Chemistry PhD Supervisors in Australia: A Study of the Relationship between their Conceptions of Doctoral Purpose and their Reported Educational Practices

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Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of the author's knowledge, it contains no material previously published or written by another person, except where due reference is made in the text.

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Abstract

Over the past 30 years, the literature on doctoral education has raised a number of debates about the research doctorate. This has included debates over its purpose and whether its graduates are well prepared to address the diverse and complex problems of today's workforce. However, scholarly literature on doctoral education in the academic discipline of chemistry is mostly non-existent. To address this research gap, I draw upon key concepts arising from the doctoral education literature such as doctoral purpose, practice, and evaluation to provide the necessary framing for this study. Based on this, I ask the following question: 'What are the Positions of Chemistry PhD Supervisors in Australia in Relation to Contemporary Debates and Practices in Doctoral Education?'

This study adopts a qualitative research methodology in which 31 chemistry PhD supervisors in Australia were interviewed using the semi-structured interview method. Data were analysed thematically using both deductive analysis for pre-existing themes from the literature, and inductive analysis for emergent themes from the data. Three main themes characterised the analysis: supervisors' conceptions of doctoral purpose; their reported educational practices; and their reported methods of self-evaluation of supervisory success and graduate follow-up.

It was found that the reported practices for two groups of supervisors in the sample did not align with their conceptions of purpose. Instead, they showed a strong tendency to socialise their students into becoming custodians or 'stewards' of the discipline, despite interviewees expressing conceptions of doctoral purpose that aligned with the development of graduates as knowledge workers equipped with the knowledge and skills for wider employment. For the other group, their conceptions of doctoral purpose did align with their reported educational practices of preparing 'stewards' of the discipline, with their reported practices also tending towards setting up their students to become stewards. These issues were further compounded by supervisors not adequately following up with their graduates in terms of their career outcomes, despite them indicating that they considered graduate employment as one measure of supervisory success.

The main scholarly contribution this thesis makes is in initiating the scholarly debates and discussions about contemporary doctoral education within the discipline of chemistry. These debates and discussions are needed in order to not only critically reflect on the role and influence chemistry PhD supervisors have in the education of future chemistry PhD candidates, but also to critically contemplate the purpose and contribution of the chemistry doctorate in

relation to the labour market and broader society. Practical implications arising will also be discussed.

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CHAPTER 1 – INTRODUCTION

1.1 My Educational Background and Experiences

One of my earliest memories involving a science experience was when my father bought me my first science kit. It came with a green plastic microscope, three plastic test tubes with red stoppers, and a bunch of other gadgets. Several hours if not days of my childhood were spent playing with that kit, and I even took it to school so that my friends could experience what I was experiencing. Many years later, in high school, chemistry had become my favourite science subject, and I was excelling at it to the point that when I was around 16 years old, I decided that I wanted to complete a Bachelor of Science with a major in chemistry, challenge myself with the highest academic degree possible and complete a PhD in chemistry, and work on a drug that would cure cancer. So, when I was accepted at the Australian National University (ANU) in 2009, I started my Bachelor's Degree in Science and aimed for a double major in Chemistry.

I truly enjoyed my time in chemistry: I did well in my studies, I peer mentored first-year undergraduates as a later-year student, I was a chemistry representative making sure student needs were communicated to the School, and I got to do an undergraduate research project with one of the best Research Groups in the discipline. But just like everything in life, I changed, and I became more interested in chemistry education than chemistry itself. Particularly towards the end of my degree, and as the prospects of employment loomed closer, I became increasingly reflective about the education I had received in chemistry, but in relation to things like communication, teamwork, research skills – or 'generic' skills as I later learnt. I felt I had much more to learn, and I eventually enrolled in my Honours degree in Science Communication at ANU in 2013, where I looked at the relevance of the graduate attributes to different Australian tertiary chemistry education stakeholders. My dream to challenge myself and complete a PhD was still there, despite having left chemistry. In early 2015, the factors lined up, and I started my PhD at the College of Arts and Social Sciences.

1.2 Early Justification for the Research

I came into this PhD with a strong interest in chemistry education and matters related to student employability. From a research interest perspective, it made sense to pursue my PhD along those lines. In addition, I had completed my Honours degree in Science Communication looking at those issues, so it also made sense to choose a line of research that built upon the knowledge and skills I had gained in my Honours year. Despite the 2014 Postgraduate Research

Experience survey reporting doctoral graduates in the chemical sciences as being highly satisfied with their skills development (96.7%) (Graduate Careers Australia, 2015b), the 2014 Postgraduate Destinations survey reported that only around 61% of chemistry Higher Degree by Research (HDR) graduates were in full time employment (Graduate Careers Australia, 2015a). This coincided with the then Minister for Education and Training, Christopher Pyne, commissioning the Australian Council of Learned Academies (ACOLA) to conduct a review of Australia's research training system in order to ensure that HDR graduates were equipped with the knowledge and skills necessary for the needs of Australia in the 21st century, with an increased emphasis on student engagement with and employment in industry (Department of Education and Training, 2015b). In addition, the Office of the Chief Scientist's report on Australia's Science, Technology, Engineering and Mathematics (STEM) workforce showed the Higher Education industry class of employment as disproportionately employing chemical sciences doctoral graduates (Office of the Chief Scientist, 2016). With all of these considerations in mind, and particularly the apparent shift being detected in Australia in terms of increased focus and attention on HDR graduates and broader employability, it became reasonably sound to approach a research project along these lines of inquiry.

1.3 The Structure of this Thesis

This research project began by looking at the major debates that constituted the doctoral education research space. Two chapters constitute the literature review. In Chapter 2, the history of the research doctorate was examined in order to provide the general backdrop for the study. The early history of the doctorate can be traced back to Europe since its inception as a licence to teach, with its rebirth into the more familiar research degree seen in Germany in the early 1800s. Following that, the degree was first awarded in the US in 1861, and first introduced in the UK in 1917 (Hancock, 2012; Park, 2005, 2007; The Group of Eight, 2013). In Australia, the degree was first introduced at the University of Melbourne in 1946. What traditionally distinguished the degree in Australia compared to the US and UK was the absence of coursework and an oral examination respectively. Australia's geographic isolation meant a reliance on examining the candidate by examining the thesis (Dobson, 2012a; Kiley, 2014, 2017a; The Group of Eight, 2013).

Having examined the brief history of the research doctorate across the US, UK, and Australia, attention is turned to the current major debates in the doctoral education literature from the US, UK, and Australia, in order to formulate the necessary tools to use when conducting

research into the discipline of chemistry. Three major areas of the doctoral education literature framed the parameters of the study: Doctoral purpose, doctoral practice, and doctoral evaluation. Debates on the purpose of the doctorate are first considered as the basis and common point of understanding of consequent debates in doctoral education. Despite there being various questions and ambiguity surrounding the purpose of doctoral education, in practice, two dominant paradigms have underpinned doctoral education purpose and practice: that of 'Stewards of the Discipline' (Golde & Walker, 2006) and that of 'Knowledge Workers' (Boud & Lee, 2009). Historically, disciplines have ensured they remain alive and well by the constantly training and supplying individuals capable of taking the discipline forward by expanding the boundaries of its knowledge, as measured through their written theses. These individuals were the so-called stewards. The doctorate, however, is being repositioned away from this paradigm where the focus on the outcome of a period of doctoral study is the thesis (or the product), to that of the student (the person) and the assets they possess in terms of their knowledge and skills. Indeed, within the knowledge economy environment, the knowledge and skills a doctoral graduate possesses become economic assets of value in the workplace (Boud & Lee, 2009; Golde & Walker, 2006; Park, 2007; The Group of Eight, 2013).

