dealing with problems generated in the world outside of the discipline (Beck 2002). Finally, where the 'voice' of the discipline is very weak, there are generic modes that are focused on developing 'trainability' in students (Bernstein 2000, 2001; Beck and Young 2005). Bernstein (2000) argued that such modes are empty because they simply refer to themselves and are focused on responding to the changing demands of technology, organisations and the market. These generic modes can be seen in the promotion of generic employability skills discussed earlier.

The evaluative rules are focused on the transformation of curriculum into pedagogic practice (knowledge-as-student-understanding). From Bernstein's (2000) perspective, the key to pedagogic practice is the continuous assessment of whether students are creating the legitimate 'texts' demanded by the curriculum. By 'text', Bernstein is referring to forms of evidence that a given aspect of curriculum has been acquired, which may not necessarily be a physical text. To produce a text, students need to both be able to 'recognise' the text and to 'realise' the text. Bernstein (2000) refers to these as recognition rules and realisation rules. As a whole, the evaluative rules that govern the production of these texts also regulate educational practices by defining the standards that the students must reach (Bernstein 1990).

The three sets of rules of the pedagogic device are organised hierarchically, so that the distributive rules, by setting what counts as knowledge, limit what can be turned into curriculum and the curricula established by the recontextualising rules limit the kinds of pedagogic texts that can be produced according to the evaluative rules (Bernstein 1990, 2000).

It is important to recognise that the pedagogic device describes a site of struggle over how ways of thinking will be structured through pedagogic discourse and whose interests will be served through this structuring (Bernstein 1990, 2000; Singh 2002; Maton and Muller 2007; Barrett 2024). In higher education, this can be seen as a struggle over the identities that students will form through their engagement with knowledge. Within this struggle, disciplinary knowledge practices are one voice, but there are others related to national and institutional policies and priorities that seek to shape what counts as worthwhile knowledge, curriculum and pedagogic texts (for further discussion, see Ashwin 2009). In this way, the pedagogic device suggests that the relationships between knowledge-as-research, knowledge-as-curriculum and knowledge-as-student-understanding are complex and contingent because they involve the interweaving of local, national and global processes.

This view of knowledge is very different from that which tends to be advocated by politicians when they promote 'knowledge-rich' approaches to school education. Such viewpoints position knowledge as a single, coherent, authoritative, flat and fixed (Young & Muller 2016; Yandell 2017; Craske 2021), whereas Bernstein saw different disciplines as having particular knowledge structures that are transformed as they are recontexualised into curricula structures and changed again when students engage with them (Bernstein 2000; Ashwin 2014).

Structure of the book

We use the pedagogic device to organise the structure of the book. In Chapter 2, we examine the distributive rules in terms of '*who may transmit what to whom, and under what conditions*' (Bernstein 1990, p. 183) in the higher education systems in England, South Africa and the United States. We show how the three countries have intertwined histories and are the site of intense debates about the role and value of mass higher education, which has led to a sense of disillusionment with mass higher education. We argue that Trow's (1973) notions of elite, mass and universal higher education can be seen to reflect different sets of distributive rules and show how the six universities in our study provide a range of contexts in which to examine their provision of degrees in chemistry and chemical engineering. Rather than examining the differences between mass and elite educational settings, we explain that our focus is on whether students engage with knowledge in similar ways in these different contexts.

In Chapter 3, we focus on the recontextualising rules of the pedagogic device and examine the history and the formation of university curricula in chemistry and chemical engineering. We show that the chemistry programmes in our study varied according to whether they offered an elite or inclusive form of chemistry. In chemical engineering, there was a greater diversity of approaches because the regional nature of chemical engineering meant that there was a greater amount of content to be covered. Drawing on the accounts of the degree programme leaders, we argue that whilst the chemistry degrees aimed to foster students' engagement with a world created by chemistry, the chemical engineering degrees focused on helping students to engage with an external world in their professional roles as chemical engineers.

In Chapter 4, we focus on the evaluative rules of the pedagogic device and particularly on how students recognise the subject matter of their degrees. Students tended to see some aspects of their degrees in transformational terms and others in instrumental terms. Whilst most students chose to study chemistry and chemical engineering for instrumental reasons, by the end of their degrees, most had developed a transformational focus on their degree programmes, even as they continued to see their relationship with their universities in instrumental terms.

In Chapter 5, we again focus on the evaluative rules of the pedagogic device, but this time we shift attention to how students 'realised' their understanding of their subject matter. In chemistry, students were prepared to engage with the world that was constructed from the perspective of chemistry, whereas in chemical engineering, students were prepared to engage with the complexity of the external world as chemical engineers. Where students saw their education in instrumental terms, we found their way of seeing chemistry and chemical engineering, and their relation to the knowledge tended to be less developed.

In Chapter 6, we focus on how our participants, who had by then graduated, reflected on the benefits of their degrees. We argue that most graduates highlighted the importance of knowledge in what they gained from studying their subjects. These graduates tended to be more likely to be in graduate roles than those who focused on their degrees instrumentally.

In Chapter 7, we examine the more general notion of 'graduateness'. Based on our findings, we argue that graduates who saw knowledge 'from the inside' had more flexibility in what they did next, whereas graduates who saw knowledge 'from the outside' were more likely to be in non-graduate employment and more likely to feel their education was a waste of time. Based on this, we contend that seeing knowledge from the inside is key to the educational potential of mass higher education.

In Chapter 8, we examine the implications of our findings for understanding the educational potential of mass higher education and how we might respond to the disillusionment with mass higher education. We examine the implications of the arguments in this book for higher education research, for educational practices, higher education institutions and policy makers.

In following this structure, we focus on our participants' changing relationships to chemistry and chemical engineering over the seven years of the study. There are other aspects of the study's findings that we do not touch upon. We do not consider how the global Covid-19 pandemic affected the participants that we interviewed throughout this study, even though some of our interviews were conducted during the pandemic. Given that our main focus is on understanding the different ways in which engagement with the knowledge of chemistry or the knowledge of chemical engineering, we do not focus on other comparisons that could be made with our data. We do not offer an in-depth comparison of the different countries or the different institutions in our study. We also do not offer an in-depth analysis of how demographic elements such as ethnicity, gender and social class impacted the experiences of our participants. As far as our data would allow, we have examined these relationships but found no consistent patterns.

This should not be taken to imply that we consider the institutional and national locations, or ethnicity, gender and social class to be somehow unimportant. It is rather, in line with Bernstein's (2000) focus, that we are interested in examining students' relationships to knowledge within the higher education process. In doing so, we are fundamentally focused on how social and economic inequalities are amplified or mitigated by higher education and the question of how mass higher education can give all students access to knowledge that can transform their senses of self and their ways of engaging with the world.

It is also important to note that we do not cover all of the ground explored by previous publications in this study. These are listed in Appendix 2. Of particular note are the two doctoral theses (Abdalla 2023; Goldschneider 2023) that were written based on the study data.

Conclusion

In this introductory chapter, we have set out the context for our exploration of the educational potential of mass higher education. We explained the reason for our focus and discussed the current disillusionment with mass higher education. We argued that focusing on generic benefits of mass higher education cannot address, and indeed can only serve to exacerbate, this sense of disillusionment by making promises that mass higher education simply cannot keep. We also argued that the educational potential of mass higher education is to be found in the relationships to knowledge that students develop through their undergraduate studies. Over the course of this book, we will track this relationship in chemistry and chemical engineering degrees from when students start their undergraduate studies to up to four years after their graduation in England, South Africa and the United States. Based on this, we will develop an argument for what is needed to realise the educational potential of mass higher education.

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2

How Were the Six Universities Situated in Their Higher Education Systems?

In this chapter, we place the universities in our study in the context of the three higher education systems in which they were located: England, South Africa and the United States. We give a broad introduction to the three societies before examining each system of higher education. In this chapter, our focus is on the distributive rules of the pedagogic device (Bernstein 2000), which means we are particularly interested in who gains access to what kind of higher education.

We argue that whilst there were important differences between higher education in the three countries, all three faced similar issues in terms of unequal access to, experiences of and outcomes from higher education. In particular, in all three systems, there were strong relationships between social privilege and the benefits of elite higher education. We explore the regulation, funding, participation and outcomes from the three systems. We then place the six universities in our study in the context of these systems and consider how they reflect the issues we raised in relation to the distributive rules. By doing this, our intention is to set the scene for the introduction to the disciplines of chemistry and chemical engineering in Chapter 3 and to show how our selection of institutions gave us access to potential variations in degrees in chemistry and chemical engineering in elite and mass higher education institutions.

In introducing the three countries and their higher education systems, we draw on data from those systems from 2017, when our study began and, when considering outcomes from higher education, from 2020, when the first participants from our study would have graduated. In doing so, there were several issues that we faced. First, given the differences in the structures of the higher education systems and the data held about them, it was not always possible to make direct comparisons between the systems. For example, as will be clear later in the chapter, ethnicity is categorised in different ways in each of the three countries. We use the categories used in each setting without trying to integrate them. In addition, there are some important characteristics where data are not available in all of the countries. For this reason, we do not discuss the social class of students in this chapter even though, particularly through its intersections with gender and ethnicity, social class has a significant impact on access to, experiences of and outcomes from higher education in all three national contexts (for example, see Boughey & McKenna 2021; Reay 2021; Garriott et al. 2023).

Distributive rules

The distributive rules govern '*who may transmit what to whom, and under what conditions*' (Bernstein, 1990, p. 183). In this way, the distributive rules impact the distribution of knowledge to different social groups (Bernstein 2000). Whilst Bernstein (2000) wrote about educational systems more generally, in relation to higher education, the distributive rules represent a site of struggle over what can legitimately be taught through the degree programmes offered through higher education, who may legitimately take on the role of a 'teacher' or 'learner' and the conditions under which educational processes take place (Ashwin 2009).

Trow's (1973) ideal types of elite, mass and universal higher education, which we discussed in Chapter 1, can be seen to reflect different distributive rules for each phase of higher education. Under elite education, academically elite students have close personal relationships with professors as they are offered an education that seeks to shape their minds and character and prepare them for leadership roles in government and leading professions. In mass higher education, students are still selected based on their academic achievements, but there is a greater commitment to equality of opportunity. Students tend to study collections of modules and move between fields that help them to develop skills and have more distant relationships with their teachers, who are often teaching assistants, in large lecture settings. They are prepared for a broader range of professions. In universal higher education, there is open access to higher education that is focused on preparing students for their lives in an advanced industrial society rather than any profession. Education experiences are relatively unstructured, with educational relationships that are more impersonal and distant. There is a much less sharp distinction between formal education and everyday life. Thus, in each case, the distributive rules regulate differently who is a teacher, who is a student, the relations between teachers and students, the knowledge that is studied, the settings in which students study and the purposes of their education.

Trow (1973) is clear that elite, mass and universal higher education are not separate systems. For example, he argues that elite institutions can thrive in a mass system but suggests there are significant challenges to any system delivering all three versions of higher education given their different structures, values and relationships.

In this chapter, we focus on the distributive rules at the level of higher education systems. It should be noted that distributive rules also impact the development of knowledge through research. For reasons of clarity, we discuss the development of chemistry and chemical engineering when we focus on the production of curricula through the recontextualisation rules in Chapter 3. For the same reason, the aspects of the recontextualising rules relating to state agencies (what Bernstein 2000 calls the Official Recontextualising Field) are discussed in this chapter rather than the next.

England, South Africa and the United States

This study examined the experiences of students studying chemistry and chemical engineering in England, South Africa and the United States. As we explained in Chapter 1, our primary intention is not to compare the experiences of studying in these different countries. Instead, our focus is on exploring the differences between students' experiences and outcomes from studying chemistry and chemical engineering. However, there is a need to give a sense of the national contexts and higher education systems that we are focusing on. In the study, we considered England separately from the UK because UK higher education has been devolved to the administrations in England, Northern Ireland, Scotland and Wales since the late 1990s (Shattock & Horvath 2019). However, some of the figures we use to situate the three countries were only available at the level of the UK.

All three countries have overlapping and intertwined histories shaped by colonialism (for example, see Scott 1995; Brubacher 2017; Saurombe 2018; Stein 2020) and the intersection between colonialism and capitalism (Wright 2020). Importantly, for the design of this study, these histories mean that English is an official language in all three countries. Despite these overlapping histories, there are stark differences between the three countries. Table 2.1 shows that England and South Africa had similar-sized populations in 2017, whilst the population of the United States was over five times larger. The United States was the wealthiest country in the study, with a GDP per capita a third higher than the UK and over four times higher than that in South Africa. In terms of economic inequality,

Table 2.1 Population size and demographics of countries in the study in 2017–18

	England	South Africa	United States
Population	56.5 million	60.1 million	332 million
GDP[1]	$2.68 trillion (UK)	$0.38 trillion	$19.61 trillion
GDP per capita[2]	$46,048 (UK)	$13,738	$60,300
Gini coefficient[3]	0.33 (UK)	0.63 (2014)	0.41
Youth unemployment[4] (15–24)	12% (UK)	43%	9%
Gender[5]	51% female; 49% male	52% female, 48% male	51% female, 49% male
Age[6]	65+ 18% 25–64 52% 15–24 12% 5–14 12% <5 06%	65+ 06% 25–64 48% 15–24 18% 5–14 18% <5 10%	65+ 15% 25–64 53% 15–24 13% 5–14 13% <5 06%
Ethnic groups	White 82%, Black 4%, Asian 9% Mixed 3%, Other 2% (England and Wales 2021 Census[7])	Black African 81%, Coloured 8%, White 7%, Indian/Asian 3%, Other 0.4% (South African Census 2022[8])	White 58%, Hispanic or Latino 19%, Black/African American 12%, Asian 6%, Indigenous/Alaska native 0.7%, Native Hawaiian/Other Pacific Islander 0.2%, two or more races 4.1% Other 0.5% (United States Census 2020[9])

1 https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?view=chart

2 https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD?end=2023&start=1990&view=chart

3 https://data.worldbank.org/indicator/SI.POV.GINI

4 https://data.worldbank.org/indicator/SL.UEM.1524.ZS

5 https://data.worldbank.org/indicator/SP.POP.TOTL.FE.ZS

6 https://population.un.org/wpp/data-sources

7 https://www.ons.gov.uk/census

8 https://census.statssa.gov.za/#/

9 https://data.census.gov/table?g=010XX00US&d=DEC+Demographic+Profile

South Africa had the most unequal distribution of wealth, as measured by its Gini Coefficient, and very high youth unemployment. In both cases, these were amongst the highest in the world. England and the United States had Gini coefficients that were above what is usually expected in developed countries, suggesting relatively high levels of economic inequality, although they had lower levels of youth unemployment. All three countries had similar gender distributions. South Africa had a younger population with 46 per cent of its population under twenty-five compared to around 30 per cent in England and the United States. In terms of ethnicity, the United States was arguably more diverse with its largest group, making up 58 per cent of the population compared to over 80 per cent in England and South Africa.

Overall, despite their differences in size, wealth and age distributions, the three countries in our study shared characteristics of being diverse societies that faced relatively high levels of inequality.

The three higher education systems

In line with our discussion of the three societies, the higher education systems of England, South Africa and the United States shared some similarities, although there were some important differences between them. As a result of the intertwined histories we discussed earlier, there is a fairly high degree of exchange of policy ideas and student movements between the three countries (for example, see Smith et al. 2002; Jansen 2004; Sunnemark & Thörn 2023). In discussing the systems, we focus on how they were positioned at the time of our research rather than examining the history of their development or how they moved from being collections of individual institutions to systems of higher education (Scott 2019).

Across all three higher education systems, there was some sense of disillusionment with higher education, as we discussed in Chapter 1. This sense of disillusionment came from both ends of the political spectrum, with some losing faith in higher education because of its role in supporting neoliberalism and colonialism (for example, see Featherstone 2023; Karger & Stoesz 2024; Maistry 2024) and others claiming that it has been taken over by a left-wing elite (for example, Ellis 2021).

In discussing these systems, in line with the focus of this book, we examine institutions offering full undergraduate (bachelor's) degrees. It is important to recognise that this only accounts for part of the overall higher education system in each country. For example, in the United States in 2015–16, there were over 2500 four-year institutions who offered full bachelor's degrees and more than 1500 two-year institutions that offered associate (two-year) degrees (National Centre for Education Statistics 2023).

The size of the higher education systems

In 2017–18, as would be expected given its relative size and wealth, the US higher education system was much bigger than those in England and South Africa, with nearly 11 million undergraduate students and over 2500 four-year higher education institutions. Half of these were private non-profit institutions, a quarter public universities and a quarter private for-profit institutions, although the vast majority of students were studying in (the larger enrolment) public universities and colleges (Cantwell 2018; Hillman 2024). In England, there were 1.4 million undergraduate students and 425 registered providers, of which 126 had the title of university (OfS 2024a). Most of those that were not universities were small and did not have the power to award their own degrees (Atherton et al. 2024). In South Africa, there were 0.9 million undergraduate students and 26 public higher education institutions (9 traditional universities, 11 comprehensive universities and 6 universities of technology) and around 89 registered private institutions (Council on Higher Education 2022). Thus, the US higher education system, in terms of undergraduate student numbers, was over seven times bigger than the English higher education system and over twelve times bigger than the South African higher education system.

The societal purposes of higher education

There was some variation in the way that the societal purposes of higher education are positioned within the three systems. In England, Shattock and Horvath (2019) argued that, whilst English universities used to be among the most autonomous in the world, this was no longer the case. They have been increasingly regulated and required to meet thresholds in terms of student continuation, completion and outcomes. This has had the effect of giving increasing prominence to government priorities for the societal purposes of higher education. These priorities focused on ensuring high levels of employment for graduates and addressing inequalities in access, participation and success in higher education. In 2017, higher education institutions in England were regulated by the state through the Office for Students, which had an explicit role to encourage the development of a private higher education sector to diversify the sector (Shattock & Horvath 2019; Atherton et al. 2024).

In South Africa, the purposes of higher education have been shaped by its apartheid history, under which inequalities on the basis of race had been deliberately institutionalised through separate and differentially funded institutions for whites and 'non-whites' (Reddy 2004; Badat 2022) in order to fulfil their ideological function of naturalising severe inequalities based on ethnicity (Reddy 2004). Post-apartheid, the 1997 Education White Paper 3 (WP3) positioned higher education as having a transformational role in South African society. Its role was to redress past inequities, eradicate all forms of unfair discrimination and provide fair access to higher education, to support the development of democracy and a culture of human rights, to contribute to the rigorous advancement of knowledge and to address national development needs in the context of a global economy (Department of Education 1997; Saidi 2022). The 1997 Higher Education Act set out to transform South African universities so they could undertake this role whilst maintaining their autonomy and freedom (Reddy 2004; Badat 2022). Badat (2022) argued that there was a tension between these aims, as the global capitalist market in which national development needs would be addressed was predicated on the continued existence of structural inequalities. This put higher education institutions in the difficult position of being required to be socially transformative within a market-dominated system (Cross & Kulati 2022). This tension can be seen to have fuelled the disillusionment with higher education expressed through the #FeesMustFall movement in 2015 and 2016 (Boughey & McKenna 2021). The urgent need to transform the higher education system post-apartheid led to a highly regulated system with government agencies approving qualifications, accrediting programmes and registering qualifications (Cross & Kulati 2022). This shaped significant changes to the South African higher education system. For example, in 1993, Black students constituted 53 per cent of the total headcount enrolments and Black academic staff were 20 per cent of total permanent academic staff, whereas, in 2017, this increased to 85 per cent of students and 55 per cent of staff (Cross & Kulati 2022).

In contrast, in the United States, the purposes of higher education were not set at the level of the national (federal) government. Hillman (2024) explained that this is because the US Constitution does not mention 'education' and states are largely responsible for public institutions of higher education, providing funding, overseeing the programmes offered and setting levels of tuition. The federal government regulated the overall higher education market and provided financial aid to students. Independent accreditation agencies were responsible for quality assurance. This created a decentralised and loosely coupled governance system. Whilst institutions had some autonomy from states, they were held accountable for a range of outcomes. Private educational institutions had to adhere to certain governmental guidance at the state level, but had even greater independence to determine their own purpose, curricula and guiding principles. Despite a lack of purpose from the federal government, Brint (2018) argued that the traditional structures of universities and colleges were built around the expansion of knowledge and the development of students' cognitive capacity and subject-matter knowledge. He argued they are now shaped by three logics: an intellectual logic focused on the advance of, and education in, the disciplines; a market logic focused on the generation of revenue and technological innovation; and a logic of social inclusion to incorporate members of disadvantaged groups into higher education.

Tuition fees in the three systems

We consider the systems for tuition fees for public higher education institutions in England, South Africa and the United States in the first year of the study, 2017. In all three countries, rises in tuition fees and the level of graduate debt were the focus of public concern and raised questions about whether they led to unequal access to higher education (for example, see Webber & Burns 2021; Brint 2022; Callender & Davies 2024; Mbhalati 2024).

In England, over half of the income for public higher education came from tuition fees (HESA 2018), a much higher percentage of income than in South Africa and the United States. These tuition fees include those taken out by students based in England using income-contingent loans as well as tuition fee income from international students. In England, nearly all higher education institutions charged home undergraduates the same amount in tuition fees for their undergraduate degree, which was the highest average undergraduate tuition in the OECD (OECD 2021) and English graduates had the highest average debt in the Anglophone world (Kirby 2016) with over 90 per cent take-up of income-contingent loans by those eligible for them (Callender & Davies 2024).

In South Africa, around a third of the income for public higher education came from tuition fees (Mbhalati 2024). The overriding principle of funding was that costs were shared between the government and students and their families (Wangenge-Ouma & Carpentier 2018). Unlike in England, tuition fees varied according to students' programmes and institution, although the government set caps on increases in tuition fees. Support for students below a certain level of income was provided by the National Student Financial Aid Scheme (NSFAS). Tuition fees and student debt were a major political issue in South Africa and underpinned the widespread student #FEESMUSTFALL protests from 2015 to 2017 (Webb 2021). These protests were exacerbated by large-scale administrative problems with NSFAS (Mbhalati 2024).

In the United States, around a fifth of the income for public higher education came from tuition fees (National Center for Education Statistics 2020). Tuition fees varied by institution, and state governments determined how much tuition public institutions could charge, which academic programmes public institutions could offer and how much funding institutions received each year (Hillman 2024). Students on low income had access to federal Pell Grants as well as State and institutional support (Brint 2022). Institutions also offered different base tuition rates to students who resided inside and outside of the state the institution operated in. Furthermore, many institutions were authorised to provide both need-based and merit-based aid, depending on available funds and their institutional discretion. The provision of scholarships by universities meant there was often a significant difference between the published tuition fees and the costs paid by individual students (Cantwell 2018; Brint 2022; Hillman 2024).

Participation and success in higher education

Table 2.2 shows higher education participation rates in 2017, when our study started, and higher education completion rates in 2020, which was when the first involved in our study graduated. Table 2.2 shows that participation rates were higher in England and the United States than in South Africa and that completion rates were higher in England than in South Africa and the United States. In all three countries, women had higher participation and completion rates than men. In terms of ethnicity, in South Africa and the United States, white students had the highest participation and completion rates. In England, they had the lowest participation but highest completion rates. There were complex relationships between gender and ethnicity and students' participation, completion and outcomes after higher education. In each of the countries, white students were more likely to attend more prestigious and highly resourced institutions (Hlengwa et al. 2022; Bolton & Lewis 2024; Hillman 2024). For example, in England, whilst women were more likely to gain access to and complete higher education, men were more likely to end up in 'highly skilled employment' and had significantly higher earnings after graduation (Bolton &

Table 2.2 Participation rates (2017) and completion rates (2020) in higher education in England, South Africa and the United States

		England			South Africa			United States	
		Participation	Competition		Participation	Competition[1]		Participation	Competition[2]
Overall		42%	89%		22%	61%		40%	60%
Gender	Female	47%	91%	Female	26%	66%	Female	44%	63%
	Male	37%	86%	Male	19%	54%	Male	36%	57%
Ethnic Groups	Asian	64%	88%	African	19%	59%	American Indian/ Alaska Native	20%	31%
	Black	60%	82%	Coloured	16%	56%	Asian	65%	74%
	Mixed	47%	86%	Indian	51%	65%	Black	37%	40%
	White	38%	90%	White	61%	67%	Hispanic	36%	54%
							Pacific Islander	33%	59%
							Two or more races	42%	60%
							White	41%	64%
Source		Department for Education 2019	OfS (2024b)	CHE (2022)			National Centre for Statistics (2024)		

1 Completion of three-year degrees at public universities within six years.

2 Completion at four-year institutions within six years.

Lewis 2024). Table 2.2 does not show socioeconomic inequality. In England, being in receipt of free school meals is an indication of economic deprivation. Those who receive free school meals are the least likely to engage in higher education, the most likely to not complete their studies, are less likely to get a job after graduation and, if they do, tend to earn less (Bolton & Lewis 2024). Similar patterns exist in South Africa (for example, Cosser 2018) and the United States (for example, see Kazis 2020).

Participation rates for students with disabilities are not included in Table 2.2 because official statistics were not available for all the countries. However, in all three countries, there is strong evidence that students with disabilities have lower levels of participation and face challenges in completing and succeeding in their education (for example, see Brown et al. 2021; McKinney & Swartz 2022; Shaw 2024).

Overall, there are differences in terms of size and levels of funding, participation and success across the three systems of higher education. However, there are similarities in terms of persistent inequalities in each system in terms of access, experiences and outcomes from higher education. Whilst it is important to recognise the differences in these inequalities and how they might be addressed (for example, see Case, 2025), the differential access to and benefits from higher education are a key part of the higher education landscape in each country.

Key differences and similarities in three higher education systems

Before we introduce the institutions involved in our study and their position in their higher education system, there are a few differences and similarities in the systems that are particularly relevant to our study.

Key differences between the higher education systems

There are three key differences between the three higher education systems that are particularly relevant to our focus in this study. These are the stages of their education when students start their undergraduate studies, the extent to which students move between institutions during their undergraduate studies, and the extent to which they pause their education during their engagement with higher education.

First, due to the earlier specialisation in the English education system, the first year of degree programmes in England has more in common with the second year of degrees in South Africa and the United States. In England, students register for a three-year Bachelor of Science degree with honours or a four-year Master's degree. In South Africa, in some subjects including chemistry, students register for a three-year Bachelor of Science degree and then can apply for a stand-alone one-year honours degree and, in other subjects including chemical engineering, they register for a four-year degree that includes honours. As mentioned earlier, in the United States students register for a two-year associate degree or a four-year bachelors' degree. Whilst it is four-year degree students who were our focus in the United States, some of these students will have transferred from two-year institutions.

Second, as the previous point would suggest, transfer between institutions is far more common in the United States than in England and South Africa, with one in three community college students transferring form two-year to four-year colleges and one in ten students transferring between four-year institutions (Hillman 2024). The transfer rate in England in 2017 was 3 per cent (OfS 2024c) and in South Africa around 5 per cent (Council on Higher Education 2022).

Third, in line with the completion rates in Table 2.2, in England most students tend to complete their studies without having a break in their registration, whereas in South Africa and the United States, it is more common for students to retake a year or to have a break in their studies for personal, often financial, reasons.

Key similarities in the three higher education systems

There are three interconnected similarities that are important in shaping the distributive rules of higher education in the three higher education systems, in addition and related to the histories of colonialism discussed earlier. First, all three systems are, to different degrees, marketised systems of higher education. Second, in all three countries educational policies are strongly influenced by human capital theory. Third, and related to Trow's (1973) three models of higher education discussed at the start of this chapter, there is a high degree of vertical stratification across the three higher education systems.

All three countries have marketised higher education systems in which students pay fees (Czerniewicz et al. 2023; Durán Del Fierro 2023) and reflect, to some degree, the instrumental view of education that is argued to have become embedded in the Anglosphere due to the dominance of a neoliberal policy logic

(Olssen & Peters 2005; Busch 2017; Walker 2018; Lauder & Mayhew 2020; Mintz 2021).

Second, as we discussed in Chapter 1, the coming together of neoliberalism and the knowledge economy led to a focus on human capital. In all three countries, human capital theory plays a strong role in shaping educational policies (for example, in England see Tholen 2022; in South Africa see Shrivastava & Shrivastava 2014; Allais 2017; Walker 2018; in the United States see Slaughter et al. 2015; Holden & Biddle 2017; Mintz 2021). Human capital theory positions education as an investment in which the human capital gained, usually understood as skills, leads to higher future earnings (Becker 1964; Deming 2022; in relation to higher education, see Marginson 2019). Such is the hold of human capital theory that when individuals' investments in education fail to develop in the way predicted, policy makers have seen this as evidence of the failure of education rather than the limitations of the theory (Brown et al. 2020; Moodie & Wheelahan 2023). Whilst the development of human capital is clearly one of the educational roles of higher education, the danger raised in all three countries is that developing human capital becomes the main purpose or end of higher education (Walker 2018; Ashwin 2020; Mintz 2021).

The third key similarity in the three settings is the 'vertical stratification' (Cantwell & Marginson 2018) of institutions across the higher education systems. Cantwell and Marginson (2018, p. 125) argued that in systems of high participation, there tends to be a 'bifurcation' between artisanal elite institutions and lower-value accessible institutions, reflecting Trow's (1973) distinction between elite universities and mass and universal institutions. Whilst of the three countries in this study only the United States is examined by Cantwell and Marginson (2018), aspects of this tendency can be seen across all the countries in our study, with clear differences between elite and mass higher education institutions. As we discussed when introducing Trow's (1973) ideas, this bifurcation has important implications for considering the distributive rules. Different students can be given access to different forms of higher education through elite and mass higher education institutions in terms of who they are studying with, who they are taught by, what they are taught and the setting in which they are taught. However, in contrast to Trow's (1973) strong belief in elite education (see Scott 2019), the position taken here is that the difference between elite and mass institutions is more about prestige than it is about the quality of the education offered by these institutions (Brewer et al. 2002; Eckel 2008; McLean et al. 2018; Ashwin 2020).

In relation to who they are studying with, elite institutions tend to be more academically selective (Trow 1973; Volkwein & Sweitzer 2006; Eckel 2008; Cantwell & Marginson 2018) and have a higher proportion of international students (Cantwell & Marginson 2018; Ford & Cate 2020) than mass institutions. As academic performance is closely linked to family background (OECD 2019), this means that elite institutions tend to have a more socially homogeneous student population with a high proportion of privileged students (Trow 1973; Marginson 2018; Holland & Ford 2021).

In terms of who they are taught by, more elite institutions tend to focus on employing active researchers who are educated to a PhD level and contribute to their internationally focused research agenda (Trow 1973; Cantwell & Marginson 2018). This also impacts the version of students' subjects that is taught, as there tend to be closer relationships between research and teaching in elite institutions. Finally, the version of the subject is also shaped by the educational mission of institutions, with more elite institutions tending to be focused on educating students who will form parts of social elites upon graduation (Trow 1973; Cantwell & Marginson 2018).

Introducing the six institutional settings

We now introduce the six institutions in our study. The universities in this research were given pseudonyms based on chemical elements. These were:

- England – Erbium University and Europium University
- South Africa – Samarium University and Sodium University
- United States – Argon University and Astatine University

Comparing institutions across national settings is challenging (Lepori 2022), and we did not examine these universities in order to offer a representative view of universities in England, South Africa and the United States. Rather, we wanted to examine students' experiences of studying chemistry and chemical engineering in institutions with different levels of prestige across the three countries. To preserve their anonymity, we do not provide full rich descriptions of the six institutions but, in line with our focus, outline how the institutions relate to five markers of institutional prestige. Table 2.3 sets out the institutions according to five markers of institutional prestige that we discussed earlier:

- High selectivity (Trow 1973; Volkwein & Sweitzer 2006; Eckel 2008; Cantwell & Marginson 2018): we examined the extent to which each

university was focused on selecting using high academic entry criteria or recruiting students.
- A homogeneous student population (Trow 1973; Marginson 2018; Holland & Ford 2021): we examined whether the largest single ethnic group made up over 50 per cent of the student population in each university.
- A higher proportion of international students (Cantwell & Marginson 2018; Ford & Cate 2020): we examined how the percentage of international students in each institution compared to the national average in each university's country.
- An internationally focused research agenda (Trow 1973; Cantwell & Marginson 2018): based on the institutional research strategy of each institution, we examined the extent to which its research agenda was focused on having an impact globally (elite) or was focused on developing excellent research (aspirational).
- An education agenda focused on producing elites (Trow 1973; Cantwell & Marginson 2018): based on the institutional educational strategy of each institution, we examined the extent to which it was focused on educating the brightest and the best students (elite) or whether it was focused on educating all students regardless of their background (inclusive).

Table 2.3 shows that Argon University, United States, and Sodium University, South Africa, were the most clearly elite institutions with selective admissions, relatively homogeneous home student populations, above the national average of international students and elite research and educational agendas. This suggests that the distributive rules in these two universities were the most restricted, focusing on offering an elite education to highly selected and homogeneous students. Erbium University, England, and Samarium University, South Africa, were similarly prestigious except the distributive rules were slightly relaxed, albeit in slightly different ways. Erbium had an inclusive educational agenda, and Samarium had a more diverse student population. The distributive rules at Astatine University, United States, and Europium University, England, were less restricted with more inclusive admissions, a more diverse student population and lower levels of international students. There were differences, as Astatine had an elite research agenda and Europium an aspirational one.

As a group of universities, these six institutions provided the study with a diversity of educational contexts in which to examine students' experiences of studying chemistry and chemical engineering. This allowed us to explore whether students in institutions with different levels of prestige appeared to benefit from their educational experiences in a similar way. Rather than comparing the

Table 2.3 The universities' positions in relation to five measures of institutional prestige

University	Admissions	Home student population*	% International students	Research agenda	Educational mission
Argon	Selective	Homogeneous	Above national average	Elite	Elite
Astatine	Inclusive	Diverse	National average	Elite	Inclusive
Erbium	Selective	Homogeneous	Above national average	Elite	Inclusive
Europium	Inclusive	Diverse	Below national average	Aspirational	Inclusive
Samarium	Selective	Diverse	Above national average	Elite	Elite
Sodium	Selective	Homogeneous	Above national Average	Elite	Elite

* Diverse if no single group in ethnicity-related category makes up over 50 per cent of student population

differences between elite and inclusive institutions, this means we were focused on understanding whether students' engagement with knowledge was similar across all the institutions in our study. This was crucial if the study was to be able to gain insights into the impact of studying these disciplines that was not simply a reflection of the prestige of the institutions where students were studying.

Conclusion

In this chapter, we have examined the similarities and differences between the three higher education systems that were the focus of our study. We have discussed how, despite the differences between the systems, there were key questions in each system about whether students from all backgrounds had equality of access to higher education. We showed how human capital theory and vertical differentiation played a key role in each of the systems. Whilst the former tends to frame the purposes of education in terms of employment outcomes, the latter tends to result in more privileged students being given access to a more elite form of education than less privileged students. In the next chapter, we introduce the subjects and degrees of chemistry and chemical engineering and examine the extent to which the differences we identified in the distributive rules of the six institutions were reflected in the degree programmes offered to students.

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3

What Were the Educational Intentions of the Degree Programmes?

In this chapter, we introduce the degree programmes that our participants were studying. We focus on the recontextualising rules of the pedagogic device (Bernstein 2000). We initially introduce Bernstein's (2000) view of the recontextualising rules and the differences that this way of thinking would see between chemistry as a singular and chemical engineering as a region. We then compare chemistry and chemical engineering in terms of their professional accreditation and their curricula. For the latter, we particularly draw on the accounts provided by the programme leaders of each degree programme. It is important to be explicit that the programme leaders were long-standing members of their departments and had led their programmes for between five and twenty years. The observations we make were also supported by our analysis of programme handbook statements of the purposes and educational approach of the programmes. In order to preserve the anonymity of the institutions, we do not quote directly from these documents.

We argue that the chemistry programmes are largely very similar across the institutions, with the differences related to whether the programmes position themselves as an elite or inclusive form of education. In all cases, the focus is on the relationship between students and chemistry. While the elite and inclusive framing also has an impact on the chemical engineering programmes, there is a much wider range of differences that group these institutions in different ways. These differences seem to relate to the challenges of the sheer amount of material that needs to be covered in chemical engineering and the focus on how students will use their knowledge in the world.

Recontextualising rules

In this chapter, we shift to consider the recontextualising rules of the pedagogic device. For Bernstein (2000), recontextualising rules govern the transformation of legitimate knowledge into pedagogic discourse, that is to say, the transformation of disciplinary knowledge practices into 'teachable' material. In this process, Bernstein argued that knowledge is removed from the principles of practice through which it was developed and transformed into a 'virtual practice' (Bernstein 1990, p. 184). There are two elements to the recontextualisation of disciplinary knowledge practices: the extent to which disciplinary knowledge practices maintain their specialised voices, what Bernstein (2000) referred to as 'classification', and the processes by which these recontextualised voices are transformed into the messages of curriculum, which Bernstein (2000) referred to as 'framing'.

For Bernstein (2000), classification is about power and how boundaries are maintained **between** categories, whilst framing is about control and how relations are positioned **within** categories. For students, classification is about recognition rules, how they recognise a particular form of knowledge, which we consider in Chapter 4, whereas framing is about realisation rules, how they produce their own texts in relation to a particular form of knowledge, which we consider in Chapter 5. Thus, classification is about what makes chemistry or chemical engineering distinct from each other and other subjects, disciplines and fields and what form of chemistry or chemical engineering is offered to students, whereas framing is about how chemistry or chemical engineering is taught to students and how they, in turn, produce their own versions of chemistry and chemical engineering.

In examining the educational intentions of our degree programmes, we first examine the differences in the pedagogic discourses of chemistry and chemical engineering as reflected in the accreditation documents from the professional bodies and subject benchmarks. We then examine the differences in the versions of chemistry and chemical engineering in each university, drawing on interviews with the programme directors.

Comparing chemistry and chemical engineering

This study examined students' experiences of studying chemistry and chemical engineering undergraduate degree courses. As we discussed in Chapter 1, there were two reasons for focusing on these two subjects. First, in examining these two closely related disciplines, we will be able to examine the different in ways in which 'chemistry' is produced in a 'pure', or in Bernstein's (2000) terms, 'singular' form in chemistry and an 'applied', or what Bernstein (2000) would call 'regional', form in chemical engineering. An important difference between singulars and regions is that engagement with the world is an intrinsic property of the knowledge of regions whereas this is not the case with singulars (Smit 2017). Second, they are representatives of broader programmes in science and engineering, which, whilst sharing some similarities in basic science foundations, have very different histories.

The history of chemistry can be traced back at least to 700 BCE with the development of the idea of classifying compounds into elements (Uleanya et al. 2023). There are debates about when chemistry moved from being a set of 'profane' practices to being a 'sacred' science, with some identifying the seventeenth and others the eighteenth century (Bensaude-Vincent & Stengers 1996), although such debates tend to be tied up in a colonial understanding of the history of chemistry (Uleanya et al. 2023). Bensaude-Vincent and Stengers (1996) argued that the development of chemistry as a science was gradual and part of a network of practices that brought together laboratory techniques, amateur chemists and artisans, and different kinds of institutions. The development of chemistry was bound up with the development of scientific journals, supported by developments in printing, which were crucial in its identity as a science and its incorporation into universities (Hannaway 1975; Knight 1992; Bensaude-Vincent & Stengers 1996). Many argue that chemistry is the central science, between the basic elements of reality focused on in physics and the complex world of living organisms that are focused on in biology (Mahaffy et al. 2019). Mahaffy et al. (2019) argue that this centrality means that chemistry can be seen to have a role in every aspect of human societies, given that everything is made up of atoms, molecules and chemical processes, which are increasingly important in developing sustainable ways of living on the planet.

In contrast, the history of chemical engineering is more recent. As with chemistry, its history as a profession and a degree subject is disputed (Cohen 1996), but it is generally accepted that both the profession and degree programmes grew out of the needs of the emerging modern chemical industry in the 1800s (Cohen 1996; Gillett 2001; Perkins 2002; Bolton et al. 2023). This has meant that, whilst historically the chemistry curriculum has been relatively stable (Cooper & Klymkowsky 2013), university curricula in chemical engineering have faced regular calls for reform in order to take account of developments in practice and changes in the needs of industry (Bilques et al. 2023). This has been both in terms of a wholesale rethinking of the curriculum (for example, Armstrong 2006; Wood 2007; Meyer et al. 2022) and the need to respond to new developments in the field and the profession (for example, Cameron et al. 2019; IChemE 2022; Byrne 2023; Horio & Clift 2023).

In chemistry, changes to the curriculum have been related to debates over what to include, how to order the curriculum and how to respond to new developments in chemistry research (Holme 2023) as well as how to respond to calls to decolonise the chemistry curriculum (Dessent et al. 2021). Whilst chemical engineering faces similar pressures, including to decolonise the curriculum (Agrawal & Heydenrych 2024), its strong links to industry create additional pressures and an even greater danger that degrees can become overloaded with content (Campbell & Belton 2016). This raises tensions and dilemmas over the extent to which the curricula of these degrees should be designed to cover the basics or to address new developments in the field and whether the curriculum should be designed to help graduates in the early years of their careers or to support a long career in the profession (Brown et al. 2019). One response to these challenges is to argue for diversity in the curricula of degrees in chemical engineering within the parameters set by professional accreditation (Brown et al. 2019), and there is indeed evidence both within chemical engineering (Bliques et al. 2023) and engineering more generally (Klassen & Sá 2020) of variation in the chemical engineering degrees offered by different universities.

Whilst arguing for diversity in chemical engineering curricula offers a way to avoid overloaded courses, it raises questions about the different versions of chemical engineering offered by different degree programmes and the extent to which there are unifying aspects across all curricula in a way that is not faced by chemistry. Horio and Clift (2023) argued that whilst it was initially the scale involved in chemical engineering as a discipline that distinguished it from chemistry, by the early 1900s, five essential elements of chemical engineering curricula were identified: (i) design, (ii) problem solving, (iii) production processes, (iv) scale and (v) professionalism; however, in different approaches to chemical engineering education, different aspects of these five elements have been emphasised (for example, Gillett 2001). The essential elements of a chemical engineering degree can also be considered in terms of the competencies that are needed to be a professional chemical engineer (Bolton et al. 2023; Franco et al. 2023). Again, in some cases, particular competences are highlighted. For example, Horio and Clift (2023) posit that it is problem-solving that is the key competence and that focusing on it allows chemical engineers to go beyond the commercial plant and play a role in the transition to a sustainable society. As part of the Frontiers in Chemical Engineering Education initiative in the United States in the early 2000s, Armstrong (2006) argued that the chemical engineering curriculum should be organised around the three themes of molecular transformations, multiscale analysis and a systems view. Armstrong (2006, p. 107) summarised the ways in which chemical engineers see the world: '*chemical engineers leverage knowledge of molecular processes across multiple-length scales in order to synthesise and manipulate complex systems comprising processes and the products they produce*.'

The messiness of the comparison

We initially examine the differences in the way that chemistry and chemical engineering are positioned within the accreditation documents of the professional bodies. These comparisons are not straightforward and there are a number of inconsistencies we need to highlight in our analysis.

In relation to chemistry, for England and the United States, we drew on the documents of the Royal Society of Chemistry (RSC 2023) and the American Chemical Society (ACS 2015), respectively, as they approve the degree programmes in our English and US universities. We also draw on the Subject Benchmarks used by the English universities (QAA 2022) as these are referred to by the RSC. We did not include documents from South Africa as the South African Chemical Institute does not accredit degree programmes. Degree programmes in South Africa are accredited through the standards of South African Qualifications Authority and the Council for Higher Education. For first degrees, they accredit a more general Bachelor of Science with students qualifying as chemists if they complete an honours programme which, unlike in England and the United States, is a separate postgraduate qualification. One of the implications of this difference is that South African undergraduates do not complete an integrative, independent piece of research unless they complete an honours programme.

In relation to chemical engineering, we drew on documents from the Institute of Chemical Engineers (IChemE 2024) that accredited the programmes at the two English universities, ABET (2021) that accredit the programmes at the US universities, and the Engineering Council of South Africa (ECSA 2023) that accredited the programmes at the South African universities. All three forms of accreditation are recognised as equivalent by the Washington Accord. However, there are differences. The IChemE documents relate directly to chemical engineering whereas the ABET and ECSA documents are focused more generally on engineering. ECSA mention chemical engineering as a potential qualifier and ABET has brief subsections on the requirements for different types of engineering, including chemical engineering.

Differences in the recontextualisation of chemistry and chemical engineering

The requirements for the chemistry and chemical engineering programmes can be compared in terms of the concepts focused on and the positioning of practical skills, problem solving, integrative experiences, employment skills and employability.

In relation to concepts, unsurprisingly, chemistry focuses on the different aspects and approaches to chemistry, with the only difference between the RSC and the ACS being that biochemistry is explicitly included in the ACS required concepts. For chemical engineering, there is a mix of a focus on chemical engineering processes, mathematical models, the underlying scientific principles from physics, chemistry, biochemistry, biology and materials science, as well as engineering principles. The much greater variety and number of conceptual elements that chemical engineers need to engage with is striking, and this pattern is repeated throughout the other aspects of the programmes. This is related to the sense that the world is presented as much more complex and understanding of it as more partial in the chemical engineering requirements than those of chemistry, which reflects engineering's focus on transforming and manipulating the world to meet human needs (Rogers 1983).

In relation to practical skills, the focus in chemistry is on the skills needed to understand and assess safety in the lab, whereas in chemical engineering the focus is both more systematic in terms of understanding systems of risk management and involves taking account of a greater range of factors such as legal frameworks and environmental issues. There are similar differences in the approach taken to problem solving. In chemistry, it is about problem solving in largely controllable experimental settings, even if measurement can be uncertain:

> *Students should be taught how to define problems clearly, develop testable hypotheses, design and execute experiments, analyze data using appropriate*

statistical methods, understand the fundamental uncertainties in experimental measurements, and draw appropriate conclusions.

(ACS 2015, p. 17)

In chemical engineering, problem solving is about taking an engineering approach, with a recognition that problems may be poorly defined, unfamiliar, require originality to solve and are based on incomplete information:

Complex engineering problems

(a) These require a fundamentals-based, first principles analytical approach, use in-depth engineering knowledge and have one or more of the following characteristics:

- *(i) A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.*
- *(ii) Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much of which is at the forefront of the discipline.*
- *(iii) Knowledge, including efficient resource use, environmental impacts, whole-life cost, re-use of resources, net zero carbon, and similar concepts, that supports engineering design and operations in a practice area.*
- *(iv) Knowledge of engineering practice (technology) in the practice areas in the engineering discipline.*
- *(v) Engagement with selected knowledge in the current research literature of the discipline, awareness of the power of critical thinking and creative approaches to evaluate emerging issues.*

(b) and have some or all of the following characteristics:

- *(i) Involve wide-ranging and/or conflicting technical, non-technical issues (such as ethical, sustainability, legal, political, economic, societal) and consideration of future requirements.*
- *(ii) Have no obvious solution and require abstract thinking, creativity and originality in analysis to formulate suitable models.*
- *(iii) Involve infrequently encountered issues or novel problems.*
- *(iv) Address problems not encompassed by standards and codes of practice for professional engineering.*
- *(v) Involve collaboration across engineering disciplines, other fields, and/or diverse groups of stakeholders with widely varying needs.*
- *(vi) Address high-level problems with many components or sub-problems that may require a systems approach.*

(ECSA 2023, p. 17)

In relation to the integrative experience, in chemistry, this is about bringing together the elements of the programme and bridging between students' academic and professional experiences:

> *An integrative experience that requires them to synthesize the knowledge and skills introduced across the curriculum. Such experiences provide a bridge between the students' academic and future professional activities.*
>
> (ACS 2015, p. 15)

In chemical engineering, the integrative experience is about being able to undertake the many aspects of a design study and seeing from a range of perspectives from a systems approach. This again involves many more perspectives and elements than chemistry:

- *Understand the importance of identifying the objectives and context of the design in terms of: the business requirements; the technical requirements; sustainable development; safety, health and environmental issues; appreciation of public perception and concerns;*
- *Understand that design is an open-ended process, lacking a pre-determined solution, which requires: synthesis, innovation and creativity; choices on the basis of incomplete and contradictory information; decision making; working with constraints and multiple objectives; justification of the choices and decisions taken;*
- *be able to deploy chemical engineering knowledge using rigorous calculation and results analysis to develop a design and with appropriate checks on feasibility and practicality;*
- *be able to take a systems approach to design appreciating: complexity; interaction; integration;*
- *be able to evaluate the effectiveness of their design, including its immediate and life cycle environmental impacts;*
- *be able to work in a team and understand and manage the processes of: peer challenge; planning, prioritising and organising team activity; the discipline of mutual dependency;*
- *be able to communicate effectively to: acquire input information; present the outcomes of the design clearly, concisely and with the appropriate amount of detail, including flowsheets and stream data; explain and defend chosen design options and decisions taken.*

(IChemE 2024, p. 51)

In relation to employability skills, the focus in chemistry is on describing the attributes that a chemistry graduate has in terms of their way of engaging with the world:

> *Chemistry graduates are therefore innovative and enterprising in their outlook and excited by the challenge of finding solutions to problems. They are confident and resilient, and are capable of adapting to uncertainty, assessing risk and actively embracing change. They are self-motivated and independent, but also able to work effectively as part of a team. Chemistry graduates should be logical and analytical and be confident in the use of evidence to develop, support or refute arguments. They are constructive and objective in challenging the ideas of others and resilient and reflective when their own ideas are challenged. They are responsible and act with integrity, considering the impacts of their actions and decisions on both individuals and wider society. They value diversity in all of its forms, and respect and recognise the contributions of others.*
>
> (QAA 2022, p. 11)

In chemical engineering, the focus is on describing the professionalism of graduates:

- *They must have developed and demonstrated ability to integrate transferable professional skills (such as communications, time management, team working, inter-personal, effective use of IT and digital technologies including information retrieval skills) that will be of value in a wide range of situations.*
- *be able to reflect on their own work and implement strategies for personal improvement and professional development.*

(IChemE 2024, p. 12)

These differences again underlie the sense that in chemistry, the focus is on the relationship between the students and chemistry, whereas in chemical engineering, it is about the relationship between students and the world.

Finally, both sets of requirements focus on sustainability. In chemistry, this position is an appreciation of the importance of sustainability within chemistry:

> [the programme should] *establish in students an appreciation of the importance and sustainability of the chemical sciences in industrial, academic, economic, environmental and social contexts.*
>
> (QAA 2022, p. 3)

In engineering, this is framed much more in terms of an ethical and professional responsibility in engaging with the world:

> [graduates should demonstrate] *an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.*
>
> (ABET 2021, p. 8)

Overall, there is a sense that the requirements for chemistry are focused on the relations between students and chemistry. Where there is discussion of the world, it is very much the world that is created through the study of chemistry. In chemical engineering, the focus is on how students will be prepared to engage as professional engineers in a world that is complex and of which our knowledge is partial and limited. These differences very much align with how Bernstein (2000) contrasts the differences between singulars and regions. In addition, it is striking how many different ways of thinking chemical engineering requires students to engage with and the greater specification of these ways of thinking within the standards. In chemistry, there is a sense that simple terms like 'analytical chemistry' are pregnant with meaning and do not need to be explained to the expected reader of the standards.

Comparing the degree programmes

We now consider how these differences in the chemistry and chemical engineering degree programmes played out in each of our programmes. In doing so, we shift to focus on each subject in turn before coming back to consider the implications of these differences.

The chemistry programmes

The differences in the chemistry programmes were mainly related to the institution's positions in institutional hierarchies discussed in Chapter 2. Argon, Erbium, Sodium and Samarium were all featured in global rankings for chemistry and had a selective approach to student recruitment. They tended to teach smaller cohorts of students than Astatine and Europium, and, in the interviews with programme leaders, there was an emphasis on the way in which the programmes gave students a good general introduction to chemistry.

In contrast, Astatine and Europium did not feature in global rankings for chemistry and took an inclusive approach to student recruitment. They had more diverse students than all of the other institutions apart from Samarium and, in the interviews with programme leaders, there was an emphasis on lab-based chemistry and the ways in which they prepared their students for employment.

Argon, Erbium, Samarium and Sodium all emphasised aspects of their education that fitted into an elite conception of higher education. There was an emphasis on the relatively small, close-knit communities that students were introduced to:

> *We're a fairly small department so we do like to think of ourselves as a family, and I think our students, especially since there aren't a lot of them- you know, by the time they get to senior, some of their classes are very small; they're actually a pretty close-knit community. So just even the people skills- we have a first-year experience class that is in their freshmen year, where we really work hard on community-building and that whole sense of including everybody and learning how to learn, I guess.*
> (Chemistry Programme Leader, Argon, United States)

They all emphasised the broad education that was offered in their chemistry programmes which gave students options about what they would do in the future. There was a sense that students came to their programmes without a clear sense of what career path they would follow, and that the degree would help them to work out where to go next.

> *We do cover the bases, like the range of the basics really well. So it is a good degree if you are not sure which area of chemistry you like, because you are doing everything … So I accept it is broad knowledge, obviously, they are having to do everything and not specialise. So broad knowledge of all the areas of chemistry. I would hope by that point as well that they have specialised in one of them, so obviously their third or fourth year they do their research project and we do see it. By that point they have decided which branch they are more interested in. So you will get some by that point who don't want to go in the lab anymore and they have gone down that computational, the analytical route, and then you have got others that absolutely want to be in the lab, morning till night, so they go more for the synthetic projects.*
> (Chemistry Programme Leader, Erbium, England)

This was seen as part of a reflection of chemistry as a disciplinary area and one of the strengths of what it offered to the students studying it:

> *I think the thing about chemistry is it is incredibly broad. Even if I just think about most of the other subjects, until a few years ago, most subjects only did two modules at third year. Most still only do two modules and second year, so it's much more narrow, whereas chemistry is incredibly broad. Because it's incredibly broad, I think students … learn how to bring some very disparate concepts together in order*

> *to understand the overall field. This is one of the issues that we've actually had with students in the past, is that we keep saying, 'But they don't do this,' but actually they do. They actually do get that feeling that all of these strands knit together, so I think it makes them very flexible in that respect.*
>
> (Chemistry Programme Leader, Sodium, South Africa)

This was also seen as important, whether or not students ended up going into chemistry or another area.

> *So if you are interested in chemistry this is fantastic because there are so many different ways that you can go and be a chemist. But if you are not interested in chemistry it is also quite a fabulous underpinning to so many other things that you can go and do. So I think, what I would like to think people come out with is a good appreciation of the scientific method, the way that science actually operates, feels quite important right now. But also an approach to seeing what the problem is, deriving a problem statement and then finding ways to actually tackle that and see how to solve it. I think that is the kind of … And those skills are very valuable, no matter what you land up doing.*
>
> (Chemistry Programme Leader, Samarium, South Africa)

This contrasted with Astatine and Europium, where there was more of a focus on preparing students for employment in chemistry:

> *I want them to make us proud. I want them to go to interview well … I am a real stickler with students who are writing something. In some of the advanced classes, we will do group work in small groups, on boards, and I will walk around. Mechanisms is a perfect example. If they are drawing these wacky looking benzene rings, I am like, 'That is not going to make a good impression on anyone. You are going to have to interview for something at any time', so just those little details. Sometimes I look about- I look at that course as organic chemistry finishing school in a weird sort of way.*
>
> (Chemistry Programme Leader, Astatine, United States)

At Europium, this priority informed a focus on students being given practical lab-based training:

> *At bachelor's level, we insist that all of our students do a laboratory-based research project. That is relatively unusual … I think it tells employers that they're going to get a competent laboratory scientist and that that laboratory scientist will relatively unusually be trained in and understand, to some level of depth, analytical chemistry as a specialism. So I think that is the big seller, and it seems to be reflected in the fact that those types of employers do continue to take to take our students into employment.*
>
> (Chemistry Programme Leader, Europium, England)

This was in contrast to the emphasis on the importance of students appreciating the beauty of chemistry at Argon, Erbium, Samarium and Sodium.

> *I actually think chemistry is an amazing subject, and what I hope that we get through in our degree is just some appreciation of, first of all how broad the topic is, so how many different branches and areas. And I know certainly in my teaching, and I think in my colleagues as well, we make the point that we can't do it all in an undergraduate degree. So we are trying to give people a sense.*
>
> (Chemistry Programme Leader, Samarium, South Africa)

> *To me, teaching is just you're passing on knowledge, which I guess you can get from anything, but it's that, 'how does that knowledge fit in with everything else?' It's about educating them. It's about a holistic worldview of 'where does chemistry fit into everything else?'*
>
> (Chemistry Programme Leader, Sodium, South Africa)

Astatine and Europium also emphasised their inclusion and diversity:

> *Our big, big seller has always been inclusion and widening participation and getting in students that are not necessarily from those traditional … backgrounds.*
>
> (Chemistry Programme Leader, Europium, England)

> *So I mean I think the diversity of our faculty and our student body is something that, certainly, is going to stay with them and hopefully make them- I don't want to use the word 'better', because better than what, but make them good world citizens, maybe, is a way to say that.*
>
> (Chemistry Programme Leader, Astatine, United States)

This again contrasted with the sense in the other programmes that they were very demanding of their students. For example, at Sodium, the sense of what would make them proud is different from the quote from Astatine earlier:

> *I think, as lecturers, we're very demanding of our students. I think that we expect high standards of them, and I think that we are very passionate about our training and we don't just teach, that we actually educate. Or at least we try to educate. So, I think that it means that the students do come out of here not just having knowledge, but knowledge that they can apply and use, and that they have a little bit of savvy, that they can think as well. It's never as much as we, as lecturers, would like, but I do think that I can send a student out there and say that I can hold my head high and go, 'That student is somebody that I can be proud of'.*
>
> (Chemistry Programme Leader, Sodium, South Africa)

At Samarium, there was a sense that students would be able to be a chemist anywhere in the world:

> *What I would certainly say what I think is that a student who comes out of a degree in chemistry from Samarium, first of all can go anywhere in the world and hold their own against other people with an equivalent level of training. So I think what we do we do well and the students get it and they just do well.*
>
> (Chemistry Programme Leader, Samarium, South Africa)

Overall, across the chemistry programmes, there was a sense that Argon, Erbium, Samarium and Sodium offered an elite form of chemistry education in which students were offered a broad introduction to the beauty of chemistry that would equip them to go anywhere in the world. Whereas at Astatine and Sodium, there was a sense that a diverse range of students were being prepared so that they could gain employment as a chemist. These differences were aligned with the institutional hierarchies discussed in Chapter 2.

The chemical engineering programmes

Compared to the chemistry programmes, there was a much greater degree of variation between the chemical engineering programmes. The way that institutions grouped together was also much more variable than chemistry and did not relate to the institutional hierarchies. The difference with chemistry seemed to relate to the much greater amount of content in chemical engineering, which meant that the programmes needed to find a pragmatic path through the sheer volume of potential areas of chemical engineering. We discuss these in relation to the extent to which the programmes foregrounded the diversity of their students, the different relationships between chemistry and engineering in the different programmes and the educational intentions of the programmes. We finally discuss a feature that all the programmes had in common that differentiated them from the chemistry programmes. This was an explicit focus on how to design the curriculum to give students access to the range of bodies of knowledge that made up chemical engineering, which was generally recognised as a process that required compromise.

Astatine and Europium focused on ways their curricula were shaped by their more inclusive admissions policies. At Astatine, this was related to the high number of transfer students from community colleges who would join later in the programmes.

> *That's actually to accommodate, we have many transfer students who transfer from community colleges that don't offer the classes that are offered in our department. To be able to accommodate those community college students and still allow them*

philosophically to graduate in four years, we've pushed many of our departmental classes to junior and senior year.

(Chemical Engineering Programme Leader, Astatine, United States)

This presented a challenge for the design of the programme in terms of finding a balance between the accessibility and inclusivity of the programme and the need to not overload particular years in the curriculum:

[The] very dramatic burden that students have in their junior year, and it's most burdensome probably the spring semester of their junior year which is coincidentally when I teach a class.

So, I get to experience the students as they go through the most challenging semester of their career and all of the mental health fall out that accompanies that. It's a really challenging scenario where we don't want to exclude our transfer students or make the degree by definition a longer time trajectory, we don't want to do that, but we also don't want the native freshmen and transfers honestly to be crushed by this heavy class burden. So, we're trying to figure out how to space things out without effectively making a five year degree. We don't have an answer to that yet, so we're working on that as we speak.

(Chemical Engineering Programme Leader, Astatine, United States)

For Europium, there was a clear sense that they took students mainly from their local area and a commitment to offer an education that was designed for these students:

We are not attracting the best and the brightest. We are attracting students who, I firmly believe, will do better, because they've had the quality of education that we're giving them … We have a lot of what we call commuter students. It draws, a lot, on the local area. So we do get international students. We get students from elsewhere in the country. But the majority of our students are from the local area. That does influence their cultural background, the mindset, their ambitions. It does play a part. [I] firmly believe you teach the students you've got, not the students you wish you had. Anybody can say, 'Our students ought to be like this and ought to behave like this.' Yes, lovely, but these are the students we've got.

(Chemical Engineering Programme Leader, Europium, England)

The commitment was to teach these students to the level of more elite education settings:

However, I also believe what we're teaching is the right thing to teach, and we're teaching it well. If you teach well, then these students ought to be able to cope with it. We are certainly not pulling our punches … we want to be teaching a worthwhile

> *programme. We don't want to be dumbing it down. But the students that we're getting, they really do struggle with it. So we've had to approach that, in terms of, we are determined to teach at the level that we think is right, and we're determined to empower our students to perform by teaching really well, by good practices in relation to teaching.*
>
> (Chemical Engineering Programme Leader, Europium, England)

A key aspect of this for chemical engineering at Europium was to focus on assessment:

> *So somebody has said, 'Good students can, with difficulty, escape poor teaching. They can't escape poor assessment.' I like that quotation, because it gets to the heart of the issue … So I emphasise good practice in assessment, because good practice in assessment is good for its own sake, but it's also good for inclusivity. So poor practice in assessment disproportionately affects people who are not of the same mindset, if you like. If you're from the same culture as me, you can read between the lines. We both have the same tacit understanding. Whereas good practice in assessment is about transparency, validity, marking against explicit learning outcomes, against clear criteria … inclusivity is, best practice in assessment.*
>
> (Chemical Engineering Programme Leader, Europium, England)

This commitment to teaching students in a way that worked to bring them up to the same level as other students was seen as more problematic for chemical engineering at Sodium, where students with less supportive educational backgrounds were initially supported through a bridging year but then had to make their way in the mainstream programme:

> *So it's students with potential, but who have unfortunately not had the right kind of background in their secondary education … So let's call it the 'extended degree programme's bridging year' is intensive, it's small, and there is a lot of input from the academics responsible, and it's a wonderful thing to be doing. But at some point, those students then still get let loose into what are effectively now gigantic first year classes. And I think this is something that we're all experiencing at South African universities, the so called massification of education. But that's a very big jump. For those students who have come from the disadvantaged background, then had almost intensive coaching, and then suddenly, you're exposed as one of a thousand first year students, and that's very hard place to be in, I think.*
>
> *So we're quite aware of this, and it's an ongoing thing that we wrestle with.*
>
> (Chemical Engineering Programme Leader, Sodium, South Africa)

In terms of the relationship between engineering and chemistry in the chemical engineering programmes, there appeared to be two different ways in which this was organised. In the programmes at Argon, Erbium and Sodium, the approach was that students began studying general engineering courses before then specialising in chemical engineering:

> *The way it's set up is, their very first year, they enter engineering education. So that basically is a holding place for all of the students for one year until they've completed their first-year courses. Then they go into a degree granting programme for three years.*
>
> (Chemical Engineering Programme Leader, Argon, United States)

> *So our students would start in the first year in a common first year. There will be one particular module that is discipline specific. So that's been introduced probably in the last five years, in the first year. And then thereafter, as students move through the programme from the second, third, and fourth years, the degree of specialisation in terms of what modules they're doing increases to the point that in the fourth year, these are obviously now rather specialised engineering modules aimed primarily at chemical engineers.*
>
> (Chemical Engineering Programme Leader, Sodium, South Africa)

At Astatine, Europium and Samarium, students began studying chemical engineering from the first year of their programme. At Astatine, there were different pathways that students could follow within chemical engineering:

> *The tracks, in a sense, just give that degree a different flavour. We have the traditional track which is what most would think of as traditional chemical engineering … we first added a second track which was biotechnology and biomedical engineering track, so a bio track if you will. Then we added a third track, which was environmental engineering and sustainability track. Students are able to choose which of those three tracks. It depends on how you define things, so it's not comprehensive in the sense that they're not earning an environmental engineering degree if they're on the environmental engineering track. They still earn a Chem E degree.*
>
> (Chemical Engineering Programme Leader, Astatine, United States)

At Europium, there was a particular focus on the chemistry within chemical engineering:

> *So the driving force, initially, was creating this chemical engineering programme that has a strength in chemistry … The key to teaching chemical engineering is to teach it such that its breadth becomes its power, not its weakness. Now, chemical engineering is the broadest and the most scientific, but often, it's missing the scientific bit. So that's where the chemistry comes in.*
>
> (Chemical Engineering Programme Leader, Europium, England)

However, these different configurations of chemistry and chemical engineering did not appear to be related to differences in the educational intentions of the programmes. Based on our analysis of the interviews with the programme leaders and the curriculum documents, we identified three different educational intentions in relation to the kinds of graduates that the degree programmes were intending to produce. These were graduates who could problem solve as a chemical engineer, graduates with the competencies of a chemical engineer and graduates who saw the world like a chemical engineer.