With the tensions surrounding doctoral purpose now in mind, debates on employability and HDR skills are examined next. Two constructs are used to define employability in the literature: employability at the level of the person; that is, the knowledge, skills, and attributes they require to both gain and maintain employment, and employability at the 'structural' or external level; that is, one's gender, race, age, and labour market situations that externally affect one's employability. This thesis focuses on the former definition. Under that definition, the debates concede, although with some turbulence, an HDR skills deficit particularly in relation to the preparation of PhD graduates as knowledge workers (Craswell, 2007; McGagh et al., 2016; Sin & Neave, 2016).

The literature on doctoral supervision is then studied. Apart from the apparent linkages between supervision and its impact on candidature and post-PhD careers, it is argued in this thesis that supervisors are the 'cultural reservoirs' of the discipline, acting as arguably the most powerful socialising agents of doctoral students, by inducting them with the norms, values, rules that make them members of their disciplinary communities (Bills, 2004; McGagh et al., 2016; Nulty, Kiley, & Meyers, 2009; Sinclair, 2004; Western et al., 2007).

Given the shift in graduate employability within the doctoral education space, and given the cultural significance of supervisors as primary socialising agents, the literature on doctoral evaluation was consulted. Two kinds of practices are employed within doctoral evaluation: candidate evaluation of their program and follow-up with graduates over career outcomes (McGagh et al., 2016).

In Chapter 3, the literature on STEM education is visited, given the location of the study within the discipline of chemistry. The literature reveals, within the Australian context, great investment in science and the training of science graduate students by the Australian government, especially with science recognised as a key driver of innovation and nation building. The key messages arising from the debates argue for both 'transferable skills' training and interdisciplinary exposure of HDR candidates in science, as per the 'knowledge worker paradigm', in order to better prepare students for the diverse and complex career problems they will face in today's workforce (Hancock, Hughes, & Walsh, 2017; McGagh et al., 2016).

Finally, the literature on chemistry education is examined for its engagement with doctoral education debates within chemistry. In the US, the debates seemingly consist of only three essays on doctoral reform published in one seminal text, one review report, and a couple of scholarly texts scattered across the literature. No research was done with supervisors despite their status as the 'cultural reservoirs' of the discipline. In the UK, two reports published by the Royal Society of Chemistry make some reference to the narrowness of chemistry doctoral education. In Australia, 19 journal publications under AusJEC between 2001 and 2016 yield only two articles on this topic, one with marginal reference. Even the Academy of Science's 2016 *Decadal Plan* for chemistry glosses over the topic, despite the latter's commitment to bolstering chemical knowledge and the general image of chemistry in Australia (Australian Academy of Science, 2016; Golde & Walker, 2006; Harding, 2004; Varella, 2012). Based on this examination, it is argued that the research landscape on chemistry doctoral education is largely barren, and the following overarching research question is posed:

'What are the Positions of Chemistry PhD Supervisors in Australia in Relation to Contemporary Debates and Practices in Doctoral Education?'

Which is constituted by the following sub-research questions:

- What are the conceptions of doctoral purpose held by chemistry doctoral supervisors in Australia?

- How do their educational practices relate (or not) to their conceptions of doctoral purpose?

- How do chemistry PhD supervisors evaluate their success in terms of follow-up on graduate career outcomes?

To answer this overarching research question, a qualitative research approach was adopted, and a semi-structured interview method was chosen to interview chemistry PhD supervisors in Australian universities within the discipline of chemistry as the case study, as detailed in Chapter 4. The qualitative research approach allowed for a small sample of participants to be studied closely, while the semi-structured interview method allowed for a set number of questions to be asked consistently across the interviews, while opening up the opportunity to explore emergent findings and ask new questions inductively from the data (Ayres, 2008; Gray, 2014; Morgan, 2008).

Thirty-one participants were recruited from 11 universities across Australia, spanning different states, chemical sub-disciplines, levels of supervisory experience, and genders, in order to maximise the diversity and richness of the sample. Data were analysed using qualitative content analysis which allowed the responses to be coded via themes deductively produced from concepts and ideas from the literature, while also allowing the inductive analysis of emergent themes.

Chapter 5 presents the research findings, which were separated into two stages: Stage One which consisted of the semi-structured interview analysis and Stage Two which consisted of both inductive and semi-structured interview analysis. Stage One organised the findings around the three main themes of supervisory conceptions of doctoral purpose, reported supervisory educational practices, and reported methods of supervisory success and graduate follow-up. Stage Two of the analysis followed an initial inductive approach where emergent themes revolving around academic career preferencing and privileging were further explored, alongside an exploration of the points of 'inflection' or trigger points that could potentially explain the shift in the conceptions of doctoral purpose of some supervisors from the traditional idea of stewardship to that of preparing knowledge workers.

In the first stage of the analysis, respondents were grouped based on their conceptions of doctoral purpose in chemistry: those who thought the purpose of the chemistry PhD was to develop the candidate in terms of their knowledge, skills, and attitudes (the 'Person' category);

those who thought the purpose of the PhD was to conduct research and create knowledge (the 'Product' category); and those whose conceptions of purpose covered both of the previous categories (the 'Person & Product' category).

The reported practices covered the knowledge and skills they ensured their students had upon graduation, whether they encouraged their students to reflect upon contemporary issues related to the discipline of chemistry, and whether they encouraged their students to gain work experience during the PhD. The findings show that for supervisors under the 'Person' and 'Person & Product' categories, their reported practices did not align with their conceptions of purpose. Instead, they showed a strong tendency to socialise students into becoming stewards of the discipline, despite them expressing conceptions of doctoral purpose that aligned with developing graduates as knowledge workers. For the other group of supervisors under the 'Product' category, their conceptions of doctoral purpose did align with their reported educational practices of preparing stewards of the discipline. These issues were further compounded by supervisors not adequately following up with their graduates in terms of their career outcomes, despite them indicating that they considered graduate employment as at least one measure of supervisory success.

The second stage of the analysis approached the data inductively and explored two main themes: those of 'Academic Career Privileging' and 'Points of Inflection'. Academic career privileging referred to the situation in which academic careers were preferred to and upheld over non-academic career pathways. This manifested as some supervisors expecting or assuming by default that a PhD is followed by an academic career, that 'bright' students should be encouraged down the academic career path, and feelings of supervisory disappointment and student guilt, if the student did not become an academic like their supervisor. In other cases, some supervisors reported seeing their colleagues behave this way.

The second line of inductive inquiry followed the possible trigger points or 'points of inflection' that may have contributed to the shift seen in the conceptions of doctoral purpose of supervisors under the categories of 'Person' and 'Person & Product' from the traditional ideas of stewardship to those of knowledge work. Awareness of post-PhD job realities, being exposed to new experiences through leadership positions, having gone through destabilising experiences during the doctorate or as a working academic, and a heightened sense of reflection appeared to account for the shift in the conceptions of purpose of some of these supervisors.

In Chapter 6, the findings are synthesised and discussed in reference to the literature. Here, the alignments and disconnects between the supervisors' conceptions of doctoral purpose and their reported practices are highlighted and explained in reference to the literature on socialisation. These alignments and disconnects are then graphically charted to assist in the visualisation of where supervisors 'sit' in relation to contemporary doctoral debates and practices. The chart provides a simple visual aid as part of the overall discussion on charting the positions of supervisors.