In the programme leader interviews and curriculum documents for Sodium and Argon, the emphasis was on developing the fundamental underpinnings of engineering that would enable graduates to solve problems as chemical engineers. At Sodium, there was a strong focus on the fundamental knowledge an engineer needs and the ability to solve engineering problems. The curriculum documents emphasised how students would specialise in processes that would support them to undertake crucial work in industry. This was echoed by the programme leader:

> *[M]uch of what you learn as an engineer, both in the chemical engineering programme - and I think this, of course, is true for any of the programmes - is an ability to use fundamental knowledge and fundamental principles to solve problems in an engineering context. And while clearly a chemical engineer can't immediately become a specialist and solve design problems in radio frequency antennas, you can solve general engineering problems that would help you interact with civil engineers, for example, or mechanical engineers. And I think these are absolutely critical skills that any engineering student needs to learn, and chemical engineers are no exception to this.*
>
> (Chemical Engineering Programme Leader, Sodium, South Africa)

At Argon, the emphasis was on students developing the fundamental underpinning of problem solving as a chemical engineer and having a sustainable career as a problem solver was listed as the most important programme objective in the programme documents. The programme leader explained:

> *In our core courses, we try to get the students to think about how to set up and solve problems. It isn't about plugging numbers into equations. It's about figuring out, what should the equations look like? And once you've got that, then plugging the numbers in gets really easy. So that's just the philosophy of our core courses.*
>
> (Chemical Engineering Programme Leader, Argon, United States)

At Samarium and Astatine, the emphasis was on students developing a wider range of competencies of a chemical engineer. Whilst this included problem solving, it included a wider range of competencies than was emphasised in Sodium and Argon, particularly teamwork and communication. The Samarium documents emphasised a teaching philosophy focused on technical expertise, teamwork and communication as well as problem-solving skills. This was reflected in the programme leader interview:

> *Let me call it this: complex problem-solving skills. So when you leave our degree, you should be able to look at a complex problem of any kind, actually, and figure out- not get lost in the wood for the trees, but should be able to identify the key points of that and be able to deal with those, so solve the problem quickly. Not necessarily the perfect solution. Of course, there is no perfect solution in engineering, but a solution in a reasonable time frame which will work to solve this complex problem … very strong ability to work in teams … communicating, they do the problem-solving and then they can communicate it to other people as well.*
>
> (Chemical Engineering Programme Leader, Samarium, South Africa)

In the Astatine documents, it was emphasised that the programme was designed around helping students to develop an integrated set of competencies and abilities. The programme leader explained the rationale for this approach:

> *They may transition out of a chemical engineering relevant job into a business acclimated job or a sales job or a management job or something completely different. You will still use your critical thinking, your cooperation, your communication, your capacity for lifelong learning.*
>
> (Chemical Engineering Programme Leader, Astatine, United States)

In Erbium and Europium, the emphasis was on producing graduates who could see the world like a chemical engineer, which would be useful even if students went into other kinds of roles after graduation. For both programmes, there was an emphasis on what separates chemical engineers from other fields. In the Erbium documents, the emphasis was on developing a deep knowledge of chemical engineering as a field and to use this understanding to engage with the world. The programme leader differentiated between chemical engineers and other kinds of engineers:

> *If you compare a chemical engineer to a civil engineer, the civil engineer understands structures. So the building is erect. It is stable. It stays there. It is strong enough. You come to demolish it. You convert it from this erect structure to a heap of rubble on the ground. And that is the civil engineering side, a building or a heap of rubble. Whereas the chemical engineer understands a process. Whilst they might not fully understand why the building stands erect, they will fully understand the whole process. How the bricks fall to the ground, if you see what I mean. The process*

> *of demolition. And the finance industries seek that knowledge out, because the chemical engineer can take their understanding of fluid dynamics and apply it to cash.*
>
> (Chemical Engineering Programme Leader, Erbium, England)

The Europium curriculum documents emphasised that students would develop a strong knowledge of chemical engineering, and the programme leader emphasised how he wanted students to love chemical engineering:

> *So I like to think that they get an understanding of chemical engineering, exemplified through the ability to think in a chemical engineering way … I want them to be in love with chemical engineering. I don't want them to be wannabe chemists or wannabe mathematicians. I want them to love chemical engineering … That's what I love about process integration. As I said, process integration exemplifies the heart of genuine chemical engineering, and it's about clever engineering, not about clever maths. It's about understanding insights into how the process works as a unified, holistic whole, and the maths is addition, subtraction and multiplication. It's very simple maths, but the engineering is powerful.*
>
> (Chemical Engineering Programme Leader, Europium, England)

In summary, across the six programmes there were three different emphases in the kinds of chemical engineering graduates they intended to produce. Whilst problem solving was key to all three programmes, in the Argon and Sodium degrees, problem solving was seen as the fundamental underpinning of being a chemical engineer. In the degrees at Astatine and Samarium, a greater range of competencies was emphasised, and at Erbium and Europium, it was the way of seeing the world as a chemical engineer that was seen as the key attribute of graduates.

Differences between chemistry and chemical engineering

In chemistry, the programmes differed in terms of the purposes of the degrees, in terms of developing an appreciation for chemistry or preparing students for employment. In chemical engineering, all students were being prepared to become chemical engineers, and the differences were in relation to the version of chemical engineering that students were introduced to, given the sheer range of knowledge and competencies that students needed to develop. These differences were reflected in the differences in the way that the programme leaders discussed issues of curriculum enhancement. In chemistry, the focus was on tweaking the curriculum to give students the best chance of understanding chemistry and to deal with outside demands. Whereas in chemical engineering, the focus was on bigger changes that would shape the curriculum to prepare students to engage with the world as chemical engineers and how to negotiate with the complexity of emergent and novel problems they would face beyond the curriculum.

In chemistry, the focus was on how to enhance the curriculum to enhance the student experience. For example, in chemistry at Argon and Samarium, there was a focus on using the curriculum design to help students develop an understanding of chemistry:

> *So in the spring, instead of going to their second semester of general chemistry, they're going to go to their first semester of organic chemistry. Because we want them to see, before they decide, 'chemistry's not for me,' that you don't always have to do math. And so we want to bring in the chemistry, the organic chemistry, which is not really as math-related, and it's a whole different set of skills you have to have … But a lot of them just don't have any clue what chemistry major is about.*
>
> (Chemistry Programme Leader, Argon, United States)

> *And I think that is where this idea of trying to integrate across topics, trying to draw the links quite explicitly for students around you don't do organic chemistry. You have to understand a bit of everything to be able to understand all of it- that kind of role. But I think it is still too heavy. I think it is still … It is kind of there and if we have a staff meeting and we are having a conversation everybody goes, 'Yes, yes.' But I don't think that we are communicating that well enough.*
>
> (Chemistry Programme Leader, Samarium, South Africa)

At chemistry in Erbium, the focus was on a careers module that didn't seem to working effectively and at Europium the emphasis was on iterative changes:

> *We have a careers module that is run by another department and it has never been successful. The students just don't really like it. The chemists, they don't like writing anyway and they are made to write an essay. But I think, also, because it is delivered outside the department, they definitely dismiss it as not being important … So we need to look at that and maybe bring the careers more into the department, like have the module run by us in the department rather than- yes. So we are about to tweak all those kind of things.*
>
> (Chemistry Programme Leader, Erbium, England)

> *[I]n terms of what we've done in the past[in relation to curriculum change], nothing particularly major that I can recall in my time, so that's 14 years as course leader. Everything has been, relatively speaking, quite either technical and bureaucratic or iterative.*
>
> (Chemistry Programme Leader, Europium, England)

This contrasted with the chemical engineering programmes where there was much more of a sense of ongoing re-design of the curriculum in order to prepare students to become chemical engineers. At Sodium, there was a clear sense of having to manage the sheer volume of material to be covered:

> *[W]e're all faced with this problem of being able to fit everything into a rather rigid structure that we're all faced with, and having slots available to do that, and weighing that up against saying, 'Well, actually, you know what? I'd like to teach everything at fourth year level,' which clearly is impossible. And do we get that balance correct? … I wouldn't in any way like to say that we've got the perfect programme because we're all making compromises, as we're quite well aware, and we have to do that.*
>
> (Chemical Engineering Programme Leader, Sodium, South Africa)

In the chemical engineering programmes, there was also a sense of using the curriculum in ways that prepared students to engage with the world professionally. For example, at Samarium this was discussed in terms of engaging with communities in non-directive ways and, at Astatine, it was in terms of dealing with problems that don't have clear solutions:

> *We do feel that they have got a good understanding about the impact of their profession, what it has on society and on the environment. I mean society, it used to be this sort of pat thing, oh, well, job creation, but I mean we worked hard with the society thing to also look at … a set of things there where they have to come and ask some questions to the community. It is framed as a community-driven project where they are only consultants kind of thing. So that idea of the engineer not always as the problem-solver with all the solutions, imposing their solution on other people, comes into it.*
>
> (Chemical Engineering Programme Leader, Samarium, South Africa)

> *The reason why we do that, and I talk about this with my students all the time, is that life, when you go get a job and you live life or if you go to graduate school and you're trying to get a graduate degree, when you get out life is almost by definition, completely ambiguous. Your paradigm as an undergraduate is completely opposed to that. Here is a great thought experiment, every homework problem and every exam problem you've ever had has an answer. You might not know what the answer is, but somebody does, there is a solution, and you can look it up or you'll be told the solution. Life is 180 degrees in the other direction, every worthwhile problem you're going to work by definition doesn't have an answer, nobody knows the answer.*
>
> (Chemical Engineering Programme Leader, Astatine, United States)

Finally, whilst in chemical engineering all of the participants were studying degrees in chemical engineering, in chemistry our participants were drawn from a variety of degree programmes that involved the study of chemistry. To maintain the anonymity of our institutions, we summarise these as either 'chemistry', in which students were studying single degrees in chemistry and 'chemistry in combination with other subject(s)', which included joint degrees in chemistry, degrees in biochemistry, and degrees that involved a combination of sciences including chemistry. Appendix 1 provides a summary of the participants from both chemistry and chemical engineering.

Overall, the differences in the curriculum and educational intentions of the programmes were consistent with the differences, which Bernstein (2000) argued would be expected, between chemistry as singular and chemical engineering as a region (Smit 2017). In chemistry, both the requirements and the curricula were focused on the relations between students and chemistry. Where there is discussion of the world, it was very much the world that was created through the study of chemistry. The programmes differed in terms of the purposes of the degrees, in terms of developing an appreciation for chemistry or preparing students for employment, but the curricula were broadly similar, and curriculum enhancement was in terms of tweaking the curriculum to give students the best chance of understanding chemistry and how to respond to outside demands.

In contrast, in chemical engineering, the focus was on preparing students to engage as professional engineers in a complex world, where knowledge is partial and limited. The assumption was that all students were being prepared to become chemical engineers, and the differences were related to the version of chemical engineering that students were introduced to, given the sheer range of knowledge and competencies that students needed to develop. Curriculum enhancement was focused on changes that would use the curriculum to prepare students to engage with the world as chemical engineers, and how to manage the volume of material to be covered in the curriculum.

Conclusion

In this chapter, we explored the degree programmes that our participants were studying from the perspective of the recontextualising rules of the pedagogic device (Bernstein 2000). We showed how the knowledge of chemistry and chemical engineering was recontextualised into curriculum. We found that chemistry and chemical engineering maintained their specialised voices within the curricula and educational intentions of the degree programmes. There were clear differences between the two subjects, which would be expected given the singular form of chemistry and the regional form of chemical engineering. In the next two chapters, we explore the extent to which these differences were recognised (Chapter 4) and realised (Chapter 5) in the accounts of the participants in our study when they were undergraduate students.

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4

Why Did Students Enter Higher Education and What Did They Gain?

This chapter shifts the focus to the experiences of the participants in our study when they were undergraduate students. This moves us to consider the evaluative rules of the pedagogic device. The evaluative rules of the pedagogic device dictate how teaching practices convey to students what it is to be legitimate learners and knowers. Bernstein claimed that the evaluative rules '*condense the meaning of the whole pedagogic device*' (2000,.p. 36) and '*shape any given context of acquisition*' (2000, p. 202). They regulate the pedagogical practices that transmit to the acquirer criteria about what should be 'recognised' as legitimate knowledge and how it can be 'realised' in 'texts'. In this chapter, we focus on the recognition rules and in the next chapter, we focus on the realisation rules. Recognition rules allow students to understand the distinguishing features (or classifications) of the pedagogical context so that they 'read' it correctly. In particular, we focus on the extent to which students understood their pedagogical context as being focused on knowledge or whether they simply understood it in instrumental terms.

As we discussed in Chapter 1, the way that students are seen is often at the heart of much of the disillusionment with mass higher education. They are often positioned as uninterested in knowledge and simply focused on the potential instrumental gains that are offered from higher education. As we showed in Chapter 1, these claims have been around for at least 100 years and probably as long as there have been students (Eells 1934; Moberly 1949; Carrigan 2019). Although, as we discussed in that chapter, they have been given renewed force by the dominance of human capital theory because of the way in which it positions students as instrumental consumers of knowledge (Brooks 2018; Gunn 2023).

In this chapter, we examine the extent to which students recognised their degree programmes as transformative, educational contexts or only focused on instrumental reasons for studying. Given the differences we identified in

Chapter 3, in relation to the curricula for chemistry and chemical engineering, we also examine whether there were differences in the ways that students recognised knowledge in these two subjects.

Instrumental or personally transformed students

An examination of the research literature on students' orientations to higher education highlights great concern that students have become instrumental consumers who are primarily focused on gaining credentials rather than engaging personally with knowledge (for example see, Naidoo & Jamieson 2005; Molesworth et al. 2009; Neary & Winn 2009; Saunders 2015; Brooks 2018; Gunn 2023). The concern is that they see the value of a degree simply in terms of what it allows them to do after graduation, its exchange value (McArthur 2011; Tomlinson 2018; Tomlinson & Watermeyer 2022; Mulderrig 2024), rather than as an opportunity to be personally transformed through their engagement with knowledge. Are these concerns well-founded? Is it the case that students see higher education as a process of certification rather than education?

A potentially useful way of contrasting instrumental and transformational ways that students can consider their education is expressed in Figure 4.1. The transformational relationships occur when students see the world through the lens offered by the subject they are studying. Their education takes them through the bodies of knowledge to engage with the world (the two diagonal arrows). They view the world through the structured body of knowledge they have studied and can engage with it – and understand themselves – in new ways. In this chapter, we discuss this as 'education-as-transformation'. In contrast, instrumental approaches to education do not go through the bodies of knowledge and instead help students to engage with the world through the certificate they gain (the horizontal arrow). In this case, it is the having of the qualification provided by the degree that is important. In this chapter, we discuss this in terms of 'education-as-instrument'.

One of the questions raised by this way of thinking is the relationship between education-as-instrument and education-as-transformation. In particular, to what extent is education-as-instrument a barrier to education-as-transformation? Part of the fear of those who decry student consumerism is that it will eventually erode students' intellectual commitment to knowledge. For example, Bernstein (2000, pp. 69–70) identified the dangers of a 'De-Centred Market Pedagogic Identity' in which the focus is on meeting the short-term needs of the labour

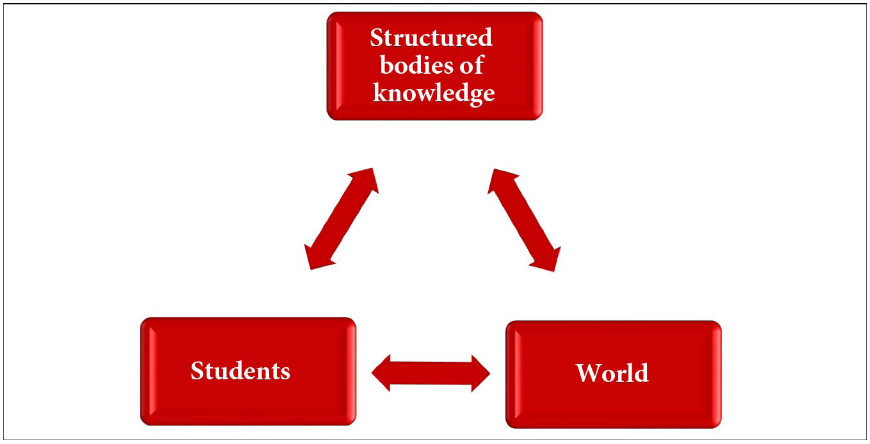

Figure 4.1 The transformational relationships of a university education (Ashwin 2020).

market and personal commitments to knowledge are seen as a barrier to the free flow of knowledge. The concern is that students' consumer attitude will undermine their academic engagement. There is evidence that an instrumental focus and a lack of personal engagement with knowledge have a negative impact on the quality of students' engagement with their education (Finney & Finney 2010; Tomlinson 2017; Brooks & Abrahams 2018; Nixon et al. 2018), leading to lower levels of academic performance (Bunce et al. 2017; Bunce & Bennett 2021). But it is not clear whether the lack of personal engagement is due to instrumentalism limiting the transformative potential of students' educational experiences or whether an initial lack of personal engagement leads students to instrumental approaches. In order to understand whether instrumentality undermines the transformational potential of higher education, it is necessary to understand how they are related within students' educational experiences. There are four ways in which this could occur.

First, different students could have different orientations to higher education, with some being focused on education-as-instrument to gain credentials for employment and some focused on education-as-transformation (for example, Brint 2012; Spronken-Smith et al. 2015; Willner et al. 2022; Schäfer 2024). However, there is strong evidence that this distinction is too crude, and the same students can see their education as both instrumentally valuable and personally transformational (for example, Tight 2013; Budd 2017; Patfield et al. 2021; Reynolds 2022; Gupta et al. 2023; Mendes & Hammett 2023; Taylor Bunce et al. 2023).

Second, rather than differences between students, the idea of 'prosumption' suggests that students' roles may be made up of different combinations of instrumental and transformative elements (Dusi & Huisman 2021). In this way of thinking, students move between instrumental and transformative modes depending on the specific tasks that they are engaged in. Third, rather than students' roles having a mixture of instrumental and transformative aspects, students could have either instrumental or transformative relationships with different aspects of their education (Ashwin et al. 2023). For example, they may have an instrumental relationship with their institution but have a transformative relationship to the knowledge they are gaining.

A fourth explanation is that education-as-instrument and education-as-transformation offer different kinds of descriptions of students' educational experiences rather than being related to each other. This explanation would suggest that, for students, an instrumental or transformative description of their educational experience can be 'evoked' by their understanding of their context in a similar way to the manner in which different conceptions of learning can be evoked depending on students' understanding of their educational context (Trigwell & Ashwin 2006; Ashwin & Trigwell 2012; Trigwell et al. 2013). Under this understanding, some situations would call for students to give an instrumental account of their educational experiences and others a transformative one, without the different accounts necessarily impacting on each other.

In this chapter, we explore the relationship between students' instrumental and transformative accounts of their education. We do this by examining why students were initially studying for a degree at university and what they felt they had gained from being at university and studying their degree in their final undergraduate year. To do so, we focus on the ninety-five students whom we interviewed over the course of their undergraduate degrees to give a sense of the trajectories through their programmes.

Why students chose to go to university in their first year

In the interviews of students in their first year of study, the reasons that students gave for going to university and for studying the subject of their degree were consistent. They answered both questions as if they were a single question about going to university to study a particular subject: either chemistry or chemical engineering. Our analysis of students' responses generated six broad reasons for studying at university. Two of the reasons were given by some students studying chemistry and some students studying chemical engineering. These were to become a professional in the field of their subject and to establish a career more generally. Some of the students studying chemical engineering also indicated that they were studying at university to contribute to society through their subject field, whilst some students studying chemistry highlighted reasons for studying focused on working out what to do next and others the opportunity to examine chemistry in more depth.

Table 4.1 summarises these reasons and the number of students from each subject that expressed each reason for studying. As can been seen, all of the chemical engineering students and most of the chemistry students were focused on instrumental reasons for studying in terms of being focused on an outcome that would be supported as a result of gaining a degree rather than the intrinsic

Table 4.1 The broad focus and initial reasons for studying at university of participants at the start of their undergraduate studies

Focus	**Initial reason for studying at university**	**Chemistry (including in combination with other subjects)**	**Chemical engineering**	**Total**
Instrumental	To establish a career	20	16	36
	To become a professional in subject field	15	14	29
	To contribute to society through the subject field	0	18	18
	To develop personally – working out what to do next	3	0	3
Transformational	To develop personally – through engagement with subject	3	0	3
	To follow the subject	6	0	6
Total		47	48	95

experiences of studying their subject. There were no clear relationships between students' gender or ethnicity and the reasons they chose to go to university.

To develop a career

Over a third of the students indicated in their first year that they were studying for a degree for the instrumental reason of developing a career. This career was not explicitly related to the subject of their degree. In some cases, in South Africa and the United States, this was because students saw their undergraduate degree as the stepping stone to a postgraduate degree, usually in the area of health and medicine. For example, Anika focused on how studying chemical engineering would give her the option of going into medicine or the cosmetics industry:

> *I figured with a chemical engineering degree I have two* options *that I really enjoy, where I could go into medicine later in the future, which I have still not decided yet. Either go into medicine, or go in into the cosmetic industry, which is another big passion of mine.*
>
> (Anika, Argon, United States, Chemical Engineering, Year 1)

Similarly, Chloe was studying Chemistry to support her career that could be in medicine:

> *Why am I getting a degree? … Because it's kind of necessary … To get a job that pays better … It's something that I enjoy that I can see myself doing it to get a degree that can help me go to medical school.*
>
> (Chloe, Argon, United States, Chemistry, Year 1)

For other students, there was a sense that they saw a degree as a route to a job that was not necessarily related to their degree, as was the case with Harrison:

> *I feel like a better way for me to get a job, that I'll be happier in, is to go to university and to get a degree, not even necessarily chemistry but chemistry is more the area I'm interested in. I feel like in this day and age, to get a satisfactory job, you need a degree.*
>
> (Harrison, Europium, England, Chemistry, Year 1)

To become a professional in their subject field

Just under a third of the students, in their first year, explained they were studying at university for the instrumental reason of becoming a professional in the subject of their degree. Unlike the students in the previous category, they were clear that they were studying their subject as a necessary step to becoming a professional in that field. For example, Janja was clear that she was studying for her degree to become a chemical engineer:

> *Because for chemical engineering, that's the necessary path, there's not a trade school for chemical engineering more of. So, I feel like that's the only route … There's no other way you could be a chemical engineer without a university degree. So that's it, one option.*
>
> (Janja, Astatine, United States, Chemical Engineering, Year 1)

Similarly, Katie was studying chemistry because she wanted to become a scientist:

> *I've kind of always enjoyed education, especially in the concepts that I like, especially like math and sciences. I have a view of myself, my future goal is to be a scientist and work in a laboratory.*
>
> (Katie, Astatine, United States, Chemistry, Year 1)

Other students were focused on becoming schoolteachers in their subject areas. For example, Samantha was clear from her first year that she wanted to be a teacher and discussed this in each of her interviews. What was clear from her interviews was that her understanding of chemistry was central to the kind of teacher she wanted to become:

> *If I've had practical experience more than just the lab in university but also in the work field I feel like I'll be a better teacher because I'll really understand things more and be able to explain to the students more. My goal with my degree is if I ever do become a teacher like I want to, I had a brilliant teacher and she was that good that she inspired me to study science and I want to be that.*
>
> (Samantha, Sodium, South Africa, Chemistry in combination with other subject(s), Year 2)

To contribute to society through the subject field

Over a third of the students studying chemical engineering were focused on improving society as a chemical engineer. This reason for studying was not expressed by students studying chemistry, and, amongst the students studying chemical engineering was more common amongst the students in South Africa, with thirteen of the eighteen students who gave this reason studying in South Africa. For example, Naas focused on the contribution that he could make with his chemical engineering degree:

> *To be able to go out, hopefully find a job, hopefully in a job that involves something to do with helping the environment, improving the lives of some people. Maybe*

desalination if that ever happens here because of the drought, if the drought continues. Or wastewater treatment or maybe good pharmaceuticals, mass producing vaccines, something like that. Who knows? I prefer to work where it would help people or help the environment rather than where it would generate more money if that were a thing.

(Naas, Samarium, South Africa, Chemical Engineering, Year 1)

Whilst this reason for studying was less individually focused than the previous two reasons, it is still instrumental. This is because it is focused on using the degree in order to achieve something else, in this case, making a contribution to society.

Personal development

Six of the chemistry students, all studying in England, were focused on studying for a degree in order to develop themselves personally. There were two different ways in which they approached this: one was instrumentally focused, and the other was focused on transformation. Three of the students were instrumentally focused on working out what they might do next in their lives. This reason for studying was defined as instrumental because in each case there was not a focus on how studying chemistry would allow them to work out what to do, but rather there was a sense that the time spent at university would give them the space to find out what to do. For example, Danny was just looking to work out what to do next without any sense of this being informed by his engagement with chemistry:

I just thought three or four more years, it will give me more time to prepare and give me an idea of what I actually want to do. I thought it will provide me with a lot better kind of basis for going and doing anything. As long as I get a good degree and a good mark in that, I'm viewing that I can go and do anything I want afterwards. I could still go and do law if I wanted, just do a conversion course for a year. I could go and do a doctor, it would be quite a lot more work but it gives you something to go and then work upon. You can go and do anything you want really.

(Danny, Erbium, England, Chemistry in combination with other subject(s), Year 1)

In contrast, for three of the students, there was a clear sense that their personal development was directly related to the subject that they were studying. This gave their personal development a transformational focus. For example, Donna was clear that it was the work for the degree that would lead to the development she was seeking:

[I]t's a hard degree because there's a lot of work. You have to understand things to the same depth as everybody else, but you have to know about different things, more than other people. That, in itself, also shows the skill-set. You can time-manage, you're good at understanding things, you can be challenged, you can think outside the box of one thing, which I think is needed.

(Donna, Erbium, England, Chemistry in combination with other subject(s), Year 1)

To follow the subject

Finally, six of the chemistry students were focused on following chemistry through their degree. For these students, the whole point of going to university was to learn more about chemistry and to be transformed by this knowledge. For example, Hayden didn't want to go to university until he found the subject that he wanted to study.

Well, actually, for a time I didn't want to go to university. I felt it was- in terms of tuition fees, as they keep climbing up and up and up, I just felt like I didn't want to rush to university. A lot of my friends were like, 'I'm going to university straight away. As soon as I'm 18, I'm gone.' And I was like, 'Well, you know, are you sure you want to do that subject?' So I just took two years out and I started buying- I didn't buy like, modern ones, because they're very expensive, but I bought some older kind of university level textbooks and I would just read them and I was just like, you know, if I can keep doing this and keep enjoying it, I think I can go to university, because I think that would make my time worth it. And I don't want to turn up, do three months, owe a couple of grand and just be like, 'No, I didn't enjoy it. I didn't want to be there. I want to do something else.' I'd rather just, you know, go 'This is my subject, this is what I enjoy.'

(Hayden, Europium, England, Chemistry, Year 1)

Similarly for Stella, the whole focus was on finding out what more she could do with chemistry:

Well, I mean, for me that likes chemistry, there is not actually, or not that I know of, like work I can do, and I mean, I wanted to know more. There is still so much about chemistry and what I can do with it that I still don't know … At this point I am still like looking or testing the waters, if I can put it like that. Is this the right thing? But I feel it is, and I mean, there is still so much that I can do with chemistry that I don't know. So I feel it's worth doing the research.

(Stella, Sodium, South Africa, Chemistry Year 1)

Overall, the students' initial reasons for studying at university fit with narratives of students being focused on the instrumental benefits of their education rather than being focused on transformation. As they entered higher education, most students were focused on the exchange value of the qualification rather than the educational benefits of engaging with knowledge.

What students gained from studying at university by their final year

In their final year of studying, what students identified as gaining from going to university was different from what they identified as gaining from studying the subject of their degree. Most students focused on instrumental gains from going to university and transformative outcomes from studying chemical engineering.

What students gained from going to university

In relation to what they gained from going to university, students focused on four outcomes: a degree, the underpinnings for a career, the opportunity to continue their education and an opportunity to contribute to society.

Around three-quarters of the participants (seventy-two out of ninety-five), identified the degree that they would graduate with as the most important thing that they had gained because of what it would allow them to do in the future. This was sometimes a general qualification:

> *That's a good question. To start off with, a degree, which is obviously a big qualification to have. Even if I don't go into chemical engineering, it's still like something to say this person has achieved something.*
>
> (Leon, Erbium, England, Chemical Engineering, Year 4)

For other students, such as Ken, it was specifically to help them move on to a particular post-graduate programme:

> *At the end of it, I hoped [it would be] a ticket into dental school to be honest.*
>
> (Ken, Astatine, United States, Chemistry in combination with other subject(s), Year 4)

Participants who focused on their degree also tended to express appreciation for the experiences and friends they had at university. However, they were clear that the degree was the first thing they would emphasise:

> *At the end of the day, obviously a degree number one. I think, to walk away with relationships and friends that I know I'm going to have for the rest of my life. Thankfully, I can confidently say that I will walk away with that. To be able to*

> *walk away as a friend of people, build relationships, and also have the technical background that I need to go into industry and to be successful in industry.*
>
> (Alexander, Argon, United States, Chemical Engineering, Year 5)

Twenty-two of the ninety-five participants were focused on the transformational educational experience of studying for a degree as the most important thing they had gained from university. This was relatively more common amongst students studying chemistry than amongst students studying chemical engineering. Rubiya focused on the way she had grown through her university experience:

> *Just an experience that will help me in the future and will teach me a lot. Uni changes people, and I completely understand that now … I think it makes you grow, and it really challenges you. It's not just your capability in a subject, or anything like that. I think it's just basic life skills, like time management, independence, dependence.*
>
> (Rubiya, Europium, England, Chemical Engineering, Year 4)

Caroline was focused on both the knowledge and skills that she had gained from studying for her degree:

> *I had hoped that what I expected that I was going to gain from university or wanted to gain from the university was not only the academic knowledge, but also building skills that would help me outside of the classroom, in like a job or in internships and things like that, such as writing skills, presentation skills, because I did a lot of presenting my research and presenting skills, writing grants, working with people, doing group projects, that was probably what I wanted to get out of it and I think that I did get out of it.*
>
> (Caroline, Argon, United States, Chemistry in combination with other subject(s), Year 4)

Simon was clear that he was not focused on gaining a degree but was much more interested in the knowledge and skills that he had gained from studying his degree:

> *I think the degree in itself is not really what you're here for at university. And sure, it's a piece of paper but it's not really … You're more here for the knowledge that accompanies the degree, and the soft skills, especially nowadays. Because you're probably not going to work in the place you thought you would. You may end up in sales, you may end up in management. So it's more the soft skills and just the experience of working with people. And, yes, there is the information as well, for your specific department.*
>
> (Simon, Sodium, South Africa, Chemistry in combination with other subject(s), Year 3)

One chemical engineering student was focused on the contribution that they would be able to make after graduating as the most important thing that they had gained from going to university, far fewer than indicated this focus in their first year:

> *I hope to be able to help solve problems that are already existing. And I can reach out to and can be able to solve. Because I feel like our tasks as engineers are mostly problem solving. And that is what I want to go into, be it with skincare disorders or nutritional benefits from getting organic food. I want to solve an already existing problem.*
>
> (Nomathemba, Samarium, South Africa, Chemical Engineering, Year 4)

In relation to what they gained from going to university, nearly all the students focused on the instrumental value of their degree rather than the transformational aspects of their education. In association with the way in which instrumental reasons for studying at university dominated students' accounts in the first year of their degree, this could be taken to suggest that, apart from rare exceptions, these students were instrumentally driven. This would raise potentially awkward questions about their engagement with higher education. However, most students gave very different kinds of answers when asked about what they had gained from studying their subject.

What students gained from studying their subject

Our analysis of students' accounts generated three things they identified as gaining from studying the subject of their degree: a way of engaging with the world, specific pieces of knowledge and access to a career.

Over three-quarters (seventy-eight out of ninety-five) of the participants focused on the way of engaging with the world that they had gained from studying chemistry or chemical engineering. There were three different ways in which students expressed this new way of engaging with the world but in each case, there was a sense that they were seeing this knowledge from the inside and using it to inform their engagement with the world.

For fifty-seven of the participants, it was the way of thinking as a scientist or an engineer that was the key thing that they gained from studying for their degree. For example, Nabeel emphasised the 'engineering judgement' that he had gained:

> *It's the thought process, the mind-set. I think, basically, engineering judgement. I don't know if it's the most important skill but it's the skill I value the most, I think it's the most valuable.*
>
> (Nabeel, Samarium, South Africa, Chemical Engineering, Year 5)

Similarly, Donna emphasised the way in which she had learned to think as a scientist over the course of her degree:

> *[I]n everything that you've learned and all the different ways that you've learned to approach things and assess things, it does teach you a way of thinking. It's not necessarily just about the facts and understanding the concepts, but it's the different ways of thinking of … Being able to do an experiment, receive an output, and understand what that means. That's something that is, I think, transferable to all aspects of life, like you do something, what's the result? Why is it like that?. You can't see electrons, but yet, we're able to understand what they are, how they behave. Also, very hypothetical situations, because as much as we know is fact, not everything has been proven … I think doing a degree in science and learning chemistry, you're actually built to be a person who can kind of think on both sides, and when confronted with a challenge, it's nothing that's going to be unfamiliar to you. It's something that you're like, 'Oh, okay, how can I go about this? Could I read more? Can I try something if that doesn't work? Can I do this?' … what I mean by 'both sides' is what you can see logically, if it's in terms of data, some kind of information. You can see that, but you can't just take the facts and figures that you see for what they are. So then, you have to go to the other side and think more qualitatively and more creatively about what it is, whatever it is that you're studying, and being able to kind of marry the two together to get the whole comprehensive picture of what it is that's going on.*
>
> (Donna, Erbium, England, Chemistry in combination with other subject(s), Year 4)

As can be seen from the quote, part of what Donna emphasised was the ability to keep going in the face of challenges. Along similar lines, for sixteen students split equally between chemistry and chemical engineering, it was this way of engaging with the world with rigour and perseverance that was the most important thing they had gained from studying their subject. For example, Thomas highlighted the self-discipline and perseverance that were demanded from studying chemical engineering:

> *Interestingly enough, I would not say the technical knowledge. I would say the perseverance and the, the self-discipline to just work hard. I feel that I can apply it to anything. I can apply it to music and mastering a new instrument if I want. I can apply it to relationships to know that things aren't going to go well all the time and yes, you need to be able to evaluate, in the long term, is this worth what it is, or … Is it what you want?*
>
> (Thomas, Sodium, South Africa, Chemical Engineering Year 4)

Similarly, Chloe vividly highlighted the resilience that she gained from studying chemistry:

I really feel like chemistry, and this has probably one of the nerdiest sentences I might speak, but it's really shaped who I am. I think that my freshman year, I didn't think I could do it. I almost failed out of my chemistry class. It was so challenging. Every single year I've come in contact with a new chemistry that has challenged me and has been hard, and then every year I get through it, and every year I can do it. I think that something it's taught me is resilience. Things are hard, but you just have to work. It's not going to just show up at your door one day and be like, oh, you did it. Chemistry. You have to sit, you have to spend the time and really work really hard, and then those things come. Something that my dad has always told me is take the path less travelled. The more difficult things you do, the more doors that open. I think that chemistry has really been something like that for me. It's ridiculous. I'm such a nerd.

(Chloe, Argon, United States, Chemistry, Year 4)

What this quote from Chloe highlights clearly is how her resilience was formed from her struggles with understanding chemistry and how this has framed her way of engaging the world.

For five of the chemical engineering students, four of whom were studying in South Africa, it was about a new way of engaging with the world that helps to contribute to addressing societal issues:

Appreciation. I'm starting to really appreciate a way of life as a society. It then gives me a very, very good platform to actually help out in society, a very good platform. I'm especially interested in energy and energy production because energy, essentially, is what fuels our everyday lives. That's why chemical engineering is very important to me. The fact that, as I said, it's the direct link between our home and our everyday lifestyle and protecting our home obviously is very important or else we can't enjoy our everyday lifestyle.

(Lekan, Erbium, England, Chemical Engineering, Year 3)

Thirteen students emphasised specific pieces of knowledge or skills they had gained from studying. In contrast to the previous category, they spoke about this knowledge as if they were engaging with it from the outside. So rather than talking about the way the knowledge had changed their way of engaging with the world, they listed things they had learned. There was no sense that it had transformed their ways of engaging with the world. For example, Rubiya speaks of chemical engineering as if it is something that she is not part of:

Understanding, I think, as in understanding the actual discipline of chemical engineering. There are so many things I've learnt, but I can't even think of them. Independence, definitely, and being confident in your own work. That is, I think, 100%.

(Rubiya, Europium, England, Chemical Engineering, Year 4)

Chaaya emphasised the different topics that she studied, which again conveys a sense that she is not actively part of the knowledge that she engages with:

> *I think, also, with learning so many topics, I've learned what's important to me, what things I want to be studying in the future and doing work for in the future, even if I don't get there right out of college.*
>
> (Chaaya, Argon, United States, Chemistry, Year 5)

Four students focused instrumentally on how studying their subject had helped them to be successful in their careers. For example, Lincoln focused on how he could use his knowledge of chemical engineering to gain a job.

> *I feel like it's definitely helped me to get a job in the industry in terms of my knowledge so if I apply this knowledge to industry, you can see how you could use it. It's been interesting as well as that because obviously when you pick the degree, chemical engineering, you're thinking in your head, 'Well I'm probably going to go into the chemical engineering industry at the end of it,' because that's what you're learning.*
>
> (Lincoln, Erbium, England, Chemical Engineering, Year 4)

Similarly, Harvey focused on how he had found his way onto a career path:

> *I would say when I first joined chemistry I actually did it more because I didn't know what to do, and also I liked it and was good at it. What I've gained from it I don't know. Obviously you needed to get chemistry grades to get a placement job, and I quite like that, so it obviously has got me slightly up the ladder of a scientific based career path if anything. I don't really know what to say. Yes, I suppose getting onto the career path, I probably wouldn't have got a job in quality control if it wasn't for this, so that's probably the main thing I've got. It's the knowledge of basic chemistry, and obviously you can talk to people in a scientific fashion and it sort of opens doors scientifically, if anything.*
>
> (Harvey, Europium, England, Chemistry, Year 4)

It is interesting that although both Lincoln and Harvey focused on the instrumental outcomes of studying their subjects, they both make reference to the knowledge they had as being an important part of this outcome.

When discussing what they had gained from studying their subject, a substantial majority of students focused on how they had gained a new way of engaging with the world by viewing it from the perspective of their discipline. Some participants focused on the knowledge they had gained but gave the sense they were seeing this knowledge from the outside and it had not changed their way of engaging with the world. A small number of students focused on how their degree had helped them be successful in their careers and appeared to be focused on the instrumental value of their degree rather than the benefits of their personal commitment to knowledge.

Relations between students' initial reasons for studying, what they gained from being at university and what they gained from studying the subject of their degree

Tables 4.2 and 4.3 compare whether students had instrumental or transformational reasons for studying at university and whether they had instrumental or transformational gains from going to university and from studying their subject. Table 4.4 compares whether students had instrumental or transformative gains from going to university and instrumental or transformative gains from studying their subject.

These tables show that most students gave instrumental reasons for studying at university and described instrumental benefits when asked about what they had gained from going to university. However, most students described transformational benefits when asked about what they had gained from studying their subject. The way in which students perceived what they achieved as instrumental gains from going to university did not appear to prevent most students from perceiving they had transformational gains from studying their subject.

Table 4.4 shows that nearly two-thirds of students saw what they gained from going to university as instrumental and what they gained from studying their subject as transformational. For example, whilst David described university as a '*career stepping stone*', he gave a rich account of how studying chemistry had changed his understanding of the world:

> *I think I could split it into academically, in terms of just learning about the world around me and stuff like that. The applications and how human knowledge has progressed and how things actually work as well, to an extent. Then also, from the course, you get the other things like professional development and trying to become better at explaining the things that you're learning to other people in presentations and stuff like that. I think it's split between the academic knowledge and the thrill of learning things, and then the other side where you develop skills.*
>
> ….
>
> *I just saw university as a career stepping stone. It was solely about the degree, and less about social things.*
>
> (David, Erbium, England, Chemistry, Year 4)

Table 4.2 What participants hoped to gain in their first undergraduate year compared to what they gained from going to university in their final year of undergraduate study

	What students gained from going to university		
Initial reasons for studying at university	**Instrumental**	**Transformational**	**Total**
Instrumental	72	14	86
Transformational	3	6	9
	75	20	95

Table 4.3 What students hoped to gain in their first undergraduate year compared to what they gained from studying their subject in their final year of undergraduate study

	What students gained from studying their subject		
Initial reasons for studying at university	**Instrumental**	**Transformational**	**Total**
Instrumental	17	69	86
Transformational	0	9	9
	17	78	95

Table 4.4 What students gained from studying their subject compared to what they gained from going to university in their final year of undergraduate study

	What students gained from going to university		
What students gained from studying their subject	**Instrumental**	**Transformational**	**Total**
Instrumental	13	4	17
Transformational	62	16	78
	75	20	95

Table 4.4 also shows that thirteen students focused on the instrumental elements of both what they gained from studying chemical engineering and what they gained from going to university. For example, Leo saw both in terms of his career:

> Interviewer: What are the most important things that you feel you've gained from studying chemical engineering?

Leo: Hopefully it gets me a career (laughter). Yes, a career that will hopefully give me plenty of variation in what I do and I can be quite comfortable living, I think that's mostly what I'm getting out of it.

…

Interviewer: Okay. What is it that you actually hope to gain from being at Erbium?

Leo: I hope it's given me the skills to exist in adult life and set me up to be employable in the future in the field of chemical engineering.

(Leo, Erbium, England, Chemical Engineering, Year 4)

Table 4.4 shows that there were four students who saw what they gained from going to university as transformational and what they gained from their subjects in instrumental terms. Interestingly, these students tended to struggle connecting their subjects to the world and ended up talking about their education in a disengaged way. For example, Chaaya initially studied chemistry because she enjoyed it and saw it as a route to getting a well-paid job. However, she increasingly could not connect the knowledge of chemistry to the world outside of university, and this made her feel alienated from her educational environment.

I think it feels kind of like a dystopia here. I don't know how to describe it. It's like you're stuck in a bubble … So it just feels like excluding a lot and just ignoring a lot during college and we just kind of focus on our own major instead of how we see the world and what the world is for us and what the world is. It's just overdone. College is weird.

(Chaaya, Argon, United States, Chemistry, Year 3)

Similarly, Kaylee sees what she learnt in relation to chemistry as a 'memorisation game' rather than connecting with the world.

What's the most important thing I got out of it? That I don't like chemistry that much. I liked organic chemistry but I don't like biochemistry. It might be how it's taught because the mechanisms get so long that they try to simplify it down, but then you can't predict it as easily. It's more of a memorisation game. I don't like that. I don't like when people expect you to memorise things.

(Kaylee, Astatine, United States, Chemistry in combination with other subject(s), Year 5)

Table 4.3 shows that all the students who described transformational reasons for studying at university reported transformational gains from studying their subject. Whilst it might be assumed that these students, who all studied chemistry, benefitted the most from their education experiences, this did not always appear to be the case. Some of these students, at the end of their degrees, were most uncertain about where their study of chemistry was taking them. For example, both Demi and Damien reported being very unclear about where chemistry would take them by the end of their degrees:

> *I'm actually not sure what I'd like to do. I'd always thought a PhD but, as I'm coming towards the end of my studies, I think I'd like to get a job and have a break from studying for a bit. …. I've definitely decided I don't want to do academia so much, so I think joining a company would be a better way.*
>
> (Demi, Erbium, England, Chemistry, Year 3)

> *Well I don't have a specific goal in mind. I said considering teaching. I was always considering doing a PhD, but that was never a firm thing. At the moment, I want to finish this year, celebrate with all of my peers, and then take some time out. Take at least six months out … It's such a crossroads at the moment, that it's difficult to see where I'm going to end up. I've been on the conveyor belt of education … I'm just suddenly going to finish and fall off the end, and God knows … And it's impossible, because there are so many jobs that I've never even heard of, that I would never consider.*
>
> (Damien, Erbium, England, Chemistry, Year 4)

For these students, it appeared that even though they had a deep engagement with chemistry, they did not know how to relate that to a role in the world beyond their degrees.

Implications for understanding the relationship between instrumental and transformational relationships to higher education

What are we to make of the apparently contradictory findings in this chapter? Table 4.2 appears to tell a depressing story of students being instrumentally focused on simply gaining a degree throughout their time at university and no longer recognising university as an educational context in which transformation takes place. However, Table 4.3 suggests that most students reported gaining a new way of engaging with the world from studying the subject of their degree, even if they initially went to university for instrumental reasons. This tells a much more optimistic story of students being transformed by knowledge through their studies. Table 4.4 indicates that students being instrumentally focused on gaining a degree from going to university generally went alongside the transformational value of gaining a new way of engaging with the world from studying the subject of their degree. These outcomes inform understanding of the relationship between instrumental and transformative in five ways.

First, in contrast to some previous research (for example, Brint 2012; Spronken-Smith et al. 2015; Willner et al. 2022; Schäfer 2024), these findings suggest that it is not the case that some students are instrumentally focused whereas others are transformative and knowledge-focused. It also appears that students' accounts of what they gain from engaging with higher education are not necessarily related to their initial reasons for studying.

Second, it suggests that when reflecting on what they gained from going to university, most students gave a response consistent with an instrumental focus on the exchange value of a credential rather than their personal engagement with knowledge (Naidoo & Jamieson 2005; Molesworth et al. 2009; Neary & Winn 2009; Saunders 2015; Brooks 2018). However, when reflecting on what they gained from studying the subject of their degree, students focused on how the bodies of knowledge they had engaged with had transformed their ways of engaging with the world. This suggests that, rather than consumerist discourses necessarily undermining students' commitment to knowledge (Finney & Finney 2010; Bunce et al. 2017; Tomlinson 2017; Brooks & Abrahams 2018; Nixon et al. 2018; Bunce & Bennett 2021), students' reflections on what they gained from higher education were shaped by the context that was evoked when they were constructing their account (Trigwell & Ashwin 2006; Ashwin & Trigwell 2012; Trigwell et al. 2013). This suggests that rather than students' roles being made up of instrumental and transformative elements (Dusi & Huisman 2021), they are better understood as different kinds of accounts that students can give about their education, depending on the context evoked when they give their account. It appears that most students see the context of their overall university experience as evoking an instrumental understanding of their education but their engagement with the knowledge of their degrees as evoking a transformational understanding.

Third, it is important to note that in their first year, all students saw questions about what they wanted to gain from studying their subject and studying at university as the same question, which called for an instrumental answer. By their final year, most students saw questions about studying their subject as requiring an education-as-transformation informed answer, whilst still seeing what they gained from university in instrumental terms. This suggests that it was the knowledge-rich context of studying for their chemistry and chemical engineering degrees that evoked transformative student accounts of their educational experiences (Taylor 1993; Bowden & Marton 1998; Ashworth 2004;

Dall'Alba & Barnacle 2005; Ashwin 2020). Therefore, such accounts may not have been evoked if they had studied for a degree that did not support them to use such knowledge to engage with the world. It appears it is the *absence* of knowledge-focused education that undermines education-as-transformation rather than the *presence* of education-as-instrument accounts.

Fourth, around one in eight of the students offered only instrumental accounts when talking about what they had gained from their degree and what they had gained from studying chemical engineering. However, this is lower than might be suggested by those concerned about student consumerism (Molesworth et al. 2009; Nixon et al. 2018) for subjects in which students are more likely to adopt consumerist perspectives on their education than students from other subjects (Bunce et al. 2017) and, as we highlighted in Chapter 2, in highly marketised higher education systems (Czerniewicz et al. 2023; Durán Del Fierro 2023).

Fifth, there was evidence that when students related transformation to their overall university experience, but not with their engagement with their subject, they tended to experience a disengagement with their education. This seemed to be related to some students being unable to see the relevance of what they were studying for their engagement with the world. Equally, there were some chemistry students who were very focused on the subject of their degree but struggled to see how this related to the world. These findings suggest that rather than instrumental or transformational approaches to education being important, it is students being able to see the relationships between themselves, the subject they are studying and the world that is key. This suggests that all three of the arrows in Figure 4.1 are important. If knowledge doesn't help students to make sense of the world beyond the university, then they struggle to relate these three aspects to each other.

Here we see a key difference between chemistry and chemical engineering that reflects the differences in their curricula that we discussed in Chapter 3. In that chapter we found that, whilst the focus in chemistry was on how the world is created through the study of chemistry, in chemical engineering the focus was on how students are prepared to engage with the world as chemical engineers. In Bernstein's (2000) terms, in chemical engineering, a region focused on the world, the relations between students, knowledge and the world are an integral part of what students are studying at university. In contrast, Chemistry as a singular subject focused on itself and students sometimes struggled to relate the knowledge they were studying to the world. This reflects differences in the nature of the knowledge in the engineering regions when compared to knowledge in the pure science singulars (Smit 2017).

Conclusion

In this chapter, we examined the extent to which students studying chemistry and chemical engineering degrees recognised they were in an educational context over the course of their degrees. Rather than purely instrumental or transformative relationships to education being the key issue in students' experiences of chemistry and chemical engineering, it is the way that students both engage with knowledge in transformational ways but can also see instrumental relationships to the world that appeared to be important. However, whilst we have emphasised that the ways of seeing and engaging with the world that students gain from chemistry and chemical engineering are important elements of this relationship, we have not discussed in any detail what these ways of seeing and engaging with the world are. We turn to this important issue in the next chapter.

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5

How Did Engaging with Knowledge Change Students' Understanding of the World?

This chapter examines how participants were changed by their educational experiences by the end of their undergraduate degrees. It analyses the ways they saw the world differently because of these educational experiences and considers how these perspectives differed across chemistry and chemical engineering.

In the last chapter, we examined the extent to which students recognised their context as an educational one focused on knowledge. In this chapter, we examine the extent to which students developed an understanding of the realisation rules (Bernstein 2000) of their subject and how these differed between chemistry and chemical engineering. Students acquire realisation rules by demonstrating that they can produce 'legitimate texts' (Bernstein 2000) by being able to articulate their understanding of the essence and 'logic' of the disciplinary field and their relation to it. In other words, we examine the extent to which the chemistry students could realise 'chemistry' and the extent to which the chemical engineers could 'realise' chemical engineering. We do this by examining how their understanding of chemistry and chemical engineering changed over the course of their degrees.

In Chapter 3, we considered the differences in the recontextualising rules (Bernstein 2000) of chemistry and chemical engineering. We found that whilst the focus in chemistry was on how the world is created through the study of chemistry, in chemical engineering, the focus was on how students are prepared to engage with the world as chemical engineers. In this chapter, we also consider whether the ways in which students talk about chemistry and chemical engineering reflect these differences.

How engagement with academic knowledge changes students' understanding of the world

In examining how students can 'realise' chemistry and chemical engineering, we were examining how students' understanding of these bodies of knowledge changes over their degrees and how these new understandings change their understanding of the world and themselves. Developing such understanding is important in order to gain a sense of how students are transformed by engagement with these bodies of knowledge (McCune and Hounsell 2005; Anderson & Hounsell 2007; Ashwin 2020; McCune et al. 2021). This requires investigating how students understand the bodies of knowledge that make up particular disciplines, professions and subject areas and how this understanding changes over time. To use Ashwin's (2014) terminology, it involves gaining a sense of how students transform 'knowledge-as-curriculum' into 'knowledge-as-student-understanding'.

Whilst there is extensive research on how students understand knowledge generally (for example, Baxter Magolda 1992, 2004), there is less research that has examined students' understanding of particular degree subjects. Most of the limited amount of research that has examined students' understanding of their subjects of study has taken a phenomenographic perspective (Marton & Booth 1997). This is because phenomenography focuses on the qualitative variation in the ways that people experience particular phenomena. Table 5.1 sets out the structure of students' accounts from phenomenographic studies examining a number of different disciplines. Whilst the studies vary in the number of accounts of each discipline produced, in each case the variation can be argued to fall into three main stages (van Rossum & Hamer 2010), even though not all of the studies cited in Table 5.1 used these terms. First, there is a 'least-inclusive' basic account that focuses only on the immediately visible aspects of the discipline. Second, there is a 'watershed' account in which students focus on a structured body of knowledge. This is a key shift because engagement with structured bodies of knowledge is the key focus of higher education (Ashwin 2020), and the watershed account unlocks an understanding of the disciplinary logic and organisation of the structured body of knowledge. In Bernstein's (2000) terms, it is when students can give an account of their subject that is at the watershed account that they can be regarded as having acquired the realisation rules of the disciplinary field. Third, there is a 'most inclusive' account in which students see this body of knowledge in a wider context. What all of the structures of variation have in common is that they are based on different configurations of the discipline, the world and the student.

Table 5.1 Structure of students' accounts of different disciplines from phenomenographic studies

Discipline	Studies	Least inclusive account	'Watershed' account	Most inclusive account
Accountancy	Sin et al. 2012	Routine work	Meaningful work	Moral work
Geography	Bradbeer et al. 2004	General world	Structured into parts	Interactions
Geoscience	Stokes 2011	Composition of earth – the earth	Processes – interacting systems	Relations earth and society
Law	Reid et al. 2006	Content	System	Extension of self
Mathematics	Crawford et al. 1994, 1998; Wood et al. 2012	Numbers	Models	Approach to life
Music	Reid 2001	Instrument	Meaning	Communicating
Sociology	Ashwin et al. 2014	Developing opinions	Study of society	Relations self, people and societies

Across the disciplines in Table 5.1, the move from the least inclusive to the most inclusive account has a common structure. The least inclusive account focuses on the most obvious aspect of the subject – routine work in Accountancy, the world and the composition of the earth in Geography and Geoscience, the content of Law, the instrument in Music, numbers in Maths, or holding strong opinions in Sociology. In the Watershed Account, this changes to a structured system of meaning. It is this move to understanding their subject in terms of its *knowledge structures* rather than its separate parts that allows students to realise their subject and is what makes this account a watershed. It is at this point that students shift to understand their subject as a body of knowledge, which is key to what 'higher' education offers students. In the Most Inclusive Account, this shifts to focus on how this knowledge is an integrated part of the way that the student engages with the world, hence the moral work of engaging with the world as an accountant, understanding interactions and relations between earth and society as a geographer and geoscientist, having the approach to life of a mathematician, communicating as a musician or understanding the relations between your self, people and societies as a sociologist. These shifts align with van Rossum and Hamer's (2010) more general accounts of understanding which shift from understanding everything to constructing meaning to a focus on the self in relation to understanding.

This way of thinking about students' engagement with knowledge through higher education is strongly aligned with Bowden and Marton's (1998) argument that what a university education offers students is a way of seeing and experiencing the world through the particular bodies of knowledge that they study. Bowden and Marton (1998) argued that students learn to discern situations in ways that are associated with the subject that they study. This means they can recognise what is important in a situation from the perspective of, for example, a mathematician, lawyer, chemist or chemical engineer.

One aspect of the way students come to understand their subjects that has been less examined is how students' accounts of their disciplines change over time. Of the studies cited in Table 5.1, only the one focused on sociology examined how student accounts developed over time, as did van Rossum and Hamer's (2010) study of students' accounts of the experience of developing understanding. The other studies were based on snapshots of how students describe their relations to their subjects at a particular moment in their educational experience. Gaining a sense of how these accounts change over time is important in order to examine the impact that students' educational experiences have on their changing understanding of these structured bodies of knowledge. Further analysis of the data from the sociological study (Ashwin et al. 2016; McLean et al. 2018) suggested that what was important, in students developing an understanding of the bodies of knowledge they were studying, was that students understood their engagement with their subject as an educational experience in which they were changed by this engagement.

In this chapter, we examine the variation in students' accounts of chemistry and chemical engineering and how student accounts changed over the course of their undergraduate degree. Such studies are not common either generally or in chemistry and chemical engineering.

In chemistry, research into students' understanding of chemistry knowledge has primarily focused on their understanding of particular chemical concepts (for example, Johnstone 1982, 2006; Ebenezer & Erickson 1996; Taber 2019). More recently, there has been a shift to focus on the development of 'chemical thinking in students' (Sevian & Talanquer 2014; Sjöström & Talanquer 2018; Talanquer et al. 2020) as well as examinations of how students developed a more general understanding of science (Flaherty 2020). However, there have been very few longitudinal studies that have examined how students' understanding of chemistry develops over time, and these have tended to focus on school children (for example, see Øyehaug & Holt 2013). Mathias (1980) followed a small group of science students, including chemistry students, through their undergraduate course. However, this study examined how students approached their studies rather than their understanding of chemistry.

In chemical engineering, previous studies of students' views and experiences of chemical engineering have focused on three main areas:

- Students' views on the skills and agency they have developed through studying chemical engineering (Martin et al. 2005; Fletcher et al. 2017; Pisani & Haw 2023);
- Students' experiences of particular approaches to teaching (Adi et al. 2012; Davey 2012; Anastasio & McCutcheon 2013; Iborra et al. 2014; Sorensen 2013; dos Santos et al. 2018; Lenihan et al. 2020; Lewin & Barzila 2021; Wilson-Fetrow et al. 2023) and assessing (Wolff et al. 2018; Sanz-Pérez 2019; Partanen et al. 2023) chemical engineering;
- Students' understanding of particular chemical engineering concepts such as heat transfer (Nottis et al. 2010), reliability of data (Davidowitz et al. 2001), sustainability (Carew & Mitchell 2002), the mole (Case & Fraser 2001), energy changes in dissolution (Ebenezer & Fraser 2001) and students views of the chemical engineering profession (Shallcross 2002).

A notable exception to this research is work by Case (2013) which examined how chemical engineering students understood their education, experienced their curriculum and how they developed their academic project over the course of their degrees. In the wider field of engineering, Khosronejad et al. (2022) examined students' conceptions of engineering but in terms of a more general sense of what engineering is (e.g. 'learning', 'thinking') rather than the relations between students, engineering and the world, which is the focus in this chapter.

In this chapter, we first examine the variation in students' accounts of chemistry and the variation in students' accounts of chemical engineering before examining how these changed over time. We then discuss the differences between the variation in accounts of chemistry and chemical engineering and consider their significance for thinking about how higher education changes students.

How did participants realise chemistry and chemical engineering?

Participant accounts of chemistry

Based on our analysis of the interview data, we generated five different ways of accounting for the discipline of chemistry:

> *Category 1: Chemistry happens when things are mixed in a laboratory;*
> *Category 2: Chemistry is seeing chemical reactions;*
> *Category 3: Chemistry is learning about molecular interactions;*
> *Category 4: Chemistry is explaining molecular interactions;*
> *Category 5: Chemistry is explaining molecular interactions in unfamiliar situations in the world.*

These different ways of accounting for chemistry involved different relations between the student, the world and the discipline of chemistry. Table 5.2 sets out the outcome space as a whole and how the different categories of description fit within this. The structural aspects focus on the changes in what is in the foreground and background of the accounts. These shift from chemistry being about *doing* things, to chemistry being about *seeing* certain things, to chemistry being about *explaining* certain things. The referential aspects focus on the meaning of chemistry which shifts from chemistry referring to *chemical reactions* to chemistry referring to *molecular interactions* to chemistry referring to *unknown situations in the world*. These structural and referential aspects come together to form each category of description: under category 1, chemistry is about doing chemical reactions whereas under category 5, chemistry is about explaining things that are happening in new situations in the world. The

Table 5.2 The referential and structural aspects of the categories of description for participants' accounts of chemistry

	Referential aspects		
	Chemical reactions	**Molecular interactions**	**World**
Structural aspects			
Doing	Category 1: Chemistry happens when things are mixed in a laboratory		
Seeing	Category 2: Chemistry is seeing chemical reactions	Category 3: Chemistry is learning about molecular interactions	
Explaining		Category 4: Chemistry is explaining molecular interactions	Category 5: Chemistry is explaining molecular interactions in unfamiliar situations in the world

watershed shift comes in category 3 where students shift from understanding chemistry as about chemical reactions to seeing chemistry as about molecular interactions. As we discussed earlier, this watershed is when students talk about chemistry in a way that suggests that they have acquired the realisation rules of chemistry.

We now set out each of the categories in turn and, in doing so, focus on giving a richer sense of the variation between the categories.

Category 1: Chemistry happens when things are mixed in a laboratory

Students' accounts which aligned with this category described chemistry in a way that focused on doing chemistry to create particular kinds of chemical reactions. Students discussed chemistry in quite general terms and tended to focus on what happened when chemistry was 'done' in a laboratory. The sense given was that chemistry was something that was external to the student, as it happened separately to the student rather than it being something that the student was necessarily involved in:

> *For me, I think it's how you can have two different elements and they can make, literally, like a hundred different things just by adding two together or adding … It just fascinates me how something so small and how you don't really need to do anything but something amazing can happen. I think that to me is like quite unique.*
>
> (Henry, Europium, England, Chemistry, Year 1)

> *A lot of educated putting things together and proving that it works. I think to be fair, our lab environments are very controlled. We have got step-by-step processes, we're not playing around with anything.*
>
> (Steffi, Sodium, South Africa, Chemistry in combination with other subject(s), Year 2)

Category 2: Chemistry is seeing chemical reactions

In student accounts aligned with this category of description, there was a shift away from doing chemistry towards chemistry being about seeing the world in terms of chemical reactions. Students whose accounts aligned with this category of description often referenced the US TV series 'Breaking Bad' and the idea that chemistry is about change. Chemistry was still talked about as something that was separate and external to the student rather than it being something that the student was directly involved in:

> *It's definitely … the main basis with chemistry is chemical reactions and how different molecules or elements react with each other. I think a lot of learning chemistry is just learning how and why those interactions take place and kind of how to analyze them.*
>
> (Katie, Astatine, United States, Chemistry, Year 1)

> *It's lots of things, really, but boiling it down to simple, it's elements and what they do. Yes, it's just how and why things happen the way they do. Generally how, and looking at it.*
>
> (Denise, Erbium, England, Chemistry Year 1)

Category 3: Chemistry is learning about molecular interactions

In student accounts aligned with this category of description, chemistry was described in terms of learning about molecular interactions rather than just seeing chemical reactions. In contrast to the first two categories, chemistry was positioned as something that students were directly engaged in rather than something that was being done or organised by other people. This can be seen as a watershed because it is the category in which students' accounts of chemistry begin to focus on the structure of the body of knowledge of the discipline through a focus on understanding the causality of molecular interactions.