The emergent theme of Academic Career Privileging is checked against the literature for further substantiation. A body of literature on doctoral shame and guilt was found that consisted of research on doctoral taboos, the treatment of teaching careers as ancillary to research careers, and supervisors 'disowning' their teaching-oriented students (Connolly, 2010; Nerad, 2015). This literature supported the emergent findings from this study. The implications of this, along with the discussion on supervisors' 'points of inflection', are presented, along with a development framework that could be used in developing supervisor workshops and programs.

Finally, Chapter 7 concludes the thesis by distilling the major conclusions that can be drawn from the study. It presents the contribution to knowledge and practice, and discusses the limitations of the study and suggestions for future research. Final thoughts and reflections are provided, bringing closure to the thesis.

CHAPTER 2 – LITERATURE REVIEW

This chapter is the first literature review chapter for this study, in which the major debates in doctoral education are reviewed. These debates are examined in order to provide the necessary conceptual understanding and framing to conduct the research in the case of chemistry. The chapter begins by covering the brief history of the research doctorate across the UK, US, and Australia. This provides the general backdrop for the study. Next, debates around the purpose of the PhD are examined because research on doctoral education needs to start from a common point of understanding. Since doctoral purpose underpins doctoral practice, the literature review then directs attention to the changes in doctoral practices that have occurred across the UK, Europe, and Australia and the emergent employability agenda. Theoretical constructs of employability are reviewed, followed by an examination of the HDR skills agenda and the increased focus on 'generic' training within this space. A section is dedicated to doctoral supervision, which underscores the importance of supervision in socialising students into their chosen disciplines and the impact supervisors have on students' postgraduate employment. The importance of supervisors following up on the career outcomes of their graduates is raised, particularly in relation to supervisors' self-reflective practice, validating them as participants for this study.

2.1 Knowledge and Employability

Education plays a significant role in preparing individuals for the workforce and in ensuring they have the necessary knowledge and skills for ongoing employment. In recent decades, the increased demand for higher education has resulted in a steady rise in the number of working-age individuals with these qualifications (Australian Bureau of Statistics, 2016). Traditionally, universities have graduated students with knowledge and skills that have proven useful for their governments, economies, and societies (Boden & Nedeva, 2010). Universities have a social responsibility and seek to improve the common good by providing an annual inflow of graduates armed with the knowledge and skills to (re)invigorate society's economic, social and cultural vitality (Boulton & Lucas, 2008). While these individuals may enact these changes in a myriad of ways, their careers will arguably provide one of the strongest platforms to place their education into utility (Morse & Weiss, 1955). Employment offers the "opportunity to self-actualize through work, have a positive social impact, fulfill one's purpose, and feel a sense of accomplishment" (Ward & King, 2017, p. 6)

Given the relationship between knowledge, employability, and employment, it makes sense to examine the relationship between the highest form of knowledge universities offer, the research doctorate, and employability. While historically deemed a qualification for an academic career, in many countries the doctorate is now increasingly seen as a highly sophisticated degree that trains people in tackling the complex problems of today's workplaces (Bogle, Dron, Eggermont, & Henten, 2011). This claim, however, is not uncontested. And as seen in the ensuing debates, heavy criticism has been mounted over the doctorate regarding its purpose, its prevailing educational practices, and its adequacy in preparing graduates in tackling complex and 'wicked' problems. To better understand and appreciate these debates, the history of the doctorate is first examined. The following section reviews the history of the PhD, its inception, and original purpose, to provide the contextual backdrop for this study.

2.1.1 A Brief History of the PhD as the Highest Degree Obtainable

The Doctor of Philosophy or PhD (Latin, *Philosophiæ Doctor*), is considered to be the highest formal education achievement and is awarded to students who have successfully completed a defined program of research in a discipline or a specific field of study (Park, 2007; The Group of Eight, 2013). Graduates who achieve this qualification have demonstrated the intellectual prowess to independently conduct research that is original and makes a significant contribution to knowledge and, potentially, humankind. Despite the title meaning Teacher of Philosophy in Greek, and originally being awarded to those who studied philosophy, it is possible to complete a PhD in most academic disciplines.

Besides the research doctorate, universities also award other forms of this degree. For example, in the UK and in Australia, Honorary Doctorates are awarded based on highly distinguished service or significant contributions to the wider community. Other forms of the doctorate are awarded such as the Doctor of Science (DSc) or Doctor of Letters (DLitt) to staff or alumni who have made excellent contributions in their fields of research. These are often termed Higher Doctorates (Park, 2007). There also exists the professional doctorate designed for individuals who want to conduct high-level research for the needs of industry or the workplace more generally (Usher, 2002). Finally, some higher education systems provide 'practice-based' doctorates such as in the visual and performing arts (Simmons & Holbrook, 2013).

According to Park (2005) and Simpson (1983), the research doctorate has a long history with key landmarks. It was born in medieval Europe during the Middle Ages as a licence to teach in universities. Its rebirth as a research degree in Germany occurred in the early 1800s, and the

educational reforms that took place underpinned the education paradigm of the Humboldt University, or the Humboldtian Model. The core foundations of the Humboldt University were the creation of knowledge for its own sake; the unification of research and teaching; the provision of a liberal curriculum; and academic freedom. The University of Berlin is considered to be the first manifestation of the modern university and the first university to award a modern doctorate, with its traditional purpose to provide the training to start an academic career (Hancock, 2012; McGagh et al., 2016; Park, 2007; The Group of Eight, 2013).

In comparison, the USA and UK had no equivalents to the research-based universities of Germany. It was only in 1861 that Yale University claims to have awarded its first three doctoral degrees (The Group of Eight, 2013). More recently, the contemporary doctorate in the US has involved the student completing advanced-level coursework, executing academic research, and providing teaching assistance, receiving supervision under several advisors (Park, 2007).

In the UK, the doctoral degree was first introduced in 1917, by the University of Oxford (Noble, 1994). The contemporary UK doctoral program admits students based on demonstrated academic merit. Students need around three years to complete. The student is assessed in two ways: via a written thesis examined by at least one examiner external to the university and who is an expert in the student's field, and also via an oral exam or *viva voce*, where they are expected to have answered the study's research question and contributed to knowledge. The conclusion of the oral defence results in a pass with no corrections; a pass with minor corrections; a pass with major corrections; resubmission for a lower degree such as a Master of Philosophy; or a fail (Vitae, 2018).

2.1.2 A Brief History of the PhD in Australia

In contrast to the US and the UK, Australia began awarding research doctorates much later, with the University of Melbourne introducing the program in 1946 and awarding its first three doctorates in 1948 (Dobson, 2012a; Rae, 2002). Between 1948 and 2009, the total number of research doctorates awarded in Australia was over 94,000 (Dobson, 2012a). More recent data collection on HDR completions in Australia appears to combine Master and PhD graduates into one cohort. For example, from 2010 till 2016, just over 65,000 candidates completed postgraduate studies (Bednall, 2018). This dramatic increase in numbers also means that the PhD graduate population is more diverse than ever and that consequently, the 'elite' status of the PhD has eroded to a certain extent. This does not come as a surprise given the large expansion the higher education sector has experienced and the increased accessibility and pathways available into postgraduate education (The Group of Eight, 2013).

What distinguished the original model of the Australian PhD compared to the US model is that it did not include coursework alongside the research (Kiley, 2014, 2017a; The Group of Eight, 2013). The Australian PhD emulated the UK model whereby students were supervised by an academic, in a form of a research apprenticeship. While this practice has permeated Australian universities for several years, recent developments have witnessed universities introducing coursework in the form of formal award study, workshops, and seminars (Kiley, 2017a).

In addition to the introduction of coursework into its program, the PhD award in Australia has been subject to the articulation of learning outcomes and requirements as per the *AQF specification for the Doctoral Degree* (Australian Qualifications Framework Council, 2013a). The AQF, or the Australian Qualifications Framework, is managed by the Australian Government Department of Education and Training, in consultation with the states, territories, and expert advisory groups. Its Council comprises "national Ministers responsible for tertiary education, skills and employment and is established under its authority" (Australian Qualifications Framework Council, n.d.-a, 2013b, p. 105).

Under this framework, the research doctorate is awarded to candidates who make a significant and original contribution to knowledge and who have demonstrated critical understanding and mastery of research skills within their field. Candidates undertake independent research under the supervision of appropriate academics for three to four years, culminating in the production of a thesis, dissertation, exegesis, or equivalent. This is then examined by at least two external expert examiners of international standing (The Group of Eight, 2013).

The nature of doctoral examination in Australia further distinguishes the degree from other PhDs around the world. Traditionally, the Australian doctorate has been awarded based on examining the thesis, rather than assessing the candidate themselves (The Group of Eight, 2013). Traditionally, an oral examination in Australia is usually reserved to resolve cases where there is doubt and concern as to whether the thesis has met the expected standards and requirements (McGagh et al., 2016).

Kiley (2009) offers some insight into the reasons for this. Given Australia's geographic isolation, having examiners travel to Australia for an oral examination was an unpractical arrangement, and the assessment process had to rely on written examiners' reports. One consequence of this practice is that a particularly robust system of utilising external examiners and their reports developed for Australia. This allowed international experts to be involved without the need to

be present locally all at once (Kiley et al., 2018). However, the other consequence of this is that in the absence of direct contact with the candidate, examiners may not be able to validate and authenticate the candidate's work as strongly and identify areas of weakness and uncertainty. From the candidate's perspective, the absence of an oral exam forgoes their ability to defend their thesis and receive face-to-face feedback for meaningful learning (Kiley, 2009).

In Australia, most universities require research candidates to present a completion or pre-submission seminar. While this presentation is publicly advertised across the university and may constitute a student progress milestone, it is not part of the formal assessment processes (The Group of Eight, 2013).

Finally, what distinguishes the Australian research doctorate even further from other countries is that traditionally in Australia, many students were admitted into the PhD upon completion of an Honours degree, compared to other countries where the entry requirement is generally the completion of a two-year Master degree. Although described as a one-year program, the Honours degree program is actually eight to nine months in length. This is due to the need to determine recipients of Australian Postgraduate Awards (APA) scholarships as well as other considerations for those wanting to complete research training the following year. The shortness of the Honours program, its lack of breadth and disciplinary depth, its lack of international recognition, and the increase in the number of candidates entering a doctorate with a Coursework Master degree are all issues that have been called into question, especially regarding the efficacy of Honours in preparing students for postgraduate research (Kiley, 2013; Kiley, Boud, Manathunga, & Cantwell, 2011; McGagh et al., 2016).

Examining the history of the PhD grants an understanding of the factors and values that came to shape it, that is, a degree that sought the pursuit of knowledge in its purest form, and granted its holder entry into the academy for the pursuit of knowledge for knowledge's sake. However, as the following discussion will show, the purpose of the research doctorate began to be questioned and challenged, and its traditional purpose destabilised. The context surrounding this destabilisation and shift in doctoral purpose will also be explored.

2.2 The Purpose of the PhD

What might have seemed as stable beginnings for the Humboldtian doctorate in Germany and Western Europe, the USA, and then in the UK, New Zealand, and Australia would later be marked by periods of scrutiny cast by academics and governments. In examining this area of the literature, a deeper understanding and appreciation of the contested nature of this debate

will emerge. This will open up the space to explore the consequent shifts in doctoral education practice and the factors involved in these shifts.

In conducting research on doctoral education, it is necessary to begin with the conceptions of the purpose of the PhD. This is particularly true, given that doctoral purpose underpins doctoral practice (Boud & Lee, 2009; Park, 2007; The Group of Eight, 2013). Here, the term 'PhD' will be used in the broadest sense to include meanings such as the award, the qualification, the program, the experience, and so on.

A lack of clarity over the purpose of the PhD can be traced to over three decades ago. For example, Blume described the tensions surrounding the PhD in the following "on the one hand it has now become, one might almost say for the first time, the explicit object of policy concern. On the other hand its purpose no longer seems clear" (Blume, 1986, p. 221), while Winfield noted that "there is an inherent tension within the degree" and "the absence of a research-based literature on doctoral study may have contributed to the apparent uncertainty about the nature, form and purpose of the degree" (Winfield, 1987 as cited by Park, 2007, p. 5).

These uncertainties regarding the doctorate extended even to students and employers who felt they were unclear about the nature and purpose of doctoral education (Park, 2005). This was further emphasised in *Redefining the Doctorate* (Park, 2007, p. 6) where it is stated that there was "persistent uncertainty and enduring lack of consensus over the purpose of the doctorate and over the benefits a doctoral education offers".

But by closely observing this uncertainty arising within the debates on the purpose of the research doctorate, one can grasp the thread underpinning it. What seems to be driving or running beneath this uncertainty discourse are the diverging stakeholders in doctoral education including, but not limited to, students, employers, and government policy makers, and the diverging demands and expectations they have of doctoral education offered by universities. However, to begin to understand these new demands, the concept of 'knowledge', upon which the function and existence of universities and doctoral education rest, needs to be visited.

2.2.1 Knowledge and knowledge production

Universities exist for the purpose of the production of knowledge and preparing the next generation of individuals armed with this knowledge (Bøgelund, 2015; Boulton & Lucas, 2008;

Sin, Tavares, & Amaral, 2017). By extension, the research doctorate has fulfilled this purpose (Bøgelund, 2015; Bogle et al., 2011; Boud & Lee, 2009).

Several conceptions of knowledge exist in the literature. For example, Gibbons et al. (1994) theorise knowledge into two main types: Mode 1 knowledge and Mode 2 knowledge. Mode 1 knowledge is the pure, blue-sky, curiosity-driven research traditionally performed by universities. This basic knowledge is fenced by strict disciplinary boundaries, and is accumulated over time by members of the discipline in paradigmatic, planned, and tested ways to produce 'truths' and 'universals'. Mode 2 knowledge, however, is multidisciplinary and transdisciplinary in nature, oriented towards solving real-world problems and is no longer solely produced by universities – government, industry and other organisations now participate in the knowledge production process. These stakeholders become knowledge workers who will be called upon to provide their expertise in diffuse and varied ways. While Mode 1 knowledge is applied in a linear fashion where discovery and application are strictly separated, Mode 2 is quite the opposite. No longer is the discipline the primary structure of knowledge, and the boundary between discovery and application dissolves. Mode 2 knowledge is inevitably utilitarian, pragmatic, and performative, and is the reason it is the more fitting conception of knowledge for the knowledge economy and will be in most demand (Usher, 2002).