> *Okay, so looking at molecules, elements, how they interact. Maybe how you can use them to make other molecules and things. And just learning about the, I don't know, their characteristics and things.*
>
> (Ming, Samarium, South Africa, Chemistry in combination with other subject(s), Year 2)

> *Virtually everything you study is about a reaction taking place or something changing on a molecular level or whatever it is – changing state.*
>
> (Dale, Erbium, England, Chemistry in combination with other subject(s), Year 2)

Category 4: Chemistry is explaining molecular interactions

In student accounts aligned with this category of description, the emphasis was on the student being able to explain molecular interactions rather than simply learning about them. In these accounts, chemistry was positioned as a way of the student using an understanding of molecular interactions in order to explain the world. Thus, in this category there was the first sense that the students' engagement with chemistry was something that had relevance to the world:

> *Chemistry is, well it's basically, let's say, the knowledge of how everything is formed. How everything, or physical properties of the universe, how it forms and how it's put together, how it's taken apart. Knowing how it happens, what happens with it, why it happens.*
>
> (Scarlet, Sodium, South Africa, Chemistry in combination with other subject(s), Year 3)

> *Chemistry is the science of understanding life at the molecular level. It's about understanding and trying to improve life at the molecular level. Making maybe alterations to those tiny things that are not visible to our eyes and stuff so that we can maybe get desired results.*
>
> (Mawonde, Samarium, South Africa, Chemistry in combination with other subject(s), Year 2)

Category 5: Chemistry is explaining molecular interactions in unfamiliar situations in the world

Student accounts aligned with this category of description positioned chemistry in terms of the explanation of molecular interactions in unfamiliar or new situations. Thus, rather than simply explaining things in situations that were already familiar, this category of description foregrounds the capacity to act on the world and develop explanations in new situations. In accounts aligned with this category of description, students' understanding of chemistry informed their action and gave them agency:

> *It's a neat way of explaining how things work. It allows you to fine-tune processes and think about things in ways that people may not have thought of before. Especially with environmental issues popping up, it's going to be more useful in finding ways around things like fossil fuels.*
>
> (Demi, Erbium, England, Chemistry, Year 3)

> *Now we've been trying to see if you bring two molecules that you've never ever seen before, you apply all of those different rules together, you'll form a new molecule. If you followed the rules properly, and then you did it in real life, you would get the same answer. So I think it's useful for if you want to design anything, any new material.*
>
> (David, Erbium, England, Chemistry, Year 3)

Participant accounts of chemical engineering

Based on our analysis of the student interview data, we constituted six different ways of understanding chemical engineering. As one of these categories expressed a lack of knowledge of what chemical engineering was, we labelled this 'Category 0'. The remaining five categories formed an inclusive hierarchy, with each subsequent category including the previous one and Category 3 being the watershed category. The categories were as follows:

Category 0. I don't know what Chemical Engineering is;
Category 1. Chemical Engineering is the application of chemistry to a large scale;
Category 2. Chemical Engineering is about processes of large-scale production;
Category 3. Chemical Engineering is the design of processes of large-scale production;
Category 4. Chemical Engineering is the design of multi-scalar processes;
Category 5. Chemical Engineering is the design of multi-scalar processes for particular contexts.

Similarly to chemistry, these different ways of accounting for chemical engineering involved different relations between the student, the world and the discipline of chemical engineering. Table 5.3 sets out the outcome space as a whole and positions the categories of description in relation to their structural aspects, in the first column, and the referential aspects in the first row. Category 0 is not included in this table as it reflects an absence of a view about what chemical engineering is.

The structural aspects focus on the changes in what is in the foreground and background of the accounts. These shift from chemical engineering being about *describing* things to chemical engineering being about *designing* certain things. The referential aspects, in the first row, focus on the meaning of chemical engineering which shifts from chemical engineering referring to chemical reactions on a *large scale* to chemical engineering referring to *production* to chemical engineering referring to *multi-scalar processes* to chemical engineering referring to these processes in *particular contexts*. These structural and referential aspects come together to form each category of description: under category 1, chemical engineering is about describing large-scale chemical reactions, whereas under category 5, chemical engineering is about designing multi-scalar processes for particular contexts. The watershed shift comes in category 3, where students shift to understanding chemical engineering as being centrally focused on design.

Table 5.3 The referential and structural aspects of the categories of description for participants' accounts of chemical engineering

	Referential aspects			
	Large scale	**Production**	**Multi-scalar processes**	**Particular contexts**
Structural aspects				
Describing	Category 1: Chemical engineering is the application of chemistry to a large scale	Category 2. Chemical engineering is about processes of large-scale production		
Designing		Category 3. Chemical engineering is the design of large-scale processes of production	Category 4. Chemical engineering is the design of multi-scalar processes	Category 5. Chemical engineering is the design of multi-scalar processes suited to particular contexts

Chemical Engineering

Category 0. I don't know what chemical engineering is

Students' accounts which aligned with this category either said that they did not know what chemical engineering was or simply offered a tautologous explanation by saying that it was an engineer who specialised in chemistry:

> *I'd say that a chemical engineer is just an engineer. So they've got a good knowledge of physics, maths, but with a specialism in chemistry, so they've got just as good a knowledge as a chemist would.*
>
> (Liam, Erbium, England, Chemical Engineering, Year 1)

> *Even till this day, after two years of doing it, I don't even know how to explain it. I would just say it's just maths and physics, maths and physics and a bit of chemistry. I honestly don't know how to explain it.*
>
> (Rubiya, Europium, England, Chemical Engineering, Year 2)

Category 1. Chemical Engineering is the application of chemistry to a large scale

Student accounts which aligned with this category focused on the ways in which Chemical Engineering was the application of chemistry knowledge to a much larger scale:

What my chemical engineering professor said last semester is how the chemists do something of a small scale sample in the lab but the chemical engineers need to be able to do a mass level, such as maybe like mass production or water treatment plant that treats like billions of gallons of water per year.

(Joy, Astatine, United States, Chemical Engineering, Year 2)

It's like chemistry applied to moving and a bigger scheme of things … So rather than just doing research in a lab where that would be more of just chemistry, you would do experiments in a factory that would be part of a bigger project.

(Annie, Argon, United States, Chemical Engineering, Year 1)

Category 2. Chemical Engineering is about processes of large-scale production

Student accounts that were aligned with this category focused on Chemical Engineering as being related to processes of large-scale production. Whereas under Category 1 the emphasis was on applying chemistry to a large scale, under Category 2, the focus shifts to processes of mass production.

With a paper mill, just a processing system in general, you study the system, you see okay, what's the goal for this system? What are we trying to make? How much are we trying to make of it? You study how the system works every day, and you focus on the different changes that go in the system in order to make that product. So it's more of you honestly focusing on system processing every day.

(Allison, Argon, United States, Chemical Engineering, Year 2)

Okay, so chemical engineering is a processing department where we process raw materials to finish products that are able to be consumed by the public, so it's turning raw materials, materials that are not useful, to useful materials.

(Tawanda, Sodium, South Africa, Chemical Engineering, Year 2)

Category 3. Chemical Engineering is the design of processes of large-scale production

Student accounts that were aligned with Category 3 focused on the design of processes of mass production. The difference between this and Category 2 was that the notion of designing the process of production was foregrounded, whereas under Category 2, the focus was on describing the production processes themselves. We identified this as the watershed category because, in accounts that align with this category, students focus on chemical engineering in terms of design. They also talk about chemical engineering as something they are involved in, rather than describing a process that they are separate from.

Chemical Engineering is the design, management, evaluation and optimization of big chemical processes and processes in general.

(Naas, Samarium, South Africa, Chemical Engineering, Year 4)

I would say it is an applied science that tries to understand how things work with the aim of improving a process or improving the structure of something or improving the safety of something. So basically, improving processes by understanding how they work.

(Tracy, Sodium, South Africa, Chemical Engineering, Year 4)

Category 4. Chemical Engineering is the multi-scalar design of processes

Student accounts that were aligned with this category emphasised the multi-scalar character of the design process. It was this emphasis that differentiates Category 4 from Category 3, as accounts aligned with Category 4 explicitly considered the different scales that the process of design needed to consider. It is under this category that students' accounts appear to move beyond a focus on production to processes more generally.

[I]t's the bulk production of feed stocks and products from raw materials in an efficient and economically viable way. And getting from point A to point B is quite difficult, and it's time consuming; you look at a project, it might take two years to set up, and by that time it might not be feasible or economically … or it might violate regulations. So it pulls so many different disciplines together … and that's why you have teams of people and you have employees that can work together and pull different aspects of chemical engineering together, because it's such a big topic that encapsulates so many things

(Richard, Europium, England, Chemical Engineering Year 4)

Where you do a lot of modelling and maths to try to design these chemical systems, not really focusing so much on the actual chemical reactions themselves. But scaling up already developed and understood reactions into more industrial scale, which involves things like heat transfer and thermodynamics, which was also in reaction kinetics.

(Nicholas, Samarium, South Africa, Chemical Engineering, Year 4)

Category 5. Chemical Engineering is the design of multi-scalar processes for particular contexts

Student accounts aligned with this category emphasised that chemical engineering involved the design of multi-scalar processes for a particular context. In contrast to Category 4, rather than focusing on chemical engineering being defined by a general design process, there was a sense that the process of design always needed to be undertaken with reference to a particular context.

> *A lot of people think it's just working with chemicals, which it is for a large extent but we're not making chemicals. We are designing processes that produce different products, whether it be in the food industry, in the medical industry, in oil and gas, mining. Yes, if you want a product made, we'll design the process which is best suited to what you want. And we take economic and environmental considerations into account when designing those things.*
>
> (Nina, Samarium, South Africa, Chemical Engineering, Year 4)

> *This plastic cup, the person who first discovered the material or how to make it and the temperatures involved to make it into that shape, they wouldn't care about how much heat they used or how much material they used. They could have used a plastic sheet the size of this wall, but only managed to get this cup out of it. Then, a chemical engineer would come and think, 'Instead of using a plastic sheet that's the size of the wall, how could I use something that's half the size and use a third of the heat used?' Or, 'How can I shorten the time taken to make this cup, from one day to eight hours or seven hours?' So a chemical engineer doesn't discover things, they just improve things. Make the economics better of the process, reduce waste.*
>
> (Rafia, Europium, England, Chemical Engineering, Year 4)

Changes in participants' accounts over time

Table 5.4 shows that twenty-nine of the thirty-three students' accounts of chemistry appeared to be more inclusive in their third year than their initial interview (the dark-shaded cells). In students' initial interviews, none of their accounts aligned with categories 4 or 5, whereas in the third-year interviews over a third of their accounts did. In five cases, the account of chemistry appeared to be the same in terms of the outcome space (the unshaded cells). In no case did the student's account appear to be less inclusive in their third year than their initial interview (the light-shaded cells). Importantly, in their third-year interview, twenty-nine out of the thirty-three students' accounts of chemistry were aligned with the watershed category of description or a more inclusive category. This shows that, by their final year, nearly all students gave an account of chemistry based on a disciplinary way of viewing the world. This suggests most students had acquired the realisation rules (Bernstein 2000) of chemistry and could see it from the inside.

Table 5.4 Relations between the category of chemistry aligned with participants' accounts in their first interview compared to their interview in their final undergraduate year

	Final undergraduate year highest category					
Initial category[1]	**1**	**2**	**3**	**4**	**5**	**Total**
1	1	2	9	4	1	17
2		1	4	10	1	16
3			3	1	1	5
4				0	0	0
5					0	0
Total	1	3	16	15	3	38

1. In thirty-five cases, this was an interview in their first year, in three cases, this was in their second year

Table 5.5 shows that thirty-nine of the forty-five students' accounts of chemical engineering appeared to be more inclusive in their final year than their initial interview (the dark shaded cells). In the first-year interviews, only one of the student's account aligned with the third watershed category, whereas in the final interview, thirty-four of their accounts did. This shows that, by their final interview, most students gave an account of chemical engineering that included a focus on design, indicating they had acquired the realisation rules (Bernstein 2000) of chemical engineering. In six cases, the account of chemical engineering appeared to align with the same category (the unshaded cells). In no cases did the student's account appear to be less inclusive in their final year than their first-year interview (the light-shaded cells).

How did participants' accounts of their degree subject relate to other factors?

In examining the relations between students' accounts of their degree subject and other factors, we need to be explicit that we are simply looking for clear patterns that might indicate areas for further exploration. This study was based on a relatively small, self-selected sample of students, and so we cannot place great weight on these relations beyond highlighting potentially meaningful relationships.

In order to examine these relationships, we compared students whose accounts of their subject were aligned with the categories of description below

Table 5.5 Relations between the category of chemical engineering aligned with participants' accounts in their first interview compared to their interview in their final undergraduate year

	Final undergraduate year highest category[1]						
First year category	**0**	**1**	**2**	**3**	**4**	**5**	**Total**
0			3		1		4
1		3	5	5	5	4	22
2			2	4	7	5	18
3					1		1
4							
5							
Total		3	10	9	14	9	45

1. In six cases, this was an interview in their third year, in thirty-five cases, their fourth year, in three cases, their fifth year, and in one case, their sixth year

the threshold (Categories of Description 1 and 2 in each outcome space) in their final year interview with those whose accounts were aligned with the threshold or the more inclusive accounts beyond it (Categories of Description 3, 4 and 5 in each outcome space). There were no clear differences in the proportion of students giving accounts of their subject that were aligned with the threshold category of description based on gender or ethnicity, with in each case around three-quarters of students giving an account that aligned with the threshold or a more inclusive category of description. Given students were studying different programmes, we examined institutional differences. There were equally no clear institutional differences.

In Chapter 4, we discussed students' reasons for studying and what they gained from being at university and studying their subject. The one clear difference is shown in Table 5.6, which was that a higher proportion of students who reported gaining transformational outcomes from studying their subject gave an account of their subject aligned with the threshold category of description or a more inclusive category of description than students who reported instrumental gains from studying their subject.

There are two elements of this that are of significance. First, students having instrumental initial reasons for studying, and who saw what they gained from going to university in instrumental terms, did not appear to impact on the way they understood their subject at the end of their degree. This supports the argument made in the previous chapter that students seeing their reasons for studying or their university experience in instrumental terms did not shape

Table 5.6 Comparison of participants' accounts of their subject and what they reported gaining from studying their subject in their final year

		What was gained from studying their subject		
		Instrumental	**Transformational**	**Total**
Account of the subject final undergraduate year	Below threshold	6	11	17
	Above threshold	8	56	64
Total		17	78	95

their engagement with their subject. Second, students who talked about what they gained from studying their subject in instrumental terms did appear to be less likely to talk about their subject in a way that was aligned with the threshold category of description. Thus, it seems that students seeing their experience of studying their subject in transformational terms was important in them acquiring the realisation rules (Bernstein 2000) of their subject and seeing it from the inside. This highlights the importance of students understanding their engagement with their subject as an educational experience, as an experience that changes their understanding of the world and their relationship to it, in a similar way as has previously been found in relation to sociology (Ashwin et al. 2016).

Differences between participant accounts of chemistry and chemical engineering

So far in this chapter, we have focused on the similarities in participants' accounts of chemistry and chemical engineering. However, equally important are the differences between the outcome spaces in chemistry and chemical engineering. Whilst in both cases the outcomes spaces show an increasingly inclusive relationship between students, their subject and the world (as depicted in Figure 4.1 in the last chapter), the relationships between students, their subject and the world are different in chemistry and chemical engineering. The two outcome spaces are placed next to each other in Table 5.7.

If we ignore the absence of a knowledge of what chemical engineering is in Category of Description 0, both outcome spaces start with a focus on doing

Table 5.7 Comparison of the outcome spaces for participants' accounts of chemistry and chemical engineering

Category of description	Chemistry	Chemical engineering
0		I don't know what Chemical engineering is
1	Chemistry happens when things are mixed in a laboratory	Chemical engineering is the application of chemistry to a large scale
2	Chemistry is seeing chemical reactions	Chemical engineering is about processes of large-scale production
3	Chemistry is learning about molecular interactions	Chemical engineering is the design of processes of large-scale production
4	Chemistry is explaining molecular interactions	Chemical engineering is the design of multi-scalar processes
5	Chemistry is explaining molecular interactions in unfamiliar situations in the world	Chemical engineering is the design of multi-scalar processes for particular contexts

chemistry, whether in a laboratory, in the case of chemistry, or at a large scale, in the case of chemical engineering. Whilst both outcome spaces start with a focus on chemical reactions, they then take very different directions. Student accounts of chemistry were focused on explanation, whilst student accounts of chemical engineering were focused on the design of a process. Student accounts of chemistry moved from seeing, learning about, to explaining molecular interactions, to explaining these interactions in an unknown context. Student accounts of chemical engineering moved from the application of chemistry to a large scale, to focus on production, to focus on the design of production, to multi-scalar design, to design for particular contexts.

In this way, student accounts of chemistry can be seen to move from a focus on a particular explanation to a focus on a more general explanation of reality, regardless of the context. In contrast, student accounts of chemical engineering move from a general design to a design for a specific context. Thus, whilst the outcome space for student accounts of chemistry moves from the particular to the general, the outcome space for student accounts of chemical engineering moves from the general to the particular. This highlights the ways in which students produce an explanation of chemistry using different 'realisation rules' from those that are used in chemical engineering.

These differences reflect the differences in the recontextualisation of chemistry and chemical engineering in Chapter 3. The shift towards a more general explanation of the world in chemistry reflects the way in which the chemistry curriculum focuses on producing an account of the world that is structured by chemistry. In contrast, the focus on designing solutions in particular contexts in chemical engineering reflects the way that the chemical engineering curriculum prepares students to focus on engaging with the world as a chemical engineer.

It is very important to recognise the significance of this difference. It highlights the ways in which studying chemistry and studying chemical engineering prepare students to be very different kinds of graduates who engage with the world in different kinds of ways (Bowden & Marton 1998). Thus whilst we can discuss the similarities in the ways that students engage with knowledge and can focus generically on how this engagement with knowledge changes students' relationship to the world, what is equally important is the fact that through engaging with different bodies of knowledge and seeing the world in terms of these different bodies of knowledge, students develop different relationships to the world.

Implications for understanding how students benefit from studying in higher education

There are three significant aspects of the analysis in this chapter for understanding how students benefit from studying in higher education: how it offers a holistic sense of the relations to the world that students develop through studying chemistry and chemical engineering, how it highlights the distinctiveness of the outcomes of students engagement with particular bodies of knowledge through higher education and how it emphasises the importance of students being committed to engaging with these bodies of knowledge if they are to benefit fully from their engagement in higher education.

In terms of the understanding that the current study offers of students' accounts of engaging with knowledge in chemistry and chemical engineering, it offers something between the very general ways of understanding students' accounts of knowledge (for example, Baxter Magolda 1992, 2004), approaching scientific reasoning (for example, Flaherty 2020) or the profession (for example, Shallcross 2002) and studies of students' understanding of particular concepts (Johnstone 1982; Ebenezer & Erickson 1996; Case & Fraser 1999, 2001; Davidowitz et al. 2001; Ebenezer & Fraser 2001; Carew & Mitchell 2002; Nottis et al. 2010; Taber 2019). Whilst these previous studies focus on the structure of students' explanations of phenomena in chemistry and chemical engineering, the analysis in this chapter gives an insight into students' accounts of the subjects of chemistry and chemical engineering and how they position themselves in relation to this knowledge. In doing so, the outcomes from this study give a more holistic sense of the variation in the relations with the world that students develop through their engagement with two subjects in higher education.

This highlights how students' relationship with the world changes as they acquire the realisation rules of their subject (Bernstein 2000). As this happens, their understanding of the world is mediated by their knowledge of their subject. As highlighted in Figure 4.1 in Chapter 4, it is in this way that students are transformed as they understand themselves, the world and their relationship to the world in new ways (Ashwin 2020). In both of the outcome spaces, there is a shift from knowledge being external to the student and based on its most obvious features to knowledge being placed in a disciplinary structure and then a shift to students developing a personal relationship to knowledge in a similar way to studies from other disciplines (Crawford et al. 1994, 1998; Reid 2001; Bradbeer et al. 2004; Reid et al. 2006; Stokes 2011; Sin et al. 2012; Wood et al. 2012; Ashwin et al. 2014). It is important to be clear that whilst students can have a personal relationship to knowledge prior to knowledge being placed in a disciplinary structure, what is important in the second shift is to develop a personal relationship with knowledge that has been placed within this disciplinary structure. In this way, the outcome space captures students' changing sense of what they can do in the world through their engagement with this knowledge (Ashwin 2020). What is particularly important is that these changes appear to be distinctive to particular bodies of knowledge rather than generic. Thus, we have seen in this chapter how the relationship between students, knowledge and the world is different in chemistry and chemical engineering, and which reflects the differences in the chemistry and chemical engineering curriculum that we discussed in Chapter 3.

Despite this distinctiveness, it is possible to see similarities between the shifts in some subjects. For example, the shifts in chemistry and chemical engineering are more similar to geography (Bradbeer et al. 2004) and geoscience (Stokes 2011), where the way of engaging with the world is key. This contrasts with accountancy (Sin et al. 2012), law (Reid et al. 2006), mathematics (Crawford et al. 1994, 1998; Wood et al. 2012), music (Reid 2001) and sociology (Ashwin et al. 2014) where the way in which the self is implicated by the structure of knowledge is also important. This difference is worthy of further exploration to consider whether it reflects differences in knowledge-as-research, knowledge-as-curriculum or knowledge-as-student-understanding (Ashwin 2014) or whether it is reflective of differences in the focus of the studies of these different disciplinary areas.

Finally, this chapter shows that changes in students' accounts of chemistry and chemical engineering appear to be related to them understanding the benefits of studying their subject in educational rather than instrumental terms. This suggests that to fully benefit from higher education, students need to be committed to engaging with the bodies of knowledge of their subject offered through their educational environment. Without this engagement, they will not acquire the realisation rules of their subject. This is similar to findings of students studying sociology (Ashwin et al. 2016; McLean et al. 2018) and highlights the need for institutions to consider how to support students in developing an educational relationship with the bodies of knowledge they are studying. It also highlights that part of the problem with the focus on generic higher education outcomes for students is that it can conceal that the successful achievement of these outcomes is dependent on students' committed engagement with the particular bodies of knowledge they encounter through higher education (McCune & Hounsell 2005; Anderson & Hounsell 2007; McCune et al. 2021).

Conclusion

In this chapter, we explored the ways in which students' engagement with knowledge changed their understanding of the world and themselves. We found that whilst there were similarities in the way this occurred in the two subjects, there were also important differences in the way that this related students to the world, and these differences are related to differences in the chemistry curriculum and the chemical engineering curriculum. These differences are important because they show the different ways of seeing and engaging with the world that are offered by different subjects (Bowden & Marton 1998), and the production of a legitimate text in chemistry and chemical engineering involves different realisation rules (Bernstein 2000) that are informed by their curricula.

The question now remains as to whether the different ways in which students used knowledge to engage with the world remain after graduation. In the next chapter, we examine how students saw the benefits of studying at university at the end of the seven-year study and how this appeared to relate to their employment outcomes.

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6

What Did Graduates Value about Higher Education and What Were Their Employment Situations?

So far in this book, we have considered the chemistry and chemical engineering degrees in relation to the three sets of rules of the pedagogic device: the distributive rules, the recontexualisation rules, and evaluative rules (Bernstein 2000). We have shown how students' experiences of studying for their degrees led to them developing different ways of engaging with the world, depending on whether they had studied chemistry or chemical engineering. In this chapter and the next, we examine how the participants reflected on what they have gained from their university experiences after they had graduated. In different ways, the next two chapters explore the extent to which, and the ways in which, the knowledge they gained from their degrees informed their lives after graduation. We approach this from two different but related perspectives. In this chapter, we focus on graduate employability and, in the next chapter, we focus on a more general notion of 'graduateness'.

In Chapters 1 and 2, we discussed how human capital theory has dominated policy thinking about the purposes of undergraduate higher education. This has led to the primary purpose of undergraduate degrees being increasingly positioned as being focused on the development of employable graduates in a range of national and international policy contexts (Ashwin 2020; Robson 2023; Wheelahan & Moodie 2024). Of particular concern for the arguments made in this book is the danger that the focus on employability loses a sense that important graduate outcomes are generated by students' engagement with disciplinary and professional knowledge. This is because it loses a sense of how students' engagement with knowledge prepares them to engage in democratic societies as graduates (Smith & Bauling 2013; Muller & Young 2014; Walker 2015) and to consider what it means to live a graduate life (Ingram et al. 2023). In particular, as we discussed in Chapter 1, if higher education is about the development of generic skills, it is not clear why undergraduate degrees should focus on supporting students to develop dynamic relationships with disciplinary, interdisciplinary and professional bodies of knowledge. Given the costs and inflexibility of students' studying full-time for three- or four-year degrees, this raises the question of whether it might not be much more cheaply and accessibly delivered through the stacking of micro-credentials (Wheelahan & Moody 2022, 2024; Ljungqvist & Sonesson 2023). It is also notable that this increasingly narrow policy focus on employment outcomes has developed at the same time as the future of work is increasingly in question, with some arguing that higher education will instead need to prepare people for a quality of life (Brown et al. 2020) and a post-work or no-work future (Althorpe & Finneron-Burns 2024). Thus, it is the dominance of a narrow, knowledge-blind version of what it means to be a graduate that is the issue, rather than a focus on employability being problematic in itself.

In Chapter 1, we discussed the way in which human capital theory, in presenting the knowledge that graduates gain from their engagement in their undergraduate studies as just another form of human capital, flattens and conceals the impact of the relationships to knowledge that students develop through their studies and the ways in which these relationships to knowledge vary by disciplines (Ashwin 2020). This is because human capital is focused on understanding the economic value of what is gained through education rather than the educational outcomes for graduates. However, because it is so dominant in informing contemporary policy makers' understandings of education, the effect is that it totally obscures the holistic personal relationship to particular bodies of knowledge that change students and the ways in which they engage with the world (Taylor 1993; Bowden & Marton 1998; Ashworth 2004; Dall'Alba & Barnacle 2005; Ashwin 2020). Interestingly, the difference between these two ways of understanding the relationships that students and graduates develop to knowledge reflects a similar binary between, what have been termed, more and less inclusive ways that academics understand the subject matter of their research and teaching (Prosser et al. 2008; Trigwell & Prosser 2020). This difference is also consistent with the distinction between the less sophisticated and the more sophisticated outcomes of learning expressed by the Structure of Observed Learning Outcome (SOLO) taxonomy (Biggs & Collis 1982) with human capital theory offering a general unrelated list of capitals and the personal relationship to knowledge offering a particular, holistic view of students' relationship to knowledge.

While the concern that a more general idea of 'graduateness' is being subverted by a narrow focus on employability is not new (Johnston 1997;

Eccles 2012; Steur et al. 2012), the focus on a knowledge-blind model of employability is more recent. For example, subject understanding was a key element in Knight and Yorke's (2002, 2003, 2004) model of employability. Knight and Yorke (2002, 2003, 2004) were clear that employability was based on students' transformation through their engagement with their subject area. However, more recent reviews have found research into employability tends to lose an in-depth focus on the discipline that students are studying (Tight 2023). In line with human capital theory, it is included amongst 'skills, knowledge and competences' as one in a range of individual factors (Behle 2020) or subsumed into 'skills and competencies' as a form of human capital (Clarke 2018) regardless of whether employability is seen as a possession, a position or a process (Holmes 2013). Related to this change, in Knight and Yorke's (2002, 2003, 2004) work there is a sense that if employers cannot make use of graduates then there is a need to consider how the workplace might change to make better use of them whereas there is much more focus in recent literature on the problem of what is termed the 'overeducation' of graduates (for example, Jackson 2021; Marques et al. 2022).

In addition to the dominance of human capital theory, there also appear to be methodological reasons for this lack of focus on students' relationships to knowledge. Research into graduate employability tends to focus on graduates from a variety of disciplines, and so it is not possible for them to offer an in-depth examination of the role that graduates' engagement with particular bodies of knowledge plays in developing their employability. This issue exists in three related areas of research into graduate employability.

First, studies that focus on the factors that increase graduates' employability examine how factors such as demography and self-authorship (Tomlinson & Jackson 2021), career guidance (Shury et al. 2017), career self-guidance (Okay-Somerville & Scholarios 2017), activities aimed at supporting employability (Jackson & Bridgstock 2021) relate to perceptions of employability or professional identity. Similar studies examine how demography, educational experiences and outcomes are related to graduates' salaries (Pitman et al. 2019). All of these studies include participants from multiple disciplines. This means, whilst they could examine students' relationships to knowledge generally, they cannot examine the role of particular bodies of knowledge in shaping employability. Second, studies that examine employers' views of what makes graduates employable, for similar reasons, do not consider the role of disciplinary and professional knowledge in developing employability (Hinchliffe & Jolly 2011; Tomlinson & Anderson 2021; Byrne 2022). Third, studies that focus on the mapping of graduate attributes at an institutional level tend to exclude discipline as they seek to include graduates from across all disciplines (for example, Wong et al. 2022) with universities tending to highlight similar graduate attributes (Baron & McCormack 2024).

Studies of students and graduates from particular disciplines and subjects offer a potential way of gaining a sense of the role of the knowledge that they have engaged with in understandings of graduateness. However, whether or not this occurs depends on the ways in which the studies are conceived. For example, some studies that focus on a particular subject area (for example, Fletcher et al. 2017; Chadha & Heng 2024), do not give a sense of the knowledge that students have engaged with because they focus on the development of employability or generic skills. However, where knowledge is focused on there is a strong sense of the importance of the knowledge and ways of thinking in informing graduates' professional lives (Case & Marshall 2016; Case et al. 2018; Pott & de Jager 2021).

We argued in Chapters 4 and 5 that our analysis highlighted the importance of these holistic relationships to knowledge in both accounting for what students felt they gained from studying the subjects of their degrees and how they came to understand the world through their subject over the course of their degrees. In this chapter, our focus shifts to examining what our participants were doing in the final year of the study and how they reflected on the benefits of their undergraduate degrees. We revisit the instrumental and transformational perspectives that our participants expressed whilst they were students that we examined in Chapter 4. We examine the role of knowledge in graduate employability from the perspective of the participants in the final (seventy-three participants) or penultimate (two participants) years of our study, up to seven years after they started their undergraduate degrees. We examine whether their perceptions of what they had gained from their degrees had changed and connect this to employability by examining the relation between their employment situation and their perceptions of what they had gained from their degrees.

Outcomes

Our participants' destinations at the end of the study

Figure 6.1 shows our participants' destinations by the end of the study. Of the seventy-five graduates we followed through to the final years of the study, thirty-one (41 per cent) were in graduate roles directly related to chemistry/chemical engineering, twenty-six (35 per cent) were studying postgraduate qualifications, half of which were PhDs, ten (13 per cent) were in graduate roles not directly

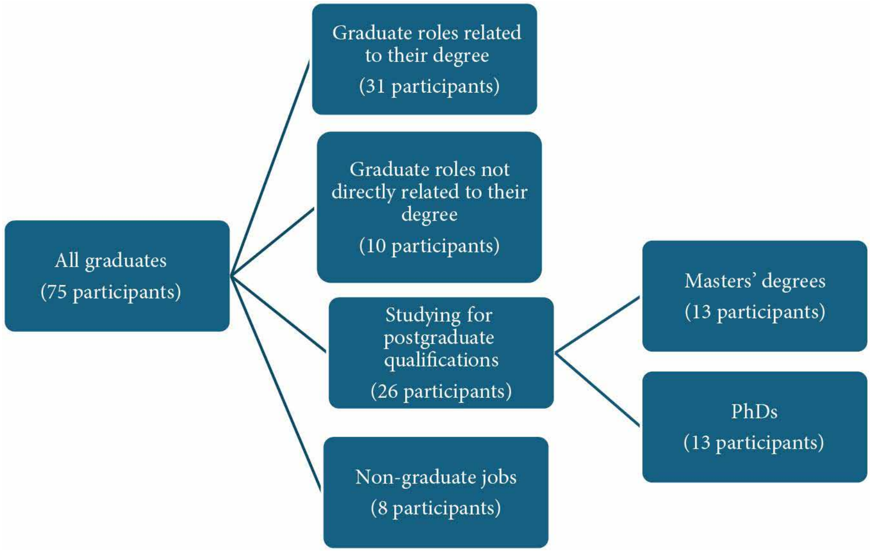

Figure 6.1 Graduate destinations at the end of the study.

related to the subject they had studied, and eight (11 per cent) were in a non-graduate job.

Most (eleven out of thirteen) of those studying for PhDs had a chemistry-related degree and six out of the eight participants who were in non-graduate roles had studied chemical engineering. In this chapter, we examine how our participants' graduate destinations related to their perceptions of what they had gained from going to university and from studying their degrees. We also examine how their destinations related to what they initially wanted to get out of studying at university in their first interview in the study. In the next chapter, we also consider how their graduate destinations are related to their relationship to the knowledge that they studied in their undergraduate degrees.

What participants gained from going to university

In Chapter 4, we showed how, in their final undergraduate year, three-quarters of participants said that the certification provided by their degree was the most important thing they gained from going to university. By the final years of the study, this was still the most common gain that students highlighted, as shown in Table 6.1. However, the proportion of participants highlighting this gain had fallen to about 60 per cent. There was a small increase in the proportion of

Table 6.1 Participants' perceptions of the benefits of going to university in their final undergraduate year and, as graduates, in their final interview in the study

	As a graduate in their final interview in the study			
	I don't know	**A degree**	**An educational experience**	**Total**
Final undergraduate year				
A degree	0	43	15	58
An educational experience	1	2	13	16
Ability to make a contribution	0	0	1	1
Total	1	45	29	75

participants highlighting a more intrinsic focus on the educational experience they had gained (from 21 to 25 per cent).