In Mode 2, the context and nature of the intellectual and social problems faced are highly complex and sophisticated. For example, researchers classically trained in the physical and natural sciences will have to draw upon the knowledge offered by the humanities and social sciences, such as economic, social, political, and ethical knowledge (Gibbons et al., 1994). This is because scientific evidence alone will most likely be insufficient to address controversial and contested problems such climate change, genetic engineering, nuclear power, and so on. Individuals will be guided by contemporary practical, social, and policy-related concerns, and will be trained communicators capable of working with others and creatively applying their knowledge in new contexts; hence, marking the rise of multidisciplinarity in Mode 2 knowledge.

Gibbons et al.'s conceptions are regularly invoked in the literature on knowledge, but other contributions within this space also mirror their work. For example, Bøgelund (2015) identifies three perspectives on knowledge production as outlined below.

Wenneberg (2001) as cited by Bøgelund (2015) explains that universities historically sought to uncover the 'objective' truth and impart these truths upon their students through teaching. Knowledge is produced for its own sake and whether this knowledge is put into practice becomes irrelevant under this scheme. Bøgelund (2015, p. 41) identifies this as "knowledge production in an academic perspective": it can be argued that this kind of perspective parallels that of Gibbons et al.'s Mode 1 knowledge production.

On the other hand, Jamison, Christensen, and Botin (2011), explain that the mid-twentieth century marked a new understanding of science and technology and with it came a new view of what constituted knowledge. Unsurprisingly, knowledge here is justified based on its responsiveness to the demands of innovation, profitability, and entrepreneurship. Knowledge is seen as productive – it is a product in and of itself. Interestingly, universities no longer take centre stage in this process, and they collaborate with companies and businesses in their knowledge transactions. Given that different kinds of knowledge have different market appeal, disciplines are rendered unequal under this arrangement, with STEM disciplines garnering the most opportunities. This perspective, "knowledge production in a market perspective" (Bøgelund, 2015, p. 41) immediately mirrors that of Gibbons et al. – Mode 2 knowledge where knowledge is valued based on its economic performativity.

Bøgelund (2015, p. 41) identifies a third perspective, "knowledge production in a changing society perspective", however it does not correspond to any of Gibbons et al.'s modes of knowledge. Central notions within this perspective are the production of knowledge being empowering and emancipatory, and the creation of change agents by universities, capable of operating this knowledge in the face of global challenges. This perspective is anchored in social movements and protestation against the militarisation and bureaucratisation of science and technology, imperialism, environmental degradation, and women's rights movements. Within this perspective, interdisciplinary and cross-cultural research are the tenets of knowledge production, and knowledge is to be used to increase equality, democracy, and liberation. Individuals must develop their personality and identity in congruence with this (Barnett, 1994; Jamison et al., 2011).

Therefore, when viewed broadly, knowledge production practices can be seen on a spectrum with one end concerned with the bounded, purely discrete form of knowledge that disciplines have traditionally been concerned with producing, and on the other end, the production of knowledge and 'producers' of knowledge within a 'flatter', interdisciplinary structure, with

greater emphasis and value on the potential applicability of that knowledge. In a similar sense, as outlined below, doctoral education has been underpinned by different paradigms that have placed different emphasis and value on knowledge.

2.2.2 Paradigms that have Underpinned Doctoral Education

Doctoral education has been underpinned by two major paradigms: the 'Stewardship' or 'Stewards of the discipline' paradigm (Golde & Walker, 2006) and the 'Knowledge Workers' paradigm (Usher, 2002).

Boud and Lee (2009) argue that while the PhD was traditionally the training ground for 'stewards of the discipline' (Golde & Walker, 2006), and that consequently, its practices had been underpinned and shaped by that purpose, it is now the 'Knowledge Worker' paradigm that more strongly dominates the direction of doctoral education. This is because under the knowledge economy, the knowledge, skills, and attitudes of the individual graduate become the centre of policy concern and scrutiny within the doctoral education space. Both of these paradigms will be examined more closely below.

2.2.2.1 Stewards of the Discipline

In 2001, the Carnegie Foundation for the Advancement of Teaching undertook a five-year project called the Carnegie Initiative on the Doctorate (CID) – a project focused on aligning the purpose and practices of doctoral education in six disciplines: chemistry, education, English, history, mathematics, and neuroscience. These disciplines were chosen for spanning academia widely and for being fundamental fields with large number of doctoral programs and students (Golde & Walker, 2006; Jackson, 2003).

The idea of the CID was to ask, afresh, the question, "What is the purpose of doctoral education?" (Golde & Walker, 2006, p. 5). The response was that doctoral programs must produce "stewards of the discipline":

> We propose that the purpose of doctoral education, taken broadly, is to educate and prepare those to whom we can entrust the vigor, quality, and integrity of the field. This person is a scholar first and foremost, in the fullest sense of the term – someone who will creatively generate new knowledge, critically conserve valuable and useful ideas, and responsibly transform those understandings through writing, teaching, and application. We call such a person a "steward of the discipline". (Golde & Walker, 2006, p. 5)

Under this notion, a steward is expected to serve the discipline in multiple ways. In addition to having made an original contribution to the knowledge reserves of the discipline, a steward will know the history of the discipline, the 'big questions' and ideas that drive the discipline, and its relation to other disciplines. A steward will also communicate the ideas of the discipline to audiences both within and outside of it. To quote Golde's words, "It's about integrity. It's about, What are your responsibilities to the discipline?" (Jackson, 2003, pp. 566–567). These lifelong responsibilities are outlined in more detail below:

> A steward thinks about how to preserve the heart and essence of the field. But there are also important forward-looking meanings, as stewardship does not imply stasis. A steward is a caretaker who trains a critical eye toward the future. A steward must be willing to take risks and move the discipline forward. (Golde & Walker, 2006, p. 13)

In addition to these expectations, it can be argued that the steward will have three main duties towards the discipline:

> The doctorate should signal a high level of accomplishment in three facets of the discipline: generation, conservation, and transformation. A PhD holder should be capable of *generating* new knowledge and defending knowledge claims against challenges and criticism, *conserving* the most important ideas and findings that are a legacy of past and current work, and *transforming* knowledge that has been generated and conserved by explaining and connecting it to ideas from other fields. All of this implies the ability to teach well to a variety of audiences, including those outside formal classrooms. (Golde & Walker, 2006, p. 10)

In this thesis, I argue that despite the CID's attempts to conceive the purpose of doctoral education "de novo" (Golde & Walker, 2006, p. 9), the paradigm of 'stewards of the discipline' is arguably the same paradigm that has underpinned doctoral education since its inception as the Humboldtian research degree, only relabelled. I also argue that despite being called 'stewards of the discipline', and appearing at face value to be all about the student, this doctoral paradigm is at heart concerned about the product of doctoral education – the knowledge – and not the person. As can be seen so far, the purpose of the research doctorate has been about the creation of knowledge, organised around disciplines, in line with Gibbons et al.'s Mode 1 knowledge or discipline-based knowledge. The notion of 'stewards of the discipline', by definition, is underpinned by knowledge production practices centred on 'cutting-edge research' and expanding disciplinary frontiers. To do this, however, disciplines

must ensure a steady influx of individuals capable of expanding the boundaries of its knowledge. The research thesis, or the 'Product' of a period of doctoral education, becomes the strongest manifestation of significant and original knowledge and a validation of stewardship. In essence, this is the paradigm of stewardship. To re-emphasise Golde's question, "What are your responsibilities to the discipline?" (Jackson, 2003, pp. 566–567). The answer to this lies in the utility of the notion of 'stewards of the discipline': to keep the *discipline* well, replenished, and alive.

2.2.2.2 Knowledge workers

The second conceived purpose of doctoral education is the notion of knowledge workers (Usher, 2002). Usher anticipated that doctoral graduates would need to contend with the realities of the knowledge economy and become 'knowledge workers' who apply their knowledge and skills within interdisciplinary environments as envisaged by Gibbons et al.'s Mode 2 knowledge. This is because under the knowledge economy, things like knowledge, skills, and even an individual's personal attributes and qualities become economic commodities sought after to drive innovation and development. Within this environment, knowledge workers are under tremendous pressure to demonstrate both breadth of knowledge and specialist knowledge, in addition to broad skill sets and specialist skills, and attitudes that facilitate creative and collaborative problem solving in a variety of workplace contexts (Boud & Lee, 2009).

Being the highest and most knowledge intensive form of education, Usher explains that the research doctorate finds itself in the middle of "contestation that pits the traditional values of the academy against the new values of the knowledge economy" (Usher, 2002, p. 145). This is because within the knowledge economy environment, the knowledge production processes pose certain problems for traditional university research. For example, publishing research findings in journal papers, scholarly books, and academic conferences remains the dominant and validated form of knowledge dissemination in academia. In the knowledge economy, in contrast, knowledge is circulated in less formal ways through online blogs, reports, or social media – achievements that are certainly not equally weighted as publishing in top tier journals in terms of career advancement in Mode 1. Because knowledge within this environment is seen as an economic asset, its value is then also measured through its utility in being applied and solving problems that arise. Usher does advise, however, that Mode 1 and 2 knowledge production models are not mutually exclusive or distinctly pure entities. The knowledge economy and its associated knowledge production practices do not necessarily mean the

dissolution of disciplinary learning and research. Disciplines will still exist and knowledge workers will still need to be initially trained in some disciplinary fashion, although perhaps not in its pure form, which is why universities will still play a significant role in the knowledge economy, just not an exclusive role. Usher argues that universities have become part of a wider global knowledge market, and due to the demands of the knowledge economy and the uncontrolled proliferation of information enabled by IT, cannot control and legitimate knowledge as before. This means that in order to survive, universities have had to partner with government, industry, and other bodies and leverage their specialised Mode 1 or disciplinary knowledge (Usher, 2002).

Despite universities being key players in the knowledge economy (Boulton & Lucas, 2008) and doctoral education being one of the best ways to build cultural capital, questions about the suitability of doctoral education within this complex, demand-driven environment and its fitness for purpose still persist. It is still contended that the research doctorate may not be the best way to produce the knowledge workers needed for the knowledge economy and its demands. It is criticised for being excessively narrow and specialised; for discouraging multi- or trans-disciplinary work; and for espousing a culture that conventionally precludes the involvement of industry, government, or other knowledge partners (The Group of Eight, 2013; Usher, 2002). This is arguably a reflection of the historically and culturally entrenched norms, rules, and values that have shaped Humboldtian doctoral education practice over the years. The enduring nature of these practices that have relied on the steady supply of graduates for the sake of disciplinary knowledge production will manifest in the tensions surrounding HDR skills training, as the literature review progresses.

In summary, discussions over the purpose of the PhD can be distilled into whether the purpose of the PhD is about the 'Product', that is, artefacts such as the thesis; the cutting-edge research; the original contribution of knowledge to the discipline; and related terms, or whether the PhD is about the 'Person', that is, the skilled researcher; the knowledge worker; and related terms (Oxford Learning Institute, 2016; Park, 2007; The Group of Eight, 2013). It is argued in this thesis that despite the apparent 'personal' focus of the paradigm of stewards of the discipline, its real and inherent focus and concern is the discipline and the knowledge of the discipline. In making this argument, the paradigm of 'stewards of the discipline' becomes synonymous with the terms under the umbrella of 'Product'. This definition is especially important because it will be used in content analysis of the findings in Chapter 5 and the discussion in Chapter 6. In summary: the paradigm of 'stewards of the discipline' is

synonymous with the 'Product' and the knowledge worker paradigm with the 'Person' when discussing the question of doctoral purpose.

Given Boud and Lee's (2009, p. 13) argument that there has been a "shift in institutional attention to the practices involved in doing doctoral work and producing doctoral graduates, rather than merely to the production of research outputs", it can be argued that the contemporary doctoral purpose has become more strongly about the student or knowledge worker (or the *Person*) and less about 'stewardship' and the ultimate concerns it has with the conservation of the discipline and its knowledge (or the *Product*).

2.3 Changes to Doctoral Education in the UK and Europe

In the previous section, it was mentioned that it is necessary in thinking about and doing research on doctoral education to begin with the conceptions of doctoral education purpose, especially given its influence on doctoral education practices. As Boud and Lee (2009, p. 5) put it, "Practice is purposeful, people are invested in it and it generates meanings and outcomes". Practices are here viewed as constituting the social world, and hence "involve actors, actions, settings, tools and artefacts, rules, roles and relationships" (Boud & Lee, 2009, p. 13). Having examined the debates on the purpose of the PhD and the paradigms that have shaped it, this discussion turns to doctoral education practice, and especially the major changes to doctoral education practices that have taken place in the UK and Europe, as these have informed some of the changes that have taken place within the Australian context, as will be seen in the following section.

Recognition of doctoral education as practice pays attention to doctoral settings, which can include: the discipline, the field, the laboratory, the policy context, the conference, the university more broadly, and so on. It also allows the contextualisation of doctoral education in both local and global settings. A focus on practice recognises the doctorate as consisting of people invested in creating shared understandings and actions: "We see at the heart of the doctorate a set of practices that produce both objects (knowledges, artefacts, institutions) and subjects (persons with skills, capabilities and attributes)" (Boud & Lee, 2009, p. 13).

One of the most influential reviews that took place in the UK higher education space is what is commonly known as the Roberts' Review (Roberts, 2002). Sir Gareth Roberts was a physicist who made a strong impact on the UK science scene, where his work in the university sector helped create career structures, support mechanisms, and skills provision for researchers and research students (Hilsum, 2011; Hodge, 2010). The purpose of the Roberts review or the *SET*

for Success review (Roberts, 2002) stemmed from the Government's unease that science and engineering graduates were inadequately prepared to work in industry. The review felt that the supply of high quality scientists and engineers should not limit the UK's future research, development, and innovation performance, given that continuous innovation is considered key to the existence and growth of businesses functioning in what are increasingly competitive global markets.

The review reported a number of key findings: decreases in the number of students studying mathematics, engineering, and physical sciences (for example, the number of enrolments in chemistry degrees dropped by 16 per cent between 1995 and 2000); mismatches in the skills possessed by graduates and those required by employers; decreases in the number of women interested in studying science at university; poor information about careers in science and engineering; unattractive career options in research for highly qualified scientists and engineers; concerns regarding postgraduate education, specifically regarding students' time-to-degree: that they were likely to need over three years to complete their degrees, despite funding generally being only available for three years; and deficiencies in science and engineering graduates' transferable skills training (Roberts, 2002).