For example, in Chapter 4, we saw how, at the end of his undergraduate degree, Ken saw the benefits of going to university simply in terms of the credential, gaining 'a ticket' into dentist school. In his final interview in the study, Ken was studying at dental school and describes the benefits of going to university in more educational terms, as finding out what he wanted to be:

> *I hoped to gain what I wanted to be and really clarify it. Because I told you I wanted to be a teacher, right? Then also I wanted to be an engineer. But at the end of it I applied to dental school. So one of the goals of undergrad was, 'Okay, where do I want to work? What is my career? What is my life like?' So in terms of did I achieve everything? I truly believe I did. I taught myself that.*
>
> (Ken, Astatine, United States, Chemistry in combination with other subject(s), Year 6)

Similarly, in her final undergraduate year, Tracy was focused on how obtaining her degree would set her up in a good financial and social position:

> *I think it sets me off at a really good financial and starting point in society, so that I can move up in society. I feel like if I don't have an engineering degree, then I'll definitely reach the ceiling very soon, so I feel it gives me the opportunity to go above that.*
>
> (Tracy, Sodium, South Africa, Chemical Engineering, Year 4)

In the interview in the final year of the study, when she is working as a consultant on machine learning, Tracy is more focused on the educational benefits of going to university:

Number one, an education. I think going there in the first place my mindset was a work-life balance situation. Work is the number one priority and you've got to always focus on that … I didn't do the usual things of going out and drinking, but I could use the environment to go for hikes and be part of the community and see other people doing interesting things. That's what I hoped to gain from it as a student experience, but still an education that is reputable. Not just mess around, self-development.

(Tracy, Sodium, South Africa, Chemical Engineering, Year 7)

In cases such as these, there is a sense that, having got on the path they wanted to be on at the end of their undergraduate degree, these graduates were able to think more about the educational benefits of their degrees rather than simply focusing on the exchange value of their degrees.

Where graduates were not as settled on their path, then there was sometimes a shift from having seen going to university in terms of their education to seeing it in more instrumental terms. For example, Chloe had focused on the educational benefits of going to university at the end of her undergraduate degree, but in her interview in the final year of the study was much more uncertain and instrumentally focused:

I think that is literally the whole idea of what I had going into college or [Argon University] was just, once I graduate, I am going to have these doors open for me. Then you get to graduation and you are like, 'I have a degree in chemistry. I can't do shit with that.' (Laughter) Like okay, just – I mean honestly, you can get a benchtop research job and max out at 50K for the rest of your life if you just have a chemistry degree. You have to get a master's or a PhD to be able to break any type of glass ceiling without years and years and years of work in your life … I mean looking back it is so silly. I mean hopefully I end up with a family one day and I can encourage that family to not think that way. Encourage those people to just – if they don't want to go to college, don't go to college. Go to trade school. As long as you are contributing to society in a positive way, I don't think it matters.

(Chloe, Argon, Unite States, Chemistry, Year 6)

This change seems to be related to Chloe's struggle with the PhD she is currently studying:

I am expected to get results, and if I don't get results it is my fault, and I am fully responsible and I should be better. I think in my lab specifically, there is not a ton of empathy from my boss, so I think that can contribute to feeling inadequate and everything is going terribly, but, well, something has finally worked so that is a plus.

(Chloe, Argon, USA, Chemistry, Year 6)

So it seems that where participants changed their view of what they gained from going to university, this appeared to be a reflection of how they felt about their current experience. It is important not to overstate this as three-quarters of our participants still saw the benefits of going to university at the end of the study in the same way that they did at the end of their undergraduate year.

What participants gained from studying their subject

In Chapter 4, we outlined how, in the final year of their undergraduate degree, three-quarters of our participants focused on the way of engaging with the world that they had gained from studying chemistry or chemical engineering. Table 6.2 shows that this proportion had increased. Of the seventy-five participants who remained engaged in the study up until the final two years, sixty-three saw the most important thing they gained from studying their subject in terms of a way of engaging with the world compared to fifty-six of these participants in the final year of their undergraduate degrees.

For example, in the final year of his undergraduate degree, Lawrence was focused on the confidence and interpersonal and analytical skills that he had developed from his degree rather than the knowledge he had gained:

> *Like I mentioned, it's broadened some of my interpersonal and some of my analytical skills. I'd say confidence is the main one. I think it's something that, perhaps, you know, by the end of the course, is incredibly useful to everyone. You, kind of, feel a lot better about what you do and what you've learned and stuff.*
>
> (Lawrence, Erbium, England, Chemical Engineering, Year 4)

Table 6.2 Participants' perceptions of the benefits of studying their subject in their final undergraduate year and, as graduates, in their final interview in the study

	As a graduate in their final interview in the study			
	Way of engaging with the world	**Specific knowledge**	**Career**	**Total**
Final undergraduate year				
Way of engaging with the world	56	3	3	62
Specific knowledge	3	5	1	9
Total	4	0	0	4
Career	63	8	4	75

By the time of the interview in the final year of the study, he was an energy consultant and had recently been promoted out of the graduate scheme. Whilst he felt that the knowledge he had engaged with in his degree was mostly background material for his role, he still identified the way of approaching problem solving as the most important thing he had gained from his degree. He discussed this more as a way of engaging with the world than a skill:

> *I think the most important things were probably the way of problem solving, where you try and break it down and find the information and solve the bits you can solve, and then use that to unlock the next piece or the next move.*
>
> (Lawrence, Erbium, England, Chemical Engineering, Year 7)

In his final undergraduate year, Harvey was focused on the way his degree had enabled him to get a job in quality control for his third-year placement:

> *I don't know. I would say when I first joined chemistry I actually did it more because I didn't know what to do, and also I liked it and was good at it. What I've gained from it I don't know. Obviously you needed to get chemistry grades to get a placement job, and I quite like that, so it obviously has got me slightly up the ladder of a scientific based career path if anything. I don't really know what to say. Yes, I suppose getting onto the career path, I probably wouldn't have got a job in quality control if it wasn't for this, so that's probably the main thing I've got.*
>
> (Harvey, Europium, England, Chemistry, Year 4)

At the time of his interview in the final year of the study, Harvey was studying a PhD in computational chemistry at Europium. For Harvey, it was the scientific method that he developed that was the most important thing he developed from his degree. Like Lawrence, he emphasised that what was important about this was the way it allowed him to engage with the world rather than the particular knowledge or skills that it involved:

> *I don't know how to actually answer that, because there are many things you could probably say. Maybe the whole scientific method thing we keep referring to I think is quite important, because I think that's the main thing. So I don't think there's that much in terms of the actual raw chemistry knowledge, now, that I actually still retain and use, because I've done undergraduate labs things where I've demonstrated it, and I got a first class on this five years ago. I can't remember it anymore. So clearly, the specifics have gone. But the train of thought, the problem solving, the logic, are probably the main things … Well, essentially, because my research doesn't always go to plan, so you have to work out why, and try this, try this. If you've got an issue that could be caused by multiple problems, for example, and the way, intuitively, I work out what's gone wrong, and you determine a*

> *problem, to me, that's a scientific method. That's the same thing. So obviously, because things don't always work, or you need to be able to suss out, 'What next?' We don't just do it by pure guesswork or pulling a random number out of a hat; there's a method to sussing it out.*
>
> (Harvey, Europium, England, Chemistry, Year 7)

In contrast, in her final undergraduate year, Nomathemba was focused on the way of engaging with the world that she had gained through studying engineering:

> *I hope to be able to help solve problems that are already existing. And I can reach out to and can be able to solve. Because I feel like our tasks as engineers are mostly problem solving. And that is what I want to go into, be it with skincare disorders or nutritional benefits from getting organic food. I want to solve an already existing problem.*
>
> (Nomathemba, Samarium, South Africa, Chemical Engineering, Year 4)

In the final year of the study, Nomathemba was working part-time in catering whilst she applied for graduate jobs. At this stage, she focused on the technical knowledge and skills that she gained from her degree rather than a way of engaging with the world:

> *There was technical knowledge. There was also teamwork, and ability to work also by myself, as an individual.*
>
> (Nomathemba, Samarium, South Africa, Chemical Engineering, Year 7)

Relations between what participants felt they had gained and their employment situation

Table 6.3 shows the relations between graduates' perceptions of the benefits of studying the subject of their degree and their employment situation at the time of their interview in the final year of the study. It shows that students in non-graduate roles were most likely to have focused on specific knowledge from their modules, whereas those in graduate roles focus on the way of engaging with the world they gained from studying. Clearly, this relationship needs to be handled carefully for two key reasons. First, it is not clear about the direction of the relationship in terms of whether graduates' employment outcomes influence the way in which they reflect on the benefits of their degree or whether the view of the benefits of their degree plays a role in their employment outcomes. Second, the small number of graduates in the study and the self-selecting nature of the sample should not be ignored.

Table 6.3 Participants' perceptions of the benefits of studying their subject by their employment outcome in the final year of the study

	Employment outcome in their final interview in the study					
	Graduate role in subject area	**Graduate role outside subject area**	**Studying for a PhD**	**Studying postgraduate degree**	**Non-graduate role**	**Total**
Benefit of studying their subject in their final interview in the study						
Way of engaging with the world	28	10	11	13	1	63
Specific knowledge	2	0	0	0	6	8
Career	1	0	2	0	1	4
Total	31	10	13	13	8	75

In order to examine the direction of the relationship further, Table 6.4 shows the relations between how the participants saw the benefits of studying their subject at the end of their undergraduate degree and their employment outcome at the end of their study. This shows that fewer of those in non-graduate roles had seen their benefits of studying their subject in instrumental terms at the end of their degree. This suggests that, for some of our participants, the lack of graduate roles after graduation may have led them to see their engagement with their subject in more instrumental terms.

For example, at the end of his undergraduate degree, Naas focused on how his degree had changed the way in which he engaged with the world:

> *I think undoubtedly I do. And it's hard to put a pin on it, because the change has been constant and it has definitely morphed me as a person. Doing the degree has made me … Because part of it was to do a humanities course. I did anthropology last year second semester. That has morphed my outlook on just being more socially aware and more aware of the positionality, boundaries, that sort of thing. It has been very helpful in shaping I think a better view of the world for me.*
>
> (Naas, Samarium, South Africa, Chemical Engineering, Year 4)

Table 6.4 Participants' perceptions of the benefits of studying their subject in their final undergraduate year by their employment outcome in the final year of the study

	Employment outcome in their final interview in the study					
	Graduate role in subject area	**Graduate role outside subject area**	**Studying for a PhD**	**Studying postgraduate degree**	**Non-graduate role**	**Total**
Benefit of studying their subject in final undergraduate year						
Way of engaging with the world	25	9	11	13	4	62
Specific knowledge	4	1	0	0	4	9
Career	2	0	2	0	0	4
Total	31	10	13	13	8	75

By the final year of the study, Naas had been on an extended 'gap year' since finishing his degree three years earlier. This was partly because of the Covid-19 pandemic and partly because he had been exploring creative projects as well as extending his knowledge of coding:

> *With regards to the creative stuff, I went into it and I've continued to learn and grow in that respect. Through the end of last year, I really went for it and started to produce more creatively, videos and music and all of that, and now I am at the point where I'm really pushing that forward. It's been, unfortunately, slow but that's how life is, sometimes, when you've been doing different things for the last few years. Now I've got my eyes on focusing, my next objective is to try to actually get some money out of those things. As far as coding, I haven't really touched it since because I'd need more motivation to find something to do with it. I learned a decent amount, and I can always springboard off that. Finishing everything I wanted to do, no but I continue to do that and I will get that done. I have applied to a few jobs with no luck, but it was a learning experience anyway and opened my eyes to new horizons.*
>
> (Naas, Samarium, South Africa, Chemical Engineering, Year 7)

These experiences appeared to change the way he thought about how he benefitted from studying chemical engineering from a way of engaging with the world towards seeing it in terms of particular elements of knowledge that are viewed more from the outside:

> *The ability to learn and the broadening of the horizons towards technology. We learned a lot of maths and technical stuff, which means when I approach something like that I have a basis. I learned how to use programs that model things, so I understand those better, that's one of the things. Coding, of course. So that's one.*
> (Naas, Samarium, South Africa, Chemical Engineering, Year 7)

However, some participants did not change their view of their degree despite not being in a graduate role in the last year of the study. For example, Robert is working in a non-graduate role in retail in the final year of the study, but still maintains a clear sense of how studying for a degree in chemical engineering has changed the way in which he engages with the world:

> *The education is just really good at shaping your thinking to helping you meet ends, meet goals because you're good at seeing things from individual standpoints and then working them out to make what you want to happen.*
> (Robert, Europium, England, Chemical Engineering, Year 7)

Relations between what participants wanted to get out of their degrees and their employment situation at the end of the study

Table 6.5 shows participants' employment outcomes at the end of the study, which we outlined earlier, by what they wanted to get out of their degree in their first undergraduate year. Whilst generally there do not appear to be any clear relationships between these, one interesting outcome is that all of the graduates who had been focused on following the subject or personal development in the first year of their degree were in graduate roles or studying for postgraduate degrees in the final year of the study. As we discussed in Chapter 4, all of these students were studying chemistry. These outcomes need to be interpreted cautiously because of the small numbers involved and because only two students who studied chemistry were employed in non-graduate roles in the final year of the study. However, it does raise some interesting questions.

First, we saw in Chapter 4 that students who were interested in following chemistry were sometimes uncertain about where chemistry was taking them. For example, both Demi and Damien reported being very unclear about where chemistry would take them at the end of their degrees. Demi withdrew from the study after she had graduated. However, Damien continued in the study and by

Table 6.5 What participants wanted to get out of going to university in their first undergraduate year by their employment outcome in the final year of the study

	Employment outcome					
	Graduate role in subject area	**Graduate role outside subject area**	**Studying for a PhD**	**Studying postgraduate degree**	**Non-graduate role**	**Total**
What wanted to get out of university in their first year						
Personal development	4	1	1	0	0	6
Follow subject	3	0	1	0	0	4
Professional in subject	8	2	6	4	2	22
Career	11	5	5	4	3	28
Contribute to society	5	2	0	5	3	15
Total	31	10	13	13	8	75

the time of his final interview had a graduate role related to chemistry working in forensics. It had taken him until that year to find that role, having started and withdrawn from a postgraduate teaching qualification. By this time, he did seem to have found the kind of role that he wanted:

> *It's something I always wanted to do, I think, be that kind of person in the office over to the side and when there's a problem they come in and they go, 'Guys, we've got a problem with such and such thing.' We look at each other and go, 'Okay, I'll have a look at this one. I'll take this one.' The ones that people come to when there's a problem, the specialist, that is something that always appealed to me, definitely … I don't suppose I had a great desire to go into forensics but certainly, once I realised that teaching wasn't for me, I thought, 'Well what else can I do that I can finish and, if I have a good day at work, I can feel good about it?' Really not a lot of people can say that, depending on what you do, feel like a good day's work is worthwhile in and of itself. I have got that. That's what appealed to me in teaching, that's a big part of what appealed to me in forensics as well but that was more recent. Yes, it's not a surprise to me. I don't look at it now and go, 'Blimey, I don't know how I got here.' I think it's pretty close to what I thought I would be doing, yes.*
>
> (Damien, Erbium, England, Chemistry, Year 7)

Implications for understanding graduate employability

These findings highlight the importance of including graduates' relationships to knowledge in the understanding of employability, as was done in the work of Knight and Yorke (2002, 2003, 2004). This is because graduates who focused on the instrumental benefits of their degree, rather than their engagement with knowledge, tended to have less positive employment outcomes at the end of the study. This appeared to be both related to the way in which they saw their subject and the fact that the lack of a graduate employment context in which to develop made them less likely to foreground the ways of engaging with the world that they had gained from studying their subject. This has four important implications for understanding employability.

First, it highlights the problems with conceptions of graduate employability that miss out knowledge (Tight 2023). The accounts provided by the graduates in this study suggest that a successful undergraduate experience involves developing a way of engaging with the world that is informed by the knowledge that was studied. This raises important questions about studies of employability that leave out or ignore the knowledge that graduates engaged with in their degrees (for example, Okay-Somerville & Scholarios 2017; Shury et al. 2017; Pitman et al. 2019; Jackson & Bridgstock 2021; Tomlinson & Jackson 2021). This is because it suggests that notions of employability are empty without a sense of the bodies of knowledge that have contributed to the development of graduates' ways of engaging with the world (Yates et al. 2016; Ashwin 2020; Wheelahan et al. 2022).

It is noteworthy that participants who at the start of their undergraduate degrees were either focused on following their subject or developing personally all had positive employment outcomes. Both of these reasons for studying imply that, as students, they were focused on the knowledge of their degree, either to follow it or to develop personally through their engagement with it. It is possible that this focus on knowledge informed their positive graduate outcomes.

Second, these findings highlight that how graduates understand the value of their university education is partly shaped by their current experiences. So whilst there was a clear relationship between being in a non-graduate role and focusing on specific bits of knowledge from their degrees, the direction of this relationship is not clear. Either not engaging with the world from the perspective of their discipline had limited these participants' employability, or a lack of graduate employment opportunities meant that these graduates had not realised the potential of their discipline to support their employability. This highlights the importance of graduates finding a context that can support them to understand how their engagement with their subject informs their employability. Thus employability is best seen as a characteristic that graduates continue to develop through their lives rather than something they have at the end of their degree. This highlights a role for higher education institutions, employers and wider society to support graduates to develop their employability on an ongoing basis and help them to understand how their engagement with their subject can play a role in their graduate lives.

Finally, it suggests that the policy picture presented of graduate outcomes simply being about employment outcomes provides a deeply misleading view of employability. This misleading view of employability serves to support approaches to higher education that do not provide students with access to meaningful bodies of knowledge, such as micro-credentials (Wheelahan & Moody 2022, 2024; Ljungqvist & Sonesson 2023). This view also misleads prospective students about what an undergraduate education involves because it does not make it explicit how any benefit from this education, including employability, is dependent on students' engagement with bodies of knowledge. In other words, without a focus on the importance of these bodies of knowledge in developing employability, approaches to employability are unlikely to be effective.

As knowledge is also central to higher education's capacity to support democratic engagement (Smith & Bauling 2013; Muller & Young 2014; Walker 2015), it also has the potential to undermine the public benefits derived from higher education. A broader view of the role of education would be supported by moving beyond human capital theory's view of the gains of education being simply different unrelated forms of capital and, instead, understanding the holistic personal relationships that graduates develop to knowledge as a key educational outcome of higher education. Such a focus would also bring to the fore the ways in which these educational outcomes vary depending on the subjects that graduates have studied. We examine this further in the next chapter.

Conclusion

In this chapter, we have examined our participants' experiences after graduation. Based on these, we have argued for a view of employability that focuses on how graduates use their engagement with particular bodies of knowledge in their degrees to develop a way of engaging with the world. This suggests that there are serious issues with the current policy focus on employment outcomes and employability that ignore the knowledge that students engage with in their degrees. Such an approach potentially narrows the purposes of higher education to the production of a skilled workforce which is a very limited view of the purposes of higher education (Ashwin 2020; Robson 2023; Wheelahan & Moodie 2024) and is likely to be ineffective in developing graduates' employability. On the view outlined in this chapter, a graduate is someone who engages with the world in particular ways based on seeing knowledge from the inside. In the next chapter, we examine what the idea of seeing bodies of knowledge from the inside means for our understanding of graduateness.

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7

How Did Graduates Use Their Knowledge to Engage with the World?

In the last chapter, we considered the ways in which students appeared to understand what they gained from studying at university and how it related to their employment situation. We argued that for most participants it was the knowledge they had engaged with in their degree that was the most important thing they reported they had gained from studying the subject of their degree. This appeared to be related to their employment situation. Overall, we argued that this highlighted the way in which discourses of employability are empty if they do not provide a sense of the knowledge that graduates have engaged with in their degrees.

In this chapter, we focus on the related, but more general, notions of 'graduateness' and graduate attributes. These go beyond employability to consider issues of graduates' values and ways of engaging with the world. We identify four different approaches to graduateness, which use the idea of graduateness in different ways. We argue that three of these approaches do not provide a sense of how graduateness is developed through students' educational experiences of engaging with the knowledge of their degrees. Based on our analysis of our interviews with our participants when they were graduates, we show that a knowledge-rich understanding of graduateness can be developed by understanding how graduates see the world from 'inside' the bodies of knowledge they studied in their degrees. This demonstrates how the potential of mass higher education can be seen in terms of graduates who engage with the world on the basis of the knowledge they have studied in their degrees.

Ways of understanding graduateness

As we argued in Chapter 6, ideas around employability tend to underplay the importance of the relationships to knowledge that are developed over the course of an undergraduate degree. For this reason, many argue for a more inclusive notion of 'graduateness' that can be seen to express both what is gained by studying for a degree and what graduates can contribute to the world, including, but not limited to, their working lives (Chetty 2012). Graduateness can also be related to ideas of sustainable assessment (Boud 2000; Boud & Soler 2016) and the development of evaluative judgement (Cowan 2010; Tai et al. 2018) that emphasise how the design of degree programmes and the assessment of these programmes supports graduates to benefit from what they have studied long after they have graduated.

Debates around graduateness raise important questions about what higher education is for. This is partly related to debates around human capital theory and critiques of the limited view of education that it offers (Bernstein 2000; Allais 2012; Wheelahan & Moodie 2024). These criticisms are related to the way that a human capital theory perspective obscures the holistic personal relationships that graduates might develop to knowledge (Taylor 1993; Bowden & Marton 1998; Ashworth 2004; Dall'Alba & Barnacle 2005; Ashwin 2020). However, as we discussed in Chapter 6, in the context of the climate and nature emergency, it is also related to the need for higher education to increasingly prepare graduates for a post-work or no-work future (Althorpe & Finneron-Burns 2024) and what it means to live a meaningful graduate life (Brown et al. 2020; Ingram et al. 2023) rather than only focusing on paid employment.

There are different ways of understanding graduateness that can be identified in the scholarly literature (Barrie 2006, 2007; Bernstein & Osman 2012). A key distinction, of major significance to our study, is whether these are generic or discipline specific (for example, see Barrie 2006; Green et al. 2009; Jones 2009a, b; Ryan 2024). For example, based on his interviews with academics, Barrie (2006) constituted four different ways of understanding graduate attributes depending on the extent to which they were separate or integrated into graduates' disciplinary understanding. These were graduate attributes as (i) generic precursor skills that students have before coming to university; (ii) generic attributes that complement graduates' disciplinary knowledge; (iii) a way of translating and transforming disciplinary knowledge which are closely related to, but still separate from, disciplinary learning outcomes; and (iv) abilities that are interwoven with and an integral part of scholarly learning.

Barrie's (2006) focus is on graduate attributes. Whilst some argue that other ways of understanding graduateness can be seen as synonymous (Wong et al. 2022), a distinction can be made between whether graduateness is positioned, like Barrie (2006) does, as an attribute or personal possession of the graduate, or

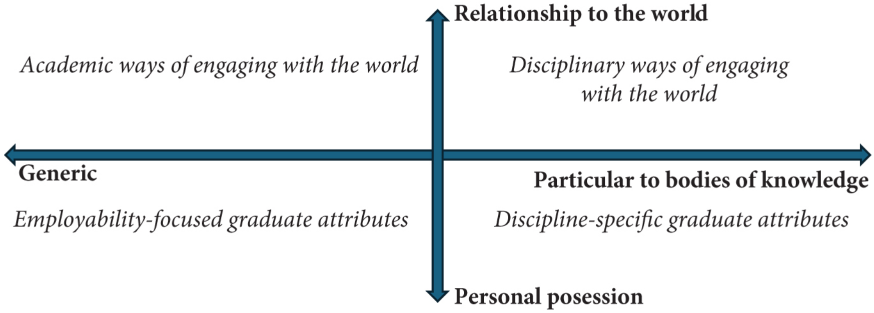

Figure 7.1 Dominant approaches to understanding graduateness.

whether it is seen in terms of a relationship that graduates have with the world (Holmes 2013; Guile 2002).

Based on these two aspects of variation, Figure 7.1 sets out four dominant approaches to graduateness. The horizontal axis is the extent to which graduateness is seen as generic or related to the particular bodies of knowledge that graduates have studied. The vertical axis is the extent to which graduateness is seen as a personal possession or a relationship to the world. This leads to the four different ways of understanding graduateness.

Graduateness as a generic personal possession

The dominant way of understanding graduateness as a generic personal possession is in terms of 'employability-focused graduate attributes' as shown in Figure 7.1. This way of understanding graduateness relates most strongly to the approaches to employability that we discussed in Chapter 6, although it tends to include employability as one of a broader range of graduate attributes (for example, Wong et al. 2022). This approach to graduateness can be seen in attempts to identify common languages of graduateness, usually by reviewing sets of attributes or transferable skills used by different institutions or in different studies that graduates need in order to make themselves more employable (Hounsell 2011; Osmani et al. 2015; Lipan et al. 2020; Wong et al. 2022). In some approaches, these graduate attributes are positioned as existing outside of what graduates have studied and are imported into their education as a set of attributes that must be covered by degree programmes and which are subject to continual change depending on the requirements of the world and particularly the world of work (Oliver & Jorre de St Jorre 2018). A key criticism of 'employability-focused graduate attributes' is that they do not reflect the kind of education that graduates have engaged in. This raises questions about why studying for an undergraduate degree would seem to be an efficient or effective way of developing these kinds of graduate attributes compared to, for example, on-the-job training (Ashwin 2020).

Graduateness as a generic relationship to the world

In Figure 7.1, 'academic ways of engaging with the world' is the dominant approach, focused on how graduates develop ways of engaging with the world through their educational experiences in higher education that are not specific to the particular subject of their degree. Rather than having employability as an explicit element of these relationships, these approaches tend to focus on how students' studies have supported them to develop new ways of engaging with the world. These ways of engaging with the world are argued to increase students' employability but are not developed simply for reasons of employability. For example, Steur et al.'s (2012) approach to graduateness is centred around reflective thinking, a scholarly stance to the world, moral citizenship and lifelong learning. Fischman and Gardner (2022) focus on the development of what they term 'higher education capital', which represents discipline-blind ways of engaging with the world that are developed through their educational experiences: abilities to attend, analyse, reflect, connect and communicate on issues of interest and importance. Walker and McLean (2010, 2013) developed a capabilities approach to the understanding of professionalism. This approach was focused on developing public-good professionals who increase the capabilities of those they work with. Across social work, theology and engineering, Walker and McLean (2010, 2013) worked with course leaders, students and professionals to develop a shared group of capabilities of informed vision, affiliation, resilience, social and collective struggle, emotional reflexivity, integrity, assurance and confidence, knowledge and skills. Mathebula (2018) built further on this work by exploring the capabilities of engineers focused on the public good in Germany and South Africa.

Graduateness as a discipline-specific personal possession

Another approach to graduateness is to position it in terms of graduate attributes that are specific to the particular degree that graduates had studied. The dominant approach to this view of graduateness is shown in Figure 7.1 as 'discipline-specific graduate attributes'. For example, the different sets of graduate attributes set out in Normand and Anderson (2017) are developed in different disciplinary and professional settings leading to different kinds of discipline-specific graduates: the learning graduate; the adaptable graduate, the self-aware graduate, the resilient graduate, the agile graduate, the empathetic graduate, the ethical graduate, the professional graduate, the digitally literature graduate and the reflexive graduate. In contrast, based on interviews with law academics, law graduates and professional lawyers, Ryan (2024) developed four different ideal types of the law graduate: the adaptable graduate, the confident graduate, the resilient graduate and the critical graduate. These ideal types collectively express the qualities and characteristics required of law graduates in a manner intended to be accessible to students from a wide range of backgrounds. Whilst these different types of graduates are expressed generically, they are discipline-specific rather than it being assumed that students develop the same graduate attributes regardless of the subject they study.

Graduateness as a disciplinary-specific relation to the world

The final approach to graduateness is to focus on disciplinary-specific relations to the world, shown in Figure 7.1 as 'disciplinary ways of engaging with the world'. Bowden and Marton (1998) argued that the purpose of higher education is to prepare graduates for an unknown world through the means of what is currently known. They argued that this is achieved through graduates having learned to see the world in ways informed by the subject that they have studied and developing ways of acting effectively based on this way of seeing the world. As different subjects support graduates to develop different ways of seeing and acting in the world, graduateness is positioned as a discipline-specific way of engaging with the world (Baille et al. 2013; Case & Marshall 2016).

The different purposes of the four approaches to graduateness

The differences in the four approaches to graduateness reflect distinct ways of using the idea of graduateness. Rather than some approaches being better than others, the four approaches to graduateness tend to be drawn upon in response to varying agendas and are used in different ways.

'Graduateness as a generic personal possession' tends to be used as a way of justifying the relevance of higher education to governments and societies that are increasingly sceptical about its relevance (Oliver & Jorre de St Jorre 2018) and to show how it can address urgent social priorities (Bernstein & Osman 2012). It can also be used as a way of marketing particular higher education institutions by distinguishing their graduates from those from other institutions (Anderson 2017) or as indicators of quality (Wong et al. 2022). In this way, 'graduateness as a generic personal possession' gives what we characterise as a *promotional* way of understanding graduateness.

'Graduateness as a generic relationship to the world' can be used as a broad framework that those designing curricula can use and consider the meaning they take on in the context of particular degree programmes. For example, a key element of Walker and McLean's (2010, 2013) approach is to identify capabilities that are essential for supporting the public good, but which will involve different kinds of practices to realise in different professions and different settings. Similarly, whilst Bowden and Marton (1998) focus on discipline-specific relationships to the world, in later work, Bowden et al. (2000) focused on generic capabilities that those designing degree programmes can use to develop programmes in particular subject areas. In this way, 'graduateness as a generic relationship to the world' can be characterised as a *developmental* way of understanding graduateness.

'Graduateness as a disciplinary specific personal possession' gives an insight into the kinds of people that graduates become through studying degrees in particular subject areas. In doing so, it gives students, employers and other stakeholders an accessible way of understanding what is meant by being a graduate in a particular subject area, which is the approach that Ryan (2024) takes in describing law graduates. Thus, 'graduateness as a disciplinary specific personal possession' can be characterised as offering an *accessible* way of understanding graduateness.

In thinking about graduateness, we focus on 'graduateness as a disciplinary-specific relation to the world' because we are interested in exploring the educational potential of undergraduate degrees in the particular subject areas of chemistry and chemical engineering. Whilst the other approaches provide a clear characterisation of graduateness, they do not provide an insight into how graduateness has been developed. In Bernstein's (1990, 2000) terms, these other approaches show how graduateness is a carrier of the skills and attributes described, but do not give an insight into how graduates have developed a voice that is informed by the knowledge they have engaged with. If we are to understand the educational potential of undergraduate degrees, then we need to have a sense of the ways in which graduates' way of engaging with the world is formed through their engagement with knowledge. It is 'graduateness as a disciplinary-specific relation to the world' that provides an *educational* way of understanding graduateness. From an educational perspective, generic attributes are empty once they are separated from the disciplinary knowledge that gives them meaning (Bernstein 2000; Jones 2009a, b; Caspersen et al. 2017; Ashwin 2020) and engagement with specific bodies of knowledge is crucial for developing a meaningful understanding of graduate outcomes. For example, students' interest in their subject is important for their interest in employment (Quinlan & Renninger 2022; Quinlan and Corbin 2023), and the development of professional knowledge and skills in particular subject areas is dependent on a strong disciplinary foundation (for example, in engineering see Case & Marshall 2016; Winberg et al. 2020).

It is worth noting that none of these four approaches foreground how students and graduates position their own graduateness, that is, graduate accounts of graduateness. Su (2014) argued for person-based graduate attributes that, as well as being relevant to the discipline, reflect students' priorities based on their understanding of their situation and what they want to achieve in their future lives and careers. In a similar way, studies of the experiences of graduates and their reflections on the meaning of their degrees after graduation also give a personal view of graduateness. For example, Case et al. (2018) highlight the intrinsic and passionate motivations for academic endeavours of the graduates in their study whilst Ingram et al.'s (2023) study of graduates focuses on what it means to live a graduate life in terms of making a life, not just a living. They highlighted that for different graduates, success means different things, such as finding degree-level work, finding work that uses their degree, finding meaningful work or finding high-paying work.