Roberts explained that because institutions were not responding and adapting promptly to the needs of industry or the expectations of future students, the Review recommended that PhD skills training, especially in transferable skills, needed to be strengthened considerably. PhD student funding had to become conditional on a student's training meeting strict minimum standards. These minimum standards included providing at least two weeks of dedicated transferable skills training per year, for which additional funding would be provided (Roberts, 2002). Doctoral supervision was also on the list, with Roberts recommending that Higher Education Institutions (HEIs) and other institutions in which PhD students work reward good supervision. His review further recommended that HEIs strongly encourage PhD projects that tested or developed the creativity valued by employers (Roberts, 2002). As a consequence of that review, Research Councils UK (RCUK) invested around £120 million, commonly referred to as 'Roberts' Money', in research organisations to address these concerns across all research disciplines (Hodge, 2010).

In Europe, the 'Bologna Declaration' led to extended reforms in the European university system. The reforms produced a system of three 'cycles' that allowed degrees to be easily comparable, consisting of a first cycle which provides an entry level qualification into the

workplace (The Bachelor Degree), a second cycle (The Master Degree), and the third cycle or Doctoral Degree, with a system of credits across Europe, and encouraged student mobility (European Higher Education Area, n.d.; European Ministers of Education, 1999). Additionally, under the European Charter for Researchers (European Commission, 2015), all researchers employed in a research career, including doctoral candidates, are recognised as professionals and treated as such. This means that employers and funders of research ensure that researchers have fair pay, equitable social security provisions, equal opportunity, pension rights, career development, and unemployment benefits under the law.

In reviewing the major reforms that shaped doctoral education practice in the UK and Europe, one sees how the knowledge worker paradigm was underpinning both doctoral purpose and practice. Concerns regarding the students and the adequacy of their training were emerging, and the language of doctoral education was being coloured with terms related to students' transferable skills and their employability within non-academic contexts. In a similar fashion, these shifts could be seen in Australia. In the following section, the major milestones that have shifted doctoral education practice in Australia are presented, as part of the ongoing and overarching discussion on doctoral education practice.

2.4 Changes in Doctoral Education Practices in Australia

Observing the major changes that have taken place within the doctoral education space in Australia can provide an understanding of what has shaped and now constitutes doctoral education practice in Australia. In *Reflections on change in doctoral education: an Australian case study*, (Kiley, 2017b) makes reference to three government reports that significantly influenced doctoral education in Australia at both organisational and educational levels since the 1980s. These reports are commonly known as the 'Dawkins Reform', 'The Kemp Report', and 'The ACOLA Review'.

Under the Dawkins Reforms, named after the Federal Minister of Education John Dawkins in the 1980s, the then Colleges of Advanced Education and Institutes of Technology were to be merged with universities to make what was known as the unified system. As a result, the number of doctoral enrolments increased, professional doctorates further proliferated, and the Australian government instituted quality reviews of doctoral education (Kiley, 2017b). Perhaps what is more notable is how the Dawkins Reforms began paving the path of employability for doctoral reform, with the increased focus on using the higher education sector to produce skilled people capable of working in a globalised economy:

> The central concern of the white paper process was to determine reforms that would expand the capacity and effectiveness of the higher education sector. With swift economic changes in the early 1980s, including decline in Australia's traditional industries and commodity-based export income, policy makers perceived a need to develop our advanced manufacturing and service industries, and increase reliance on high level skills, adaptability and entrepreneurship, to compete in a globalised economy (Department of Education and Training, 2015a, p. 11).

By the late 1990s, Federal Minister for Education David Kemp issued the white paper *Knowledge and Innovation: a policy statement on research and research training,* also known as the Kemp Report (Kemp, 1999). The report identified several changes required in doctoral education in Australia, such as improving student learning outcomes, completion times, rates, and better industry linkages. Here, the employability of research graduates resounds more loudly with:

> … persistent concerns identified by students, research institutions and employers regarding the quality and breadth of research training including:
>
> - research programmes that are too narrow, too specialised and too theoretical leading to graduates whose communication, interpersonal, and leadership skills require further development;
> - limited opportunities for students to gain experience in appropriate research environments, which tends to promulgate a cultural gap between academic researchers and staff in industry;
> - graduate outcomes both in terms of attributes and employment; and research degree graduates are often inadequately prepared for employment (Kemp, 1999, pp. 2, 17–18).

The primary impact this had on doctoral education practices was the introduction of the Research Training Scheme in 2000 by the Australian Government. The scheme reorganised funding such that universities were paid based on student completions. If a candidate did not complete, then the university did not get the full funding. Additionally, funding was allowed for a maximum of four years. If a student took five years to complete, the university would still be paid for only four years. This led to universities introducing skills training for students, such

as writing and research methods programs, to help ensure students' timely completion, and innovative supervisor development programs (Kiley, 2017b).

By 2016, the employability agenda had taken centre stage in the Australian doctoral policy narrative. Under the direction of Minister of Education Christopher Pyne, the Federal Government commissioned the Australian Council of Learned Academies (ACOLA) to undertake a review of Australia's Research Training System, to ensure that it met Australia's 21st century research needs (Department of Education and Training, 2015b). The review aimed to deliver on the Australian Government's commitment to increasing economic revenue from research by ensuring that researchers were better prepared to work with industry (Department of Education and Training, 2015b). This review forms part of the *Securing Australia's Future* program, a $10 million investment announced in 2012, which was a series of research programs delivered to the Australian Chief Scientist and the Commonwealth Science Council and coordinated by ACOLA, to provide research-based evidence to support policy development in areas important to the future of Australia (Australian Council of Learned Academies, 2016).

Several findings and recommendations were made which were specifically fastened to an HDR employability agenda. Particular attention was paid to the interaction between university and industry research, such as providing candidates with industry placements and internships, and the need to focus on graduate employability through things like skills portfolios and broader transferable skills training that opened up graduate career paths in non-academic settings. It was suggested that universities have a moral obligation to inform students of possible career opportunities and outcomes following graduation, despite there being inadequate data to provide this information. Because of this, the report required universities to collect information on graduate employment by sector in order to provide realistic career expectations for candidates, and to collect data for ongoing and long-term evaluation and benchmarking of Australia's research training performance. Doctoral examination was also considered, with the agreement that greater weighting should be placed on assessing the candidate and their skills as opposed to the predominant focus on assessing the thesis. Finally, providing quality supervision was recognised as enabling supervisors to provide better career advice and training for candidates, and was recommended to be achieved through better supervisory training programs and supervisor monitoring (McGagh et al., 2016).

In reviewing these specific major changes that have occurred in the history of doctoral education practice in Australia, one can observe the steady emergence and prominence of an employability agenda concerned with ensuring that HDR graduates are equipped with the

knowledge and skills that enable them to access and maintain a wide range of employment sectors that span beyond the traditional academic career. This marks the shift in doctoral purpose mentioned earlier in the literature review, from the focus of the outcome of a period of doctoral study being about the knowledge produced and the consequent maintenance of the discipline, to a focus on the student as a knowledge worker who is expected to navigate the post-PhD workplace using their knowledge and skills as economic assets. In other words, this can be summarised as the marker of the shift in doctoral purpose, underpinning doctoral practice, from the 'Product' to the 'Person'.

2.5 Employability and the Doctorate

The previous section on doctoral education practice in Australia shed light on the emergence of an HDR employability agenda, shifting the focus and purpose of doctoral education from preparing stewards of the discipline as means of knowledge creation and disciplinary survival, to preparing job-ready knowledge workers. Given the prominence of this agenda in shaping both the purpose and practice of doctoral education, it is necessary to examine and question the very meaning of employability and the possible implications of this employability agenda.

2.5.1 What is 'Employability'?

The literature on employability reveals "two contrasting constructs" used to explain it – one focused on the personal attributes an individual ought to have in order to gain and maintain employment, while the second focuses on more external factors such as social, economic, and labour market situations that can influence an individual's capacity to achieve and maintain employment (Sin & Neave, 2016, p. 1449).

For example, Brown, Hesketh, and Williams (2003) define employability in dualistic terms: individual characteristics make up the absolute dimension, while economic conditions and job competition construe the relative dimension. Similarly, McQuaid & Lindsay (2005) explain employability in terms of an individual's skills and knowledge, family commitments, macroeconomic factors, and employment policies.

Molla & Cuthbert (2015, p. 242) state that "broadly viewed, research graduate employability refers to graduates' skills and attributes, and their capacity to translate them into high functionality in a range of employment situations". It is expressed that the ability of the graduate to gain employment depends upon both personal and external factors. Personal factors would be a graduate's level of education and specialisation, transferable or

employability skills, while external factors would include labour market conditions. These aforementioned transferable skills may relate to teamwork, critical thinking, creative thinking, communication, introspection, and career resourcefulness.

Similarly, for Hillage and Pollard (1998, p. 3), employability is seen as one's agility and mobility within the employment space, and this mobility is facilitated and constrained based on one's personal attributes and qualities as well as the economic and employment conditions:

> Employability is the capability to move self-sufficiently within the labour market to realise potential through sustainable employment. For the individual, employability depends on the knowledge, skills and attitudes they possess, the way they use those assets and present them to employers and the context (e.g. personal circumstances and labour market environment) within which they seek work.

Clarke (2017) explains that this definition recognises employability in economic terms, and that it is contingent upon both individual characteristics (supply factors) and contextual characteristics (demand factors). She argues that while recent debates on employability have focused on the individual knowledge, skills, and attributes of graduates, it is equally important to consider demand factors such as job competition and required skills. This also includes factors such as national and global economic status and geographic location. Under unfavourable circumstances, these can lead to unemployment and less secure employment arrangements, despite individual characteristics that might suggest a high level of employability.

While some have described employability in relation to 'graduatedness', with the key elements that constitute it being reflective thinking, scholarship, citizenship, and lifelong learning (Steur, Jansen, & Hofman, 2012), others have expanded this definition to include broader social and processual factors. For example, Holmes (2013) constructs a definition of graduate employability with three constituents: one's possession of human capital, one's social position or social capital, and one's ability to self-manage their career. Holmes (2013) argues that a graduate's social background will affect the type of university attended and consequently, the student's educational learning and experience and the knowledge, skills, and attitudes they bring with them to the job market, including their capacity at building proactive career behaviours such self-management and career exposure. This identity is presented to employers to unlock the desired career pathways. Their social class will also affect the type of employment they can access (Holmes, 2013).

Fugate, Kinicki, and Ashforth (2004), on the other hand, put forth a psychological view of employability. They suggest that employability includes three key aspects: adaptability, work identity, and social and human capital. Adaptability means that individuals can tolerate uncertainty and ambiguity. Career identity provides direction and purpose to career-related pursuits. Social capital involves an individual's social networks that assist in job-related activities and can improve employment outcomes, while human capital includes one's age, educational experience, and cognitive ability.

This section of the literature review examined the meaning of employability closely by referring to the scholarly debates and discussions surrounding this term. What emerges from the synthesis of these debates is that employability can be defined in two terms: firstly, at the level of the individual or agent, that is, the knowledge, skills, and attitudes they need to possess to achieve gainful employment and maintain it. And secondly, a definition in terms of external factors such as the state of the economy and the nature of the job market.

In recognising these two definitions, the factors that have come to shift conceptions of doctoral purpose and practice to their current state to define and frame employability in individualistic terms become clear. The employability agenda poses traditional HDR skills training as a problem residing within the graduate, and remedies this by shifting doctoral education practices to include 'generic' and 'transferable' skills training, internships, and increased industry collaboration and exposure for HDR candidates. What this employability agenda does is produce another agenda: the HDR Skills Agenda. This agenda and its ensuing debates are arguably some of the most contentious within the doctoral education space, with terms such as 'generic', 'soft', and 'transferable' skills becoming subjects of fierce criticism in the literature.

2.5.2 The HDR Skills Agenda

As mentioned by Gilbert, Balatti, Turner, and Whitehouse (2004), despite knowledge production being the traditional purpose of the doctoral degree, interest in developing generic skills has proliferated within the program. Desire for economic growth (Neumann & Tan, 2011; Pedersen, 2014), the wider employment destinations of research graduates (Neumann & Tan, 2011), the decreasing number of academic positions (The Royal Society, 2010), and arguments that PhD programs are too narrow for wider workplace employment (Edwards & Smith, 2008; McGagh et al., 2016; The Group of Eight, 2013) have propelled the HDR skills agenda and

accelerated the transformation of research into professional practice (Clark, 1996 as cited by Manathunga & Lant, 2006; Gilbert et al., 2004).

Gilbert et al. (2004) show that consistently across the USA, UK, and Australia, various education-related bodies have both engaged in and responded to the HDR skills debate by prescribing lists of skills deemed important to be acquired by research students and enforcing them through development programs of various forms. In the USA for instance, Nyquist (2002) identified a series of core competencies for successful post-PhD careers based on developments in a number of national initiatives concerned with PhD reform. Some of the competencies include: disciplinary knowledge, informed career choice, teaching and mentoring competence, interdisciplinarity, communication skills, and ethical awareness (Nyquist, 2002). In the UK, Vitae (Careers Research and Advisory Centre (CRAC) Limited, 2016) is committed to realising the potential of researchers by focusing on their professional and career development, with much of its work funded by the UK Research Councils. The Researcher Development Statement (RDS) developed by Vitae sets out the knowledge, skills, and attitudes of effective and highly skilled researchers suitable for a wide range of careers (Careers Research and Advisory Centre (CRAC) Limited, 2011). Its four structures are summarised in Table 2-1:

Table 2-1 Summary of Vitae's Researcher Development Statement

Knowledge and intellectual abilities	Personal effectiveness	Research governance and organisation	Engagement, influence and impact
The knowledge, cognitive abilities, and creativity required to carry out research of high standard.	The personal qualities, self-management skills, and professional career development approaches to be an effective researcher.	The professional conduct, research management, and financial and funding knowledge and skills for excellent research.	The knowledge and skills to work in teams and communicate the broader impact of research.

Similarly in Australia, the Australian Qualifications Framework (AQF) "establishes the quality of Australian qualifications" and this includes doctoral education (Australian Qualifications Framework Council, n.d.-b). The *AQF specification for the Doctoral Degree* lists the knowledge and skills that graduates of a doctoral degree will be expected to have, such as knowledge at the frontier of a field, knowledge of research methods, understanding of theory, expert technical skills, communication skills, and skills to plan, apply, analyse, theorise, and communicate research (Australian Qualifications Framework Council, 2013a). McGagh et al. (2016) group HDR skills into three categories: research skills required to be an effective researcher; transferable skills required for success in a wide range of careers; and other broader

capabilities. Even though their report attempted to group these skills, McGagh et al. (2016) acknowledge the significant overlap in their review submission responses for these skills.

Despite there being considerable overlap