The focus in this chapter is on how graduateness is formed through the ways in which graduates engaged with bodies of knowledge over the course of their undergraduate degrees. As reflected in the diagram in Figure 4.1 in Chapter 4, it is about how their engagement with these bodies of knowledge changes how they see themselves and how they engage with the world as graduates. For this reason, whilst in the last chapter we focused on whether or not graduates highlighted the knowledge they gained from their degree, in this chapter we shift focus to explore the different ways in which graduates talked about knowledge. We examine whether their accounts of knowledge towards the end of the study appeared to place them 'inside' or 'outside' of knowledge. This is a key difference that we have explored in different chapters in this book. The argument that we have been building is that for mass higher education to realise its potential, it needs to be designed in a way that takes students *inside* particular bodies of knowledge so that when they graduate, they can use those bodies of knowledge to engage with the world. We argue that when graduates engage with the world from inside bodies of knowledge, this allows them to use this knowledge to understand a far greater range of contexts and draw on this understanding in employment contexts that are not necessarily directly related to the subject of their degree. We provide evidence for this argument by showing how graduates' relationships to knowledge develop and where these have taken them by their final study interview.

Participants' relationships to knowledge as graduates

In examining how participants positioned themselves in relation to the bodies of knowledge that they had studied in their degrees, we found that their accounts positioned them 'inside' or 'outside' of knowledge. This distinction signals whether they located themselves as owning the knowledge and using it in particular ways, or whether it was something that was separate from and external to their experience of the world. What it meant to be 'inside' knowledge was different for chemistry graduates and chemical engineering graduates whereas, when participants positioned themselves 'outside' of the knowledge of their subject, their accounts were similar regardless of the subject they had studied.

Participant accounts that positioned them inside their subject knowledge

For chemistry graduates, there were two different ways in which they positioned themselves as 'inside' of the knowledge of their subject: as a way of 'seeing the world' or as a set of processes for engaging with the world. Eighteen of the chemistry graduates positioned themselves inside chemistry and used this as a way of seeing the world. For example, Stella, who was studying for a PhD in chemistry in her final year interview, was very clear about the way in which chemistry had allowed her to see the world

> *Chemistry allowed me to see things not for what they are, I guess. It's more like, 'What are the things around you?' and the beauty behind Chemistry and how things operate in nature, like, 'Why do things do what they do?'*
>
> *I mean, if I look at my tea now, if I make tea now, just how the tea spreads in the water, I'm like, 'Oh, okay', and then I just think about, a little bit, Chemistry while I'm looking at it. I don't know. It gives more detail to your surroundings if you …*

Ah, yes, but not everything. You know? But just – I don't know – it's like a little bit sprinkles on your everyday life, if I can put it like that. Yes.

(Stella, Sodium, South Africa, Chemistry, Year 7)

Stella was clear that this way of engaging with the world was not about a fixed method but finding a path in different ways.

For us, there is not one way to do things. Say, for an experiment, there's not one way of doing it, and most of the time when you get the thing you're supposed to do, it's not like from A to B. You're probably never going to get to B. So then, it's more like the way that you figure out different paths to get what you want in different ways, to do good research and not just go search for the word you're looking for and maybe go look at that. Yes, I'm still not exactly sure how to describe the way we think, but I do think we have a way of solving things or problem solving that is typical for people that did chemistry or chemists or whatever, scientists.

(Stella, Sodium, South Africa, Chemistry, Year 7)

In contrast, there were eighteen chemistry graduates who positioned themselves inside the body of knowledge of chemistry but who did so in a way that was far more process focused. These participants described the ways that chemistry had given them a series of steps that they could follow in engaging with the world. For example, like Stella, Caroline was studying for a PhD directly related to her undergraduate degree in biochemistry focusing on the systematic way of engaging with the world she had gained through her studies

[I]f you gave somebody a car and they had never seen a car or whatever, this is how one might approach it. Be like, 'Okay, I am going to pick a part, look at it, see how it works and play around with things.' That is one style of thinking in science, breaking things down. Biochemists, we just break it. We will break something and see what happens, and systematically break things. 'Okay, what if I chain proteins made up of 200 amino acids?' Like little units strung together. 'Okay, what happens if I change this one?', 'What happens if I change this one?' You systematically go through to see which ones are important … if you change something that is important, then it will break and now, 'Oh, now I know that that is important.' From that, from breaking different things in a car- If you break the radio in a car, now you know the radio is not important for the car to still run. If you break an axle in a car, now you know it is important. From systematically breaking things, you can really learn how things work. So, anyway, that is what I want to rant about. Even just within scientific thinking. (Laughter) Scientific thinking is really just about understanding our world, and there are lots of different methods and ways to do that, but, yes, the biochemist way is, 'Let's break it to see what is important.'

(Caroline, Argon, United States, Chemistry in combination with other subject(s), Year 6)

Analysing the positions of chemical engineering graduates, we found that the twenty-one graduates of chemical engineering who positioned themselves inside of their subject knowledge had a process-focused way of engaging with the world. There were no chemical engineering graduates whose association with knowledge focused only on thinking differently about the world; this was always related towards a process for engaging with the world. However, the underlying process was different for chemical engineering graduates than for chemistry graduates. For example, whilst for Caroline, mentioned above, it was about breaking things; for Tanika, who was studying for a master's degree in chemical engineering, it was about the process of problem solving:

> *You've got a problem, you see how it's defined, how well or ill-defined it is. You see what the parameters are. You realise, 'Okay, this is the outcome and this is what we want,' so that's one fixed thing, and then you see, 'Okay, there are a lot of other variables that have an influence on this thing.' Then, you think of in terms of these variables, like, 'Okay, how can I manipulate all of this? What can I use? What tools do I have? What, what, what, what, what?' You start lining up all these things and then you start painting a picture in your mind. Then, that's where it continues, like, 'Okay, I will focus on, maybe, these variables,' because for whatever reason, in terms of environmental legislation or whatever, some of these are more important than others, or you try and optimise something but therefore you are at a disadvantage for another thing. So you start thinking about all the pros and cons, and then you start defining all this problem better. I think it's all about layering this problem until you've got a better defined problem. Then, from there, you take it further, I would say. Then, you use all the tools, knowledge and everything that you've got, take it further, and then in the end, you do this thing where you would, obviously, then come back to the original question and be like, 'Okay, to what extent have I answered all these questions? To what extent have I fulfilled the requirements?' So it's like a feedback loop constantly, I would say. Also, feedback with whomever you are doing this project for, feedback with your teammate. Yes, you try and take as much into consideration as you can.*
>
> (Tanika, Sodium, South Africa, Chemical Engineering, Year 7)

Robert, who was working in retail whilst applying for graduate positions, had a similar viewpoint that he used in his work in retail:

> *Yes. I feel like the whole system's view of thinking is something that's hard to kick after you've done the degree because you constantly ask yourself, 'Okay, what are the smaller parts of things and how does each unit make the whole?' Even at work, even when my job is just routine, I know what each part of the business or each part of the task I'm supposed to do feeds into the whole. A lot of my co-workers*

don't really see that. It's been useful. Currently our area manager, she's pregnant so they need someone to pick up the slack for her so that's kind of what I'm doing at the moment. I'm guessing I'm probably like her assistant or something. But it's like, 'Okay, now I see how each individual works,' so how much money each store will get or which store will make. Depending on that, which price stock gets sent were or which amount of stock which store gets, at what time they do because of different key times and stuff. It feeds in. I still see it a bit different. It's not like just random stuff happens. Everything is being done for a reason. It's to make the whole system work. But catering to each specific unit operation with its different needs instead of just feeding the same thing to each one because a lot of people think that's just how it works but it's not. There is a lot of random background work to make it work I guess.

(Robert, Europium, England, Chemical Engineering, Year 7)

Participant accounts that positioned them outside their subject knowledge

Eighteen of the graduates, five chemistry graduates and thirteen chemical engineering graduates, appeared to position themselves outside of the bodies of knowledge in which they had studied as undergraduates. We categorised their relationship to knowledge in this way because they talked about it as if it was something that was separate from them and their engagement with the world and rather than talking about their subject knowledge as if it had structure, they talked about it in terms of individual topics and pieces of knowledge.

For example, Kaylee, a chemistry graduate, was working as a scientist in her final interview, but still seemed to see the knowledge she had studied as if it was unconnected to the world. For example, when she is asked about what constitutes a scientific way of thinking, she gives an answer that does not engage with how the knowledge relates to the world:

Probably not very superstitious, because, if you question why things are happening, then you might just not take stuff at face value, maybe not the most religious or superstitious. … and liking to look things up a lot, probably. Like to back up what you're saying or what's your thinking, lots of Googling. (Laughter)

(Kaylee, Astatine, United States, Chemistry in combination with other subject(s), Year 6)

Similarly, in chemical engineering, graduates would talk about it in a way that suggested they were not using it as knowledge to engage with the world. For example, Nomathemba explains chemical engineering in a very general way:

> *I would describe it as, I guess, a big schedule. Engineering has a lot to do with numbers, like quantitative and practical aspects. So because of working with numbers, you would want to make sure something fits.*
>
> (Nomathemba, Samarium, South Africa, Chemical Engineering, Year 7)

The greater proportion of chemical engineering graduates who positioned themselves outside of knowledge compared to the chemistry graduates reflects the higher proportion of chemical engineering students who do not reach the threshold in the understanding of chemical engineering discussed in Chapter 4. This again seems to reflect the greater complexity of the combinations of knowledge involved in chemical engineering that we discussed in Chapter 3.

Participants' relationships to knowledge and employment situations in the final year of the study

Table 7.1 shows the relationship between participants' relationships to knowledge and their destinations in their final interview that we discussed in Chapter 6. There are two key issues to highlight from this table. First, that nearly all of the participants in non-graduate roles positioned themselves outside of the knowledge of their degree and, second, there were no participants positioned outside of knowledge who were in a graduate role outside the subject area they had studied.

Table 7.1 Participants' relationships to knowledge by their employment outcome in the final year of the study

	Employment outcome in their final interview in the study					
	Graduate role in subject area	**Graduate role outside subject area**	**Studying for a PhD**	**Studying postgraduate degree**	**Non-graduate role**	**Total**
Relationship to knowledge						
Inside	25	10	10	11	1	57
Outside	6	0	3	2	7	18
Total	31	10	13	13	8	75

It is this second issue that is particularly important as it highlights that those participants who were positioned inside of the bodies of knowledge that they studied appeared to have more flexibility about how they engaged with the world through that knowledge. For example, Jordana, a graduate of chemical engineering, and Kane, a biochemistry graduate, felt that the way of seeing they had gained in their undergraduate degrees was very useful in their postgraduate medical degrees:

> *I also had a bit of an advantage, coming from engineering, because there's a surprising amount of medicine that has to do with graphs and mathematics. I don't know I'd say the physics of the body but, like, how physics and chemistry intertwine in the body. Also, there are some statistics that you just have to know. So coming from an engineering background, where we not only did statistics but we also did a lot of practice understanding and reading graphs, made it a lot easier for me to go into med school.*
>
> (Jordana, Astatine, United States, Chemical Engineering, Year 6)

> *So everything seems to really be founded upon a basis of biochem. I feel like the degree definitely really helped me, even if not giving me the exact information I would be using, but by preparing me to think in a biochemical manner with regard to stuff, so I wouldn't be caught off guard, I guess.*
>
> (Kane, Astatine, United States, Chemistry in combination with other subject(s), Year 6)

Participants who were working in fields not directly related to their degrees could also see how their inside knowledge of their subject had helped them in their roles. For example, Donna was working in finance and saw how this relates to the way of engaging with the world that he gained through studying chemistry:

> *As I mentioned, working in big data as well. I did use data a lot in my undergraduate degree. So that is definitely relevant to what I am doing now. But now it is just on a much larger scale, being big data. Also in terms of, to an extent, experimentation, because in my undergraduate degree I did do experiments. And it is that approach of you have got something you want to test. You do the experiment. You see the results. You validate them. Even though what I am doing now is not exactly in a lab or using chemicals, it is a similar approach in terms of there is testing that needs to be done on different processes. You do need to look at the results, analyse them. And you need to validate them as well and provide evidence of that. And there are lots of different ways that you can present that evidence. In a report. In a presentation. Yeah, different formats. I think there is a lot from my undergraduate that I am using now, but it has just definitely been the breadth of it has opened. Also just the level and intensity has been a step up, in terms of the details and the*

skill that also comes with understanding the industry knowledge as well, which takes it up a level.

(Donna, Erbium, England, Chemistry in combination with other subject(s), Year 7)

Similarly, Raheemah was a business banking analyst but saw clear links to the way that studying chemical engineering had supported him to engage with the world:

I think chemical engineering centres around problem solving, and at work, that's what I do. I do solve problems, as in, we're given- There are so many different scenarios of what it could be, like tax evasion, money laundering, or where I have to investigate someone if they've come up in an article, or something. That does require problem solving, because I have to look at the numbers, which again, hones into the mathematical skills we learn in chemical engineering as well, because they're quite big numbers. Whilst we do have the software to investigate further, when doing initial reviews, my chemical engineering degree comes in useful then, because I'm quite efficient and I'm faster. Even though I'm quite new on the team, I can see that the way I've been taught in chemical engineering, I'm a bit faster than them, even though they've been there for years. So in that sense, I'm more efficient. Again, problem solving, because I have to use my analytical skills to determine whether or not something is fraudulent activity or not. Again, my report writing skills, as well, that I picked up during my time at university, because I then have to build a rationale and do a mini report on why I think something- Whether I discount it or whether I don't discount it, I have to give my thought process behind it.

(Raheemah, Europium, England, Chemical Engineering, Year 7)

Participants who positioned themselves outside of the bodies of knowledge they studied only seemed to be able to relate what they were doing now to specific course content or modules. For example, Danielle was working in a graduate role in compliance at a water company:

[I]n my undergraduate degree, I did do lessons on waste water treatment works and how they work. I just did a couple with my degree. So, that's been super-helpful, because I actually know, roughly, how they should work and what I'm looking at. I also find that, just in general, knowing a bit about data and how to manipulate it and stuff does help, because we do calculations for, like, limits and dry weather flows and stuff, and a lot of the maths side of it, and the data side of it.

(Danielle, Erbium, England, Chemistry in combination with other subject(s), Year 7)

Similarly, Arun was working as a systems engineer and related his current work to particular classes in his degree:

> *We had one class which is called process control which pertains to how different instruments and equipment are programmed in order to reach any operational goals, any industrial process we need to achieve. It was one part of our major in the coursework which kind of directly relates to what I'm doing now, which has to do with programming equipment and instruments in order to perform any industrial process. So that is one part of the overlap. I would say the other parts to my coursework are more indirectly related to the work in the sense that the science and the maths that was involved in those other courses is used in our client's operation.*
>
> (Arun, Argon, United States, Chemical Engineering, Year 7)

The important difference is that participants who saw the bodies of knowledge they had studied from the inside related the ways of engaging with the world they had gained to many different aspects of what they were doing whereas those who saw those bodies of knowledge from the outside would relate limited parts of the knowledge to limited aspects of what they were now doing. As in Chapter 6, it is important to be explicit that whilst we have evidence of a relationship between participants being inside knowledge and having an extended range of contexts in which that knowledge is relevant, we do not know the direction of that relationship. It is likely to be two-way, that graduates who see knowledge from the inside can see the relevance of their way of engaging with the world to a greater range of contexts, but also that graduates who experience a greater range of contexts are supported to see knowledge from the inside.

Clearly our findings are based on a small number of participants who engaged with the study over six or seven years. This means that it is not meaningful to discuss in detail the national, institutional and demographic differences in how participants saw knowledge. However, what is significant is that across all of our institutions, there were participants who saw the knowledge they had studied from the inside and those who saw it from the outside. Thus, there was no apparent relationship between elite education or education in particular countries and the extent to which participants appeared to see knowledge from the inside.

Equally important, for participants who saw knowledge from the inside, the subject they had studied appeared to shape the way they engaged with the world. Interestingly, there was not this difference in participants who saw knowledge from the outside. In both chemistry and chemical engineering, they talked about knowledge as a thing rather than as a way of engaging with the world.

The importance of the particularity of knowledge to educational accounts of graduateness

Our findings highlight that seeing knowledge from the inside and using this understanding to engage with the world is a key element of graduateness. Seeing knowledge from the inside appeared to support graduates to be successful in a wider range of roles and see meaningful relationships between more disparate jobs and what they had studied. Crucially, these ways of engaging with the world were different for chemistry and chemical engineering graduates despite the close relations in the development of these bodies of knowledge. These differences again highlight the importance of the discipline in giving meaning to any educational notion of graduateness (Bowden & Marton 1998; Jones 2009a, b; Case & Marshall 2016; Caspersen et al. 2017; Ashwin 2020; Winberg et al. 2020; Quinlan & Renninger 2022; Quinlan & Corbin 2023) and to recognise that this is different from the accounts offered by promotional (Bernstein & Osman 2012; Anderson 2017; Oliver & Jorre de St Jorre 2018; Wong et al. 2022), developmental (Bowden et al. 2000; Walker & McLean 2010, 2013) and accessible (Ryan 2024) accounts of graduateness.

This study found a relationship between graduates being in non-graduate roles and seeing the discipline from the outside. Whilst it was not possible to gain a sense of the direction of this relationship, the relationship is important. Either not engaging with the world from the perspective of their discipline had limited these participants' graduate activities or a lack of graduate employment opportunities meant that these graduates had not realised the potential of their discipline to support their engagement with the world. This highlights the importance of graduates finding a context that can support the development of their ways of engaging the world, which appears to be aligned with arguments that higher education needs to increasingly prepare graduates for a quality of life (Brown et al. 2020), a post-work or no-work future (Althorpe & Finneron-Burns 2024) and what it means to live a graduate life (Ingram et al. 2023).

Our findings highlight how being inside knowledge allowed graduates to see the relevance of and use their knowledge in a broader range of contexts than graduates who remained outside knowledge. Indeed, for graduates inside knowledge, knowledge became something different. Rather than being something external to the graduate; it became a way of engaging with the world. Thus, being inside knowledge gave graduates a sense of agency in how they used this knowledge that was absent from the accounts of graduates outside of this knowledge. It is noteworthy that the graduates who saw knowledge from the outside were much more aligned with the view of knowledge presented by human capital theory and those who engaged with the world from inside the body of knowledge much more aligned to the view of graduates relationship to knowledge as being a holistic personal relationship (Taylor 1993; Bowden & Marton 1998; Ashworth 2004; Dall'Alba & Barnacle 2005; Ashwin 2020). This aligns with critiques of the very limited view of education that is offered by human capital theory (Bernstein 2000; Allais 2012; Wheelahan & Moodie 2024) and importantly highlights the problem with the view of knowledge that informs human capital theory when seeking to understand educational outcomes.

The view of graduateness developed here shows how studying for an undergraduate degree has the potential to take students and graduates inside knowledge and change the way they understand themselves and engage with the world. It highlights how becoming a graduate is a knowledge-rich activity that depends on graduates moving inside knowledge. This reinforces the idea that this knowledge is the treasure of higher education (Watson 2014). It is knowledge understood, not as sets of facts, but as collective and structured bodies of knowledge that offer graduates a way of engaging with the world. This is crucial to rejecting the depressing narratives of 'overeducation' and highlighting how higher education contributes to democratic societies.

This way of understanding graduateness also highlights that it needs to be understood as something that continues to develop after students have graduated. The sense that graduates need a range of contexts to support them to move inside knowledge means that there is still an educational role for universities and employers to help graduates to move inside knowledge and learn what it means to engage with the world in this way.

Conclusion

In this chapter, we have argued for the importance of an educational way of understanding graduateness that shows how studying particular bodies of knowledge changes the ways in which graduates engage with the world. We showed how graduates who saw knowledge from the inside appeared to have more flexibility and more agency in their graduate destinations, and how what it meant to be inside knowledge was different for graduates of chemistry and chemical engineering graduates.

In the next and final chapter, we bring the book together as a whole and consider what it has shown about how to realize the educational potential of mass higher education.

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8

How Can We Realise the Educational Potential of Mass Higher Education?

Introduction

In this concluding chapter, we reflect on what this book might tell us about how to realise the educational potential of mass higher education, based on a seven-year longitudinal study of chemistry and chemical engineering students and graduates in England, South Africa and the United States. We argue that the key to realising the educational potential of mass higher education is to understand the way in which it takes students 'inside' bodies of knowledge that support them to see themselves and the world in different ways. This raises important questions about the dominance of the skills model of mass higher education that places students and graduates outside of knowledge and leaves them rooted to the contexts in which they have studied. Perhaps counter-intuitively, it is being focused on the particularity of bodies of knowledge that allows people to use this knowledge beyond the context in which they initially engaged with it.

We first summarise the argument of the book as it developed over the previous chapters. We then consider what this argument tells us about the educational potential of mass higher education and how this might inform how we respond to the disillusionment with mass higher education we discussed in Chapter 1. We then consider what the arguments in the book might mean for theorising and researching the educational potential of mass higher education. We conclude the book by considering the implications of its arguments for policy, for higher education institutions, and for educational practices.

Summary of the argument of the book

In Chapter 1, we set the book in the context of a disillusionment with mass higher education. We argued that this disillusionment, at least in part, comes from mass higher education making promises that it cannot possibly keep about the employability or the generic academic attributes that are offered through engagement with mass higher education. In different ways, promises about employability and promises about generic academic attributes lead to futures for mass higher education in which educational inequalities are increased, with students from poorer backgrounds increasingly being offered a very different kind of higher education than those from more privileged ones. We then set out how the study that underpins this book was designed to explore whether focusing on the ways that students are introduced to particular bodies of knowledge offers a way of understanding the educational potential of mass higher education.

In Chapter 2, we showed how higher education in England, South Africa and the United States provided a revealing set of contexts in which to examine mass higher education through the chemistry and chemical engineering undergraduate degrees offered by six universities. We did this by examining the distributive rules in terms of '*who may transmit what to whom, and under what conditions*' (Bernstein 1990, p. 183) in the respective national contexts. We explored the similarities and differences between these three countries and their higher education systems.

In Chapter 3, we examined the different forms of chemistry and chemical engineering offered by the six universities in our study from the perspective of the recontextualising rules of the pedagogic device. We argued that in chemistry, the degree programmes varied according to whether they offered an elite or inclusive form of chemistry. In chemical engineering, there was a greater diversity of approaches because of the way that, as a region, it is focused on the external world and needed to be responsive to a greater range of contextual variation. We argued that there were clear differences in what the programmes in the different subjects were seeking to achieve and the educational intentions of programme leaders. The chemistry degrees focused on preparing students to engage with a world created by chemistry, whereas chemical engineering focused on helping students to engage with an external and complex world.

In Chapter 4, we focused on the evaluative rules of the pedagogic device and particularly on how students recognised the subject matter of their degrees. We argued that whilst most students initially studied chemistry and chemical engineering for instrumental reasons, by the end of their degrees, most students had a transformational relationship to the knowledge that they studied in their degree. These patterns were very similar across all of our institutions and countries. We also found that it was not the case that some students in our sample were instrumentally focused whereas others were focused on transformation. Rather, it was students' understanding of the context they were in that evoked an instrumental or transformative response. This highlighted that what was important was that students understood that the educational context of studying for their degree programme required a transformational approach. Where students did not see their degree programme in this way, they were more likely to become disengaged and see their degree as irrelevant.

Whilst Chapter 4 examined the extent to which students focused on the knowledge of their degree programmes, Chapter 5 explored how students understood this knowledge by examining the ways in which they recognised chemistry or chemical engineering. In this way, we examined the realisation rules of knowledge-as-student-understanding. We found that chemistry students understood the world from the perspective of their subject differently from chemical engineering students. These differences show how the study of different subjects at university led to students engaging with the world in different ways. This supports a view of mass higher education in terms of different students being introduced to different ways of engaging with the world depending on the subjects that they have studied. Importantly, students who took an instrumental view of studying their subject were less likely than students who took a transformational view of their education to develop ways of engaging with the world informed by the knowledge of their subject.

In Chapter 6, we examined how our participants, when they were graduates, reflected on the benefits of their degrees at the end of the study. We found that, at the end of their undergraduate degrees, most graduates highlighted the importance of the way of engaging with the world they gained from studying their subjects. We also found that graduates who focused on the ways of engaging with the world they had gained from their degrees tended to be more likely to be in graduate jobs or studying for postgraduate degrees. Graduates who were more instrumentally focused were more likely to be in non-graduate jobs. Our analysis suggests that this is related to both the way in which they understood their degree but also the opportunities they had after graduation to understand how their subject supported their engagement with the world. This highlights that employability is best understood as an ongoing process rather than an attribute of graduates.

In Chapter 7, we examined in more depth what it meant for graduates to be focused on the ways of engaging with the world that they had gained from studying their degrees. We found that these graduates saw knowledge from the inside and that this was what supported them to use this knowledge as a way of engaging with the world. These graduates appeared to have the greatest flexibility in how they could use knowledge, whereas graduates who saw knowledge from the outside were either rooted to a context directly related to their degree or in a non-graduate employment. In the same way as Chapter 5, the ways in which chemistry graduates used the knowledge from their degrees to engage with the world were different to those of the chemical engineering graduates. As with Chapter 6, seeing knowledge from the inside depended on both the way that graduates understood their education and the opportunities they had experienced to see their knowledge from the inside after graduation. This highlighted how, like employability, graduateness is an ongoing achievement and graduates need contexts that support them to continue to develop their ways of seeing knowledge from the inside.

Seven lessons about the educational potential of mass higher education

The outcomes from the chapters of this book highlight that the educational potential of mass higher education lies in the ways that it brings students into a relationship with bodies of knowledge that change their way of engaging with the world. This involves taking students' inside knowledge so that they can understand how it is relevant for their engagement with the world. Graduates need contexts that support them to further explore these ways of engaging with the world. This tells us seven things about the educational potential of mass higher education.

First, it highlights the centrality to mass higher education of bringing students into a relationship with structured bodies of knowledge. It is these relationships that take students inside bodies of knowledge and support them in developing ways of engaging with the world. This does not mean that the degree programmes need to be focused only on single bodies of knowledge, as in our study, we found this was as important in chemical engineering, which involved recontextualising a number of bodies of knowledge together, as it was in the singular discipline of chemistry.

Second, for students to develop these relationships with structured bodies of knowledge, they need to understand their study of their subjects as an educational process. If they see their study of their degree only in instrumental terms, they are less likely to develop such relationships and to see these bodies of knowledge from the inside.

Third, seeing knowledge from the inside and engaging with the world from the perspective of these bodies of knowledge is an ongoing process that continues after graduation. Thus, to realise the educational potential of mass higher education also requires that graduates have access to contexts where they continue to develop their relationships with these bodies of knowledge. This way of understanding the relationships that students develop with knowledge is based on an understanding that students interpret these bodies of knowledge in different ways. All students and graduates are part of an ongoing relationship with these bodies of knowledge in which their personal understanding of their meaning shifts as they move between contexts and develop further understanding. This is how bodies of knowledge change over time, but it is also why considering what contexts graduates are able to access to continue their relationships with these bodies of knowledge after graduation is important. More privileged graduates are more likely to have networks that support them to access such contexts, which again highlights the close relationships between social and educational inequalities. Addressing such inequalities is very difficult and will require finding imaginative ways of offering all graduates opportunities to continue their relationships with the bodies of knowledge they have engaged with in higher education.

Fourth, students who do not understand their degrees in educational terms and do not see knowledge from the inside are more likely to become disengaged from their studies and to see their subject as irrelevant. This suggests that there are limitations to what mass higher education can achieve. Whilst it can be effective at supporting students to develop ways of engaging with the world based on their engagement with structured bodies of knowledge, it is not clear that it is effective for students who engage with it in instrumental ways. To be clear, this is not to suggest that it is the students' fault for being instrumental. As we found, most students in our study started their degrees being focused on instrumental reasons for pursuing the degree. However, a key part of the educational relationship is that students are supported to understand that their education is about engaging with bodies of knowledge. It is part of the responsibility of educators and educational institutions to develop educational contexts that support students to do this.

Fifth, whilst some students appeared to become disengaged from their education, across the inclusive and elite institutions and the different countries in our study, students from all backgrounds did develop relationships with structured bodies of knowledge that took them inside that knowledge and supported them to develop ways of engaging with the world. This suggests that developing such relationships to knowledge is an achievable and realistic educational intention for mass higher education.

Sixth, whilst most students in our study developed ways of engaging with the world by going inside the bodies of knowledge they studied, these ways of engaging with the world were different for students who studied chemistry than for students who studied chemical engineering. These differences reflected the differences in the curricula in these two subject areas and the educational intentions of their programme leaders. These differences were still clear after these students became graduates and entered the world of work. This suggests that different subjects and disciplines produce graduates who engage with the world in different ways. Rather than prompting us to question what kind of graduates we want, the rich variation in ways of engaging with the world that is offered by having graduates from a wide range of subjects and disciplines is precisely what is valuable about mass higher education. All of these ways of understanding the world are powerful and limited, and we gain the best chance of understanding the world by having lots of different perspectives to draw on.

Seventh, this highlights what the educational philosopher Gert Biesta calls 'the beautiful risk of education' (Biesta 2013). Whilst the bodies of knowledge that students gain access to are powerful, education itself is very delicate. This is illustrated by the self-defeating nature of students seeing their education in instrumental ways. If students see their education instrumentally, they do not go inside that knowledge, and they experience disengagement with their education and consider it a waste of time. They are entirely correct in this perception. Unless students are prepared to go inside knowledge and develop a way of engaging with the world, then they *are* mostly wasting their time. As Biesta (2013) argues, the educational way is the slow and difficult way, but it is the only way of going inside these bodies of knowledge and benefitting from the power this knowledge has for engaging with the world. This highlights that education cannot transform students on its own. It can be part of a transformation by giving students access to powerful bodies of knowledge that they can use to engage with the world. However, students have to be open to changing their ways of engaging with the world, and, for this change to be sustained, graduates need continuing opportunities to extend their engagement with this knowledge.

In a way, these insights are bordering on the obvious. The fact that it needs stating that mass higher education is about the structured bodies of knowledge that students study shows how far it has lost its way through the dominance of the language of human capital and employability. The importance of being taken inside knowledge through higher education may also explain the polarisation between advocates and critics of mass higher education that we discussed in Chapter 1. If we understand that higher education is about these structured bodies of knowledge, then we can appreciate its delicate beauty. However, if we think it is about more instrumental achievements, then it will seem incredibly obvious that it is an expensive waste of time for individuals and societies. This means that advocates for mass higher education need to be more confident and articulate in explaining the importance of these structured bodies of knowledge in the face of questions about their relevance from those who do not understand their relevance or appreciate their delicate beauty. The cruel irony is that many of those who argue that the poor should be shut out from an education that takes them inside knowledge are those whose privilege allowed them such access but appear to have forgotten what was important about their own education.

Overall, these lessons suggest that to realise the educational potential of mass higher education requires degree programmes that are focused on taking students inside structured bodies of knowledge and institutions that are focused on developing curricula that harness the power of these three-dimensional bodies of knowledge. It also requires structures in society that support graduates to continue to develop their relationships with these bodies of knowledge.

How should we respond to the disillusionment with mass higher education?

So how might these lessons about the educational potential of mass higher education inform our response to the disillusionment with it? There are two ways in which it might inform our response.

First, it suggests that our response needs to be based on a more honest advocacy of the educational potential of mass higher education. In particular, rather than suggesting that mass higher education makes a direct contribution to employability, the response needs to be clear about the ways in which employability is connected to students' engagement with particular bodies of knowledge. This is because the general focus on employability leads higher education into a doom spiral of disillusionment. This doom spiral forms as more people go to university, and higher education is increasingly seen as about the development of human capital. The more higher education is about the development of human capital, the more pressure there is on degree programmes to focus on equipping students with the skills they need to succeed rather than introducing students to particular bodies of knowledge that can change the ways that they engage with the world. The more these degree programmes focus on skills and move away from knowledge, the more disengaged students are likely to become and the more they will see their education as irrelevant. This will add to the undermining of mass higher education and generate even louder calls to make it relevant to the labour market, and so the doom spiral accelerates.

Second, this highlights that the move to justify mass higher education in terms of the generic outcomes from higher education is a move in the completely wrong direction. It is important to be clear that the move to generic approaches to higher education will not be for everyone; as Trow (1973) emphasised, different forms of higher education exist alongside each other. Whilst the socially privileged will have access to elite higher education that is focused on structured bodies of knowledge, the less privileged will be given access to generic education that is criticised for overeducating. This will serve to exacerbate and justify growing inequalities, as the differences in the kinds of education that the privileged and less privileged have access to will serve to reinforce the sense that the privileged deserve their privilege.

Thus, we have two potential futures for mass higher education. One future gives all students access to an education that offers them access to structured bodies of knowledge. The other future is more in line with Trow's (1973) dream of higher education, in which different students have access to very different kinds of higher education. What the analysis in this book highlights is that Trow's (1973) vision is, in fact, an elitist nightmare in which educational inequalities are increased by differential access to structured bodies of knowledge. Aspects of this nightmare are already a reality with those with fewer resources and less knowledge of the higher education system getting into eye-watering debt for very low-quality higher education (Mettler 2014).

So, in response to the disillusionment with mass higher education, we need to emphasise that its educational potential lies in bringing students into relationship with structured bodies of knowledge rather than being tempted to make claims about how it can contribute directly to employability.

What does this book tell us about the theory of the pedagogic device?

We have seen in this book how the knowledge of chemistry and chemical engineering is recontextualised into curricula and the educational intentions of programme leaders and how they are recognised and realised by students through the course of their undergraduate degrees. We examined how graduates then made this knowledge their own after they had graduated. Crucially, it is clear that the way in which students and graduates engage with the world on the basis of chemistry is different to the way students and graduates engage with the world on the basis of chemical engineering.

These differences reflect the differences that Bernstein (2000) identified between chemistry as a singular and chemical engineering as a region. Bernstein (2000) argued that singulars construct identities through introjection, whilst regions construct identities through projection. This was reflected in Chapter 3, where we contrasted the ways in which the chemistry curriculum was focused on producing an account of a world seen from the perspective of chemistry, whereas the chemical engineering curriculum prepared students to focus on engaging with a complex and external world as a chemical engineer. We found these differences also reflected in the accounts that students and graduates gave on their relations to knowledge in chemistry and chemical engineering.

However, in common with the study of sociology (McLean et al. 2018), we did not find the differences that Bernstein (2000) predicted would exist between the forms of knowledge realised by students in elite and inclusive educational settings. Partly this difference is related to the way that Bernstein's (1990, 2000) work and this study approach the pedagogic device from different ends. Bernstein (1990, 2000) was focused on the system of knowledge, whereas our data was focused on students' experiences of engaging with knowledge. Bernstein (1990, p. 6) recognised that his work was focused on the systemic level and argued that '*the system does not create copper-etched plates*'.

What our study shows is that there is something special about students' engagement with structured bodies of knowledge that appears to have the potential to overcome some of the structural barriers in the field of knowledge. It is important to remember that our study was based in three countries where human capital theory has played a key role in positioning education as an instrument for the achievement of economic goals (Bernstein 2000; Allais 2012, 2014; Biesta 2022; Wheelahan & Moodie 2024). Indeed, nearly all of the participants initially had instrumental reasons for studying in higher education. Yet by the end of their degree, what they valued most was the ways of engaging with the world that they had gained from their degrees, and they continued to value this as graduates. This happened, as shown by our analysis of the curricula of the degree programmes in our study, because they were studying programmes that focused on knowledge-rich versions of chemistry and chemical engineering.

Equally, our interviews with programme leaders showed how much care had been taken in working out how to give all students access to the bodies of knowledge focused on in the programmes. It is this kind of mass higher education that can achieve its educational potential.

In this way our study, in a similar way to the studies of sociology (Abbas and McLean 2010; Ashwin et al. 2012; McLean et al. 2018), shows that curricula focused around bodies of knowledge and taught by teaching staff who are committed to finding a way of giving students access to this knowledge can overcome differences in the prestige of institutions. This is crucial in addressing educational inequalities, given the way that socially privileged students are much more likely to gain access to prestigious universities (Marginson 2018; Ashwin 2020). This again highlights the importance of mass higher education being focused on giving students access to structured bodies of knowledge rather than becoming fixated on empty generic skills, as well as finding contexts in which all graduates are offered the opportunity to continue their relationship with the bodies of knowledge they have studied.

What does this book tell us about researching students' experiences of mass higher education?

Our seven-year study of students' experiences of mass higher education in England, South Africa and the United States has some important implications for future research in this area. First, it shows the value of longitudinal studies. In talking to the same participants over six or seven years, we gained a rich sense of how their views changed over time. There were so many times when our participants went in directions that we had not expected. Participants with very clear ideas of what they wanted to do in the future as a career sometimes discovered they really did not enjoy it when given the opportunity. Participants who described themselves as deeply committed to their subject sometimes later told us they had realised they had only chosen to study it to make their families happy. This was not a case of our participants being insincere. It was a case of their understanding of themselves and their lives changing over time.

Second, and relatedly, our study shows how much what students and graduates tell us about their past experiences is shaped by what they are doing and how they are feeling at that moment. As those past experiences are evoked, they are reinterpreted in terms of the present. Thus, when graduates talk about the quality of their undergraduate education, this is reinterpreted according to how well they feel things are going for them at the moment they are talking.

It is important to see the potential that this process has for reinforcing the dominance of elite education. As those with an elite education are more likely to be successful based on the prestige of that education (Chetty et al. 2017; Clotfelter 2017; Friedman & Laurison 2019; Wildschut et al. 2020; Fryer 2022), their success then reinforces their sense that their education was of a higher quality than those from a less prestigious but more inclusive higher education.

Third, our research highlights how important it is to be sensitive to the contexts that have been evoked when asking students and graduates about how they see the purposes and value of their higher education. Our findings were very clear that students and graduates tended to move between talking about their education in instrumental and transformational terms depending on the context that was evoked.

These first three points highlight how cautious we should be about studies based on single interviews with students or the completion of a succession of tick boxes on a survey. They may tell us something useful about how participants feel at a particular moment and in relation to the context that has been evoked, but as researchers, we have to be really careful not to put a lot of weight on these, particularly through claiming they can give us access to the fundamental causes of students' behaviours or achievements.

Finally, our study highlights that if we are to understand what higher education does educationally, then we need studies based in particular disciplines or interdisciplinary areas, such as those undertaken in Disciplinary-Based Educational Research (Talanquer 2014; Henderson et al. 2017) and disciplinary-focused Scholarship of Teaching and Learning (Booth & Woollacott 2018). This book has highlighted the very different ways that students engaged with the world, having studied chemistry compared to students who studied chemical engineering. This is not surprising as education involves bringing students into a relationship with particular bodies of knowledge. However, it is very often forgotten in multi-subject research studies. The effect that this has is to totally obscure the different ways that knowledge works in different disciplines, which has the unintended consequence of concealing a significant part of the educational process.

Implications for developing educational practices in higher education

The way in which education is focused on giving particular students access to particular bodies of knowledge is often also obscured in approaches to developing educational practices in higher education. However, as we have shown in this book, the structure of the bodies of knowledge that students gain access to, what Bernstein (2000) refers to as their vertical discourse, is central to the way that it supports students and graduates to develop ways of engaging with the world and to question their existing and new ways of understanding (Barrett 2024).

What this book has highlighted is that the educational challenge facing mass higher education is to support students to go inside the structured bodies of knowledge they are studying so that they can use them to inform their engagement with the world. As we have seen, this is something that happens already, but often the ways of framing educational development obscure this educational task. In particular, notions of 'best practice' and 'what works' imply that there is a single set of educational practices that will work, whatever the body of knowledge and whomever the student may be (Horrod 2023). This again is an inappropriately strong way of framing the weakness of education (Biesta 2013) because what works and what is best depends on the starting point of the students and the bodies of knowledge that they are being supported to go inside.

This focus on how to support students to go inside particular bodies of knowledge highlights the importance of the design of the curriculum in facilitating this engagement. We saw in the accounts of our programme leaders how the design of their curricula was based on a rich sense of both who their students were, what was important in the bodies of knowledge of chemistry or chemical engineering, and who they expected their students to become. Within educational development, the focus is too often on developing teachers or teaching rather than developing curriculum that supports students' engagement with particular bodies of knowledge (Ashwin 2020, 2022a).

This does not mean that academics and teachers from different disciplines and subjects cannot learn from each other. Rather, it highlights the importance of being clear about the way in which who students are, what the knowledge is, and where students are going will change what educational practices are effective in a particular setting. This highlights the need for educators to have space and time to consider how innovative educational practices might fit with their local setting (Ashwin et al. 2020).

Implications for higher education institutions

For higher education institutions, this book highlights the importance of supporting conversations about how students are supported to go inside particular bodies of knowledge, as discussed in the previous section. However, equally important are the implications for the ways that higher education institutions talk about what they do to wider society, including prospective students, local communities, employers, and policy makers.

As we highlighted earlier, part of the disillusionment with mass higher education is not just because higher education institutions have overpromised what higher education can do, but also because they have made the wrong kind of promises. In line with David Watson's (2014) higher education oath that we discussed in Chapter 1, in order to keep their promises, higher education institutions need to be more honest and modest about the power of mass higher education. Rather than making unconvincing claims about developing generic graduate attributes or employability capabilities that are unconnected to the bodies of knowledge that students have studied, they need to base their claims on the ways that they take students inside bodies of knowledge. They also need to acknowledge that graduates need to have access to supportive contexts in which to make use of their ways of engaging with the world, rather than pretending they can somehow transcend the societies of which they are part. This also means not always assuming that 'more higher education' is always the answer to any question about how education can support the economy.

In a world beguiled by the unrealistic promises of GenAI and learning technologies, it takes a great deal of confidence and nerve for universities to modestly assert the power of producing graduates who engage with structured bodies of knowledge (Blackie & Luckett 2024). However, in Watson's (2014) terms, it is an essential part of looking after the treasure of higher education and being trustworthy stewards of the collective bodies of knowledge that they sustain for society. Part of this involves recognising that what is key to realising the educational potential of mass higher education is not the institutional form of 'the University'. Indeed, this institutional form creates barriers as well as opportunities for people to engage with knowledge (Watson 2015; Ashwin 2022b). What is key is the systematic and sustained way that higher education brings people into a relationship with knowledge. This programmatic approach can be achieved in online as well as face-to-face environments, but is something that requires careful design and clear educational intentions by teachers with a deep, personal understanding of the ways in which this knowledge is structured, working with students who engage with knowledge over an extended period of time (Ashwin 2022a).

Implications for policy makers

For policy makers, the implications of this book are to understand the power of mass higher education, to understand the conditions that are needed to realise its potential, but also to be clear about its limitations.

As we have argued through this chapter, the educational potential of mass higher education lies in the ways that it provides students with access to structured bodies of knowledge that help them to develop flexible ways of engaging with the world. This is higher education's treasure that can greatly benefit society. It is impossible for anyone, let alone policy makers who are attempting to address urgent social issues, to understand the structure of all the bodies of knowledge that are offered through mass higher education. However, it is crucial to have a sense of what these bodies of knowledge entail. They are not the single, coherent, authoritative, flat and fixed pieces of knowledge so beloved of policy makers (Young & Muller 2016; Yandell 2017; Craske 2021). They are bodies of knowledge that have a structure and are transformed as they are recontexualised into curricula and changed again when students engage with them (Bernstein 2000; Ashwin 2014). This has three important implications for policy makers.

First, giving students access to these structured bodies of knowledge is dependent on the programmatic nature of higher education. Whilst, as we argued, it does not depend necessarily on the institutional form of the university, it does depend on the expertise of the teachers who are deeply and scholarly engaged with the bodies of knowledge they are seeking to give students access to. Equally, it is dependent on students being engaged with these bodies of knowledge over an extended period. Whilst it may be possible to move beyond the institutional form of the university, it still needs educational institutions to create the conditions in which this can happen. It cannot be offered through the stacking of micro-credentials (Wheelahan & Moody 2022, 2024; Ljungqvist & Sonesson 2023). These may be very useful for those who already have studied a degree and have experience of seeing knowledge from the inside, but it is difficult to see how this can provide access to knowledge-rich higher education for those without undergraduate degrees.

Second, policy makers need to understand that what counts as a good higher education varies according to the bodies of knowledge and the students involved. Demanding that higher education identify 'what works' or 'best practice' cannot improve the quality of mass higher education. It is much more likely to encourage unreflective and un-educational approaches to education as reflected in generic graduate attributes, in which generic skills are meaninglessly claimed to be generated by all and any degree programmes, regardless of who studies them or the forms of knowledge that are studied.

This last point highlights that trying to make education strong, secure, predictable and risk-free by reducing the complexity and openness of education is inevitably self-defeating because it makes education un-educational. As Biesta (2013) argued, education's power comes from its weakness.

Conclusion

In this book, we have explored what is needed to realise the educational potential of mass higher education by drawing on a seven-year longitudinal study of participants who studied chemistry and chemical engineering in England, South Africa and the United States. Our question was essentially focused on what is needed for mass higher education to be educative. We have argued that an important way of realising its potential is to focus on introducing students to structured bodies of knowledge that change their understanding of the world and themselves and the ways in which they engage with the world. Its educational potential is not always fully realised and, as there always have been, there will be people who do not benefit from what is offered either because of their educational experiences or because of a lack of opportunities to extend their engagement with knowledge after graduation. However, we have shown the educational potential of mass higher education in offering students opportunities for sustained engagement with bodies of knowledge that transform their understanding of the world and what they can do in it.

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Appendix 1: Methodological Appendix

This book is based on two Centre for Global Higher Education (CGHE) projects: 'Understanding Knowledge, Curriculum and Student Agency' (UKSA) and 'Graduate Experiences of Employability and Knowledge' (GEEK), which were funded by the Economic and Social Research Council and Research England (grant references: ES/M010082/1, ES/M010082/2 and ES/T014768/1) and the National Research Foundation, South Africa (grant reference: 105856). The data from the projects have been deposited with the UK Data Service.

Together, the UKSA and GEEK projects formed a single seven-year longitudinal study of participants who studied undergraduate degrees in chemistry and chemical engineering in two universities in England, two universities in South Africa and two universities in the United States. The methodology of this study owed a considerable debt to a previous project examining sociology (see McLean et al. 2018).

All institutions and participants were anonymised in line with the ethical approval granted by the lead institution in the research (reference numbers FL15035 and FL20056). The universities were given pseudonyms (using the names of chemical elements). These were:

- England – Erbium University and Europium University
- South Africa – Samarium University and Sodium University
- USA – Argon University and Astatine University.

In the UK and South Africa, the study tracked participants for up to seven years in total from their first undergraduate year of study to up to four years after graduation depending on the length of their degree and the time it took them to complete it. In the United States, the study started a year later and therefore tracked participants for up to six years from their first undergraduate year. Table A1.1 sets out all of the sources of data from the study.

In this book, we do not draw equally upon all the data that we generated and have analysed. We do not refer directly to the data sources listed in italics in Table A1.1. In this Appendix, we focus on discussing the generation and analysis of the data sources that are used in the book. However, the findings and the perspective we present in the book are based upon our collective engagement

Table A1.1 List of analysed data sets and the chapters where they were drawn upon

Data set	Chapters where these data are drawn upon
Analysis of professional accreditation documents, curriculum, departmental and institutional documents.	Chapters 2 and 3
12 interviews with Programme Leaders (10 hours of interviews)	Chapter 3
706 interviews with student/graduate participants (over 600 hours of interviews)	Chapters 4, 5, 6, 7
178 student assignments	*Not drawn upon directly in this book*
32 video recordings of teaching in the six universities	*Not drawn upon directly in this book*
Semi-structured interviews with 36 seminar teachers about the videoed seminars (over 35 hours of interviews)	*Not drawn upon directly in this book*

with the whole dataset over a sustained period. While the fieldwork and initial analysis took place from September 2016 to April 2024, we have continued working with the data through publishing and presenting the outcomes of the study in journal articles, conference papers and in two PhD theses based on the study. These are outlined in Appendix 2.

Analysis of professional accreditation documents, programme handbooks and institutional strategy documents

We collected and analysed the professional accreditation documents for each of the programmes, the programme handbooks and webpages, and institutional research and teaching strategies. In the case of documents relating to the programmes, in our analysis we were focused on the way that students and the world were positioned in the documents and the way in which the subject was positioned as mediating the relationship between students and the world. In the case of the institutional strategy documents, we analysed the extent to which the research strategies focused on having an impact globally or were focused on developing excellent research. We analysed the educational strategies in terms of whether they were focused on educating the brightest and the best students or focused on opening up access to education to all who might benefit.

Programme leader interviews

We interviewed the programme leaders towards the end of the UKSA project, between November 2021 and June 2022. The interviews lasted between sixty and ninety minutes and questioned programme leaders about the student outcomes they were trying to achieve in their chemistry or chemical engineering degrees and the processes by which they attempted to achieve these outcomes. We analysed the interviews by identifying the characteristics of the chemists or chemical engineers each programme was trying to produce and considered the similarities and differences between the programmes in order to group them.

Student and graduate participants

Each year of the study, we undertook semi-structured interviews with the student/graduate participants who were studying chemistry or chemical engineering. Tables A1.2, A1.3 and A1.4 set out the number of participants involved in different stages of the study. When the participants were in their first undergraduate year, we interviewed 208 participants in total as shown in Table A1.2. We aimed to recruit an equal proportion of male and female participants across each subject in each discipline. There were some cases, for example chemical engineering at Erbium, where this was not possible due to the low number of women studying the course. However, across the study, we did achieve a fairly equal distribution across the sample as a whole and within the two subject areas. Whilst all of the participants who were studying chemical engineering were studying chemical engineering degrees, some of the participants studying chemistry did so in combination with other subjects, including joint degrees in chemistry, degrees in biochemistry and degrees that involved a combination of sciences, including chemistry.

While we invited participants to self-identify their gender and their ethnicity, we have not included ethnicity in the tables. Due to the different ways of categorising ethnicity in the three countries, we were not able to develop categories that were meaningful across all of our sites. We attempted as far as possible to reflect the diversity of the programmes in the students we interviewed and gave them pseudonyms that reflected their self-identified ethnicity.

After the first undergraduate year, we aimed to interview ten participants studying chemistry and ten participants studying chemical engineering in each institution (120 in total) although we did include additional participants if they

Table A1.2 Number of participants interviewed in their first undergraduate year by country, institution, subject and gender

Country (total)	Institution	Chemistry						Chemical engineering			Total		
		Chemistry			Chemistry in combination with other subject(s)								
		All	♀	♂	**All**	♀	♂	**All**	♀	♂	**All**	♀	♂
USA (66)	Argon	**14**	7	7	**8**	6	2	**15**	5	10	**37**	18	19
	Astatine	**6**	4	2	**8**	5	3	**15**	10	5	**29**	19	10
England (65)	Erbium	**8**	5	3	**6**	4	2	**16**	1	15	**30**	10	20
	Europium	**13**	4	9	**4**	2	2	**18**	11	7	**35**	17	18
South Africa (77)	Samarium	**1**	0	1	**19**	7	12	**24**	11	13	**44**	18	26
	Sodium	**5**	3	2	**14**	11	3	**14**	11	3	**33**	25	8
	Total	**47**	23	24	**59**	35	24	**102**	49	53	**208**	107	101

Table A1.3 Number of participants involved in the study at the end of their undergraduate degree by country, institution, subject and gender

Country (total)	Institution	Chemistry						Chemical engineering			Total		
		Chemistry			Chemistry in combination with other subject(s)								
		All	♀	♂	**All**	♀	♂	**All**	♀	♂	**All**	♀	♂
USA (20)	Argon	**3**	3	0	**1**	1	0	**6**	3	3	**10**	9	1
	Astatine	**2**	2	0	**5**	3	2	**3**	3	0	**10**	8	2
England (41)	Erbium	**7**	4	3	**4**	2	2	**11**	1	10	**22**	7	15
	Europium	**10**	2	8	**0**	0	0	**9**	6	3	**19**	8	11
South Africa (34)	Samarium	**1**	0	1	**6**	2	4	**10**	5	5	**17**	7	10
	Sodium	**4**	2	2	**4**	3	1	**9**	7	2	**17**	12	5
	Total	**27**	13	14	**20**	11	9	**48**	25	23	**95**	49	46

Table A1.4 Number of participants interviewed in the penultimate or final year of the study by country, institution, subject and gender

Country (total)	Institution	Chemistry						Chemical engineering			Total		
		Chemistry			Chemistry in combination with other subject(s)								
		All	♀	♂	**All**	♀	♂	**All**	♀	♂	**All**	♀	♂
USA (16)	Argon	**3**	3	0	**1**	1	0	**4**	1	3	**8**	5	3
	Astatine	**1**	1	0	**5**	3	2	**2**	2	0	**8**	6	2
England (31)	Erbium	**6**	3	3	**3**	2	1	**9**	1	8	**18**	6	12
	Europium	**10**	2	8	**0**	0	0	**6**	4	2	**16**	6	10
South Africa (24)	Samarium	**1**	0	1	**4**	2	2	**6**	3	3	**11**	5	6
	Sodium	**3**	3	0	**4**	2	2	**7**	5	2	**14**	10	4
	Total	**24**	12	12	**17**	10	7	**34**	16	18	**75**	38	37

requested to stay in the study. Table A1.3 sets out how many were still involved in the study by their final undergraduate year. At this stage of the study, participant attrition was highest in the US institutions.

Table A1.4 shows the number of participants involved in the final two years of the study, by which time most of them were graduates. Between participants' final undergraduate year and the final two years of the study which followed them post-graduation, attrition was highest in the South African institutions.

Participant interviews

The yearly interviews with the participants normally lasted between forty-five and ninety minutes. During the years when participants were engaged in their undergraduate studies, the interviews followed a common protocol with questions covering students' background, route into university, study practices, understanding of disciplinary knowledge, assessment experiences, views on diversity, their future aspirations and their overall rating of their university experience. Once they had completed their undergraduate studies, participants were asked about their current situation and experiences of working or postgraduate study, as well as their future aspirations. They were also asked to reflect upon their undergraduate experiences covering the same areas as the interviews when they were undergraduates.

Interviews were initially conducted in-person on the university campuses. However, during the Covid-19 pandemic, interviews were moved online using Microsoft Teams. As the participants had become comfortable in this online setting, the interviews remained online for the rest of the study. This greatly assisted the retention of participants in the study after they had graduated.

Table A1.5 Total number of interviews participated in by participants.

Total number of interviews participated in	Number of participants
1	90
2	21
3	9
4	12
5	6
6	21
7	49

In total, we conducted 706 interviews that lasted over 600 hours. Table A1.5 sets out the total number of interviews participants were involved in. In some cases, participants would miss an interview for one year and then return to the project.

Data analysis

In analysing the participant interview data, we initially categorised the interviews in terms of:

- How the participants presented themselves in terms of their paths into higher education, their current experiences and who they wanted to be in the future;
- The participants' reflections on their experiences of studying in terms of their experiences in their course, their experiences of assessment and their experiences of their discipline.
- The participants' reflections on their wider experiences, including of their university, finance and diversity.

We used these initial analyses to undertake further exploration of the data. In the book, we focus on three of these: participants' accounts of chemistry and chemical engineering, participants' reasons for studying and what they gained from studying and going to university, and participants' accounts of the knowledge they had studied after graduating.

Participants' accounts of chemistry and chemical engineering

In order to analyse participants' accounts of chemistry and chemical engineering, we adopted a phenomenographic approach (Marton & Booth 1997; Åkerlind 2025). Phenomenography is a way of analysing data that seeks to capture the variation in the way that a group of people experience a phenomenon. Rather than applying theory to the data or using *a priori* categories to structure the analysis, a phenomenographic approach seeks to establish all the different ways of seeing that phenomenon that are expressed in the data and to place them in a logical and inclusive hierarchical structure (Marton & Booth 1997; Åkerlind 2025). It should be noted that the outcomes from phenomenographic studies are based on the variation across all of the interview transcripts rather than a categorisation of each individual in the study (Marton & Booth 1997; Åkerlind 2025).

The analysis focused on the qualitative variation in the ways in which the participants described their understanding of chemistry or chemical engineering as a subject. Initially, we worked individually to identify all of the different ways of understanding chemistry/chemical engineering that could be identified across the transcripts. We then worked collectively to explore which of the different ways of understanding chemistry/chemical engineering appeared to be qualitatively different and what the logical relations were between these qualitatively different accounts of chemistry.

The process led to the forming of 'categories of description' that expressed the qualitative variation between the different accounts of chemistry in an inclusive hierarchy, in which the later categories of description include the earlier categories (Marton & Booth 1997; Åkerlind 2025). In line with the inclusive structure of the hierarchy, any one interview may contain more than one of the categories of description constituted in this study. To reflect this, we discuss participants' accounts in terms of their alignment with each category of description rather than suggesting their accounts 'contain' different categories of description.

Within a phenomenographic approach, the claim being made about the outcome space is that it is constituted in the relation between the researchers and the data (Marton & Booth 1997). Thus, it is accepted that it is not the only possible outcome that could be constituted from the data. What is important is that the categories can be argued for convincingly on the basis of the data (see Åkerlind 2025 for an analysis of the different approaches taken in phenomenographic studies). In forming the categories, we were aware of Ashworth and Lucas's (1998) criticism that phenomenography tends to overly focus on authorised accounts rather than the meaning the particular phenomena have for participants. In analysing the data, we attempted to bracket our understandings of chemistry/chemical engineering. This involved putting aside our previous understanding of chemistry/chemical engineering and focusing on the accounts expressed in the interviews. This process was greatly assisted by working collectively in a group whose knowledge of chemistry/chemical engineering ranged from academic expertise to high-school level sciences, as it allowed robust conversations to take place about the extent to which the outcome space was supported by the interview data. Overall, this means that the outcome spaces presented are based on many discussions of the best way of expressing the variation in accounts of chemistry/chemical engineering identified in the interviews that captured the logical relations between the different categories and were supported by participants' accounts in their interviews.

When examining how participants' accounts of chemistry/chemical engineering changed between their first interview and the one in their final undergraduate year, individuals were assigned to the highest category of description that was evident in their interview. It is important to recognise that this aspect of the analysis involved the use of the phenomenographic outcome space rather than being a part of our phenomenographic analysis. The numbers included in this part of the analysis are lower than the number of participants included in the other forms of analysis (38/47 participants studying chemistry are included, and 45/48 participants studying chemical engineering are included). This is for two reasons. First, six of the US participants studying chemistry in combination with other subject(s) were asked about how they understood biochemistry rather than chemistry. This meant they were excluded from the generation of the categories because they were talking about a different subject than the other participants studying chemistry, including in combination with other subjects, who were focused on talking about chemistry. Second, three of the participants studying chemistry and three of the participants studying chemical engineering did not have an interview in their final undergraduate year. We excluded them from the analysis of change in accounts in order to ensure we were only comparing participants towards the end of their undergraduate studies.

Participants' reasons for studying and what gained from studying and going to university

We focused on analysing the qualitative variation in participants' initial reasons for studying chemistry/chemical engineering in their first undergraduate year and, in their final undergraduate year onwards, the variation in what they gained from being at university and the variation in what they gained from studying chemistry/chemical engineering. This involved identifying all the different initial reasons for studying chemistry/chemical engineering across all of the transcripts for participants' first interviews and all of the different things participants gained from being at university and from studying chemistry/chemical engineering in the interview in their final undergraduate year. Once these were identified, the intention was to form an inclusive hierarchy for each of these three areas of focus. However, in each case, once all of the elements had been identified, it became clear that they did not form an inclusive hierarchy that is usually generated through phenomenographic analysis (Marton & Booth 1997; Åkerlind 2025). This appeared to be because, in each case, different participants had focused on different phenomena rather than having differing perceptions of the same phenomenon. Thus, whilst a phenomenographic approach was taken to working with the data, it did not result in the generation of phenomenographic outcome spaces. We included all participants in this analysis for whom we had the relevant data. Where participants had missed their interview in the final undergraduate year, we used the account in their interview the first year after they had completed their undergraduate studies.

Once we had identified participants' reasons for studying and what they had gained from going to university and from studying for a degree, we grouped these in terms of whether they were instrumental, in terms of being focused on an outcome that would be gained by being awarded a degree, or transformational, in terms of something they would gain from the process of studying for their degree.

Participants' accounts of knowledge after graduating

In order to analyse how participants understood the knowledge of chemistry and chemical engineering after graduation, we focused on aspects of the interview in which they were asked about how they saw the world differently due to the subject they had studied and what they understood to be a scientific way of engaging with the world.

We categorised these responses as positioning participants 'inside knowledge' if participants talked holistically about the knowledge as if it were a part of their personal way of engaging the world. We categorised these responses as positioning participants 'outside of knowledge' if the participants talked about parts of the knowledge they had studied as if it was still separate from their way of engaging with the world. This often involved participants listing modules or topics they had studied.

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Appendix 2: Publications from the Project

Journal articles

Agrawal, A., Carroll, J., Blackie, M., Rosewell, K. & Pitterson, N. (2024). Impact of curricula on student learning: A comparison of six chemical engineering programmes in three Washington Accord countries. *Southern Journal of Engineering Education*, *3*(1), 4–28.

Ashwin, P. (2025). Transformational accounts of students' undergraduate education are evoked by their engagement with knowledge. *Higher Education, 90*(2), 479–95.

Ashwin, P. (2025). Why knowledge is central to 'graduateness' – implications for research and policy. *Policy Reviews in Higher Education*, *9*(1), 32–46.

Ashwin, P., Blackie, M., Pitterson, N. & Smit, R. (2023). Undergraduate students' knowledge outcomes and how these relate to their educational experiences: A longitudinal study of chemistry in two countries. *Higher Educatio*n, *86*(5), 1065–80

Ashwin, P., Goldschneider, B., Agrawal, A. & Smit, R. (2024). Beyond the dichotomy of students-as-consumers and personal transformation: What students want from their degrees and their engagement with knowledge. *Studies in Higher Education*, *49*(8), 1439–50.

Ashwin, P., Agrawal, A., Blackie, M., McArthur, J., Pitterson, N. & Smit, R. (2025). Students' changing accounts of chemical engineering: A longitudinal study in three countries. *European Journal of Engineering Education*, 1–16.

Case, J. M., Agrawal, A., Abdalla, A., Pitterson, N. & McArthur, J. (2024). Students' experiences of the value of lectures for their learning: A close-up comparative study across four institutions. *Teaching in Higher Education*, *29*(6), 1638–56.

McArthur, J., Blackie, M., Pitterson, N. & Rosewell, K. (2022). Student perspectives on assessment: Connections between self and society. *Assessment & Evaluation in Higher Education*, *47*(5), 698–711.

Pitterson, N., McArthur, J., Agrawal, A., Abdalla, A. & Case, J. M. (2024). Learning to cope in undergraduate chemical engineering: A comparative study of second year students across three countries. *International Journal of Engineering Education*, *40*(1), 154–65.

Book chapters

McArthur, J. (2020). Assessment for social justice: Achievement, uncertainty and recognition. In C. Callender, W. Locke & S. Marginson (Eds). *Changing higher education for a changing world*. London: Bloomsbury Academic, pp. 144–56.

PhD theses

Abdalla, A. (2023). *Students' Perspective on the Purposes of Engineering Higher Education: A Longitudinal Qualitative Case Study of the U.S. and England* (Doctoral dissertation, Virginia Tech).

Goldschneider, B. J. (2023). *The Journey of Becoming and Belonging: A Longitudinal Exploration of Socialization's Impact on STEM Students' Sense of Belonging* (Doctoral dissertation, Virginia Tech).

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Abdalla, A., Pitterson, N. P. & Case, J. M. (2020). Exploring how undergraduate chemical engineering students spend their time inside and outside of the classroom (WIP). In *2020 ASEE Virtual Annual Conference Content Access*.

Agrawal, A., Blackie, M. & Smit, R. (2019). An exploration of first year engineering students' perception of the university's responsibilities. *Proceedings of the 8th Research in Engineering Education Symposium* (pp. 683–92). Cape Town, South Africa.

Agrawal, A., Blackie, M. & Smit, R. (2019). An exploration of second-year students' engineering way of thinking. *Proceedings of the 47th Annual European Society for Engineering Education (SEFI) Conference* (pp. 1343–53). Budapest, Hungary.

Agrawal, A., Pitterson, N. & Case, J. (2019). First year engineering students' perceptions of the purposes of classroom assessment. *Proceedings of the 8th Research in Engineering Education Symposium* (pp. 617–25). Cape Town, South Africa.

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Working papers

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Ashwin, P., Blackie, M., Pitterson, N. & Smit, R. (2022). Undergraduate students' knowledge outcomes and how these relate to their educational experiences: A longitudinal study of chemistry in two countries. *Centre for Global Higher Education working paper series*. Working paper no. 86. Oxford: Centre for Global Higher Education.

McArthur, J. (2021). Rethinking student involvement in assessment. *Centre for Global Higher Education working paper series*. Working paper no. 58. Oxford: Centre for Global Higher Education.

McArthur, J., Blackie, M., Pitterson, N., & Rosewell, K. (2021). Can and should assessment nurture an orientation to society and social justice? *Centre for Global Higher Education working paper series*. Working paper no. 72. Oxford: Centre for Global Higher Education.

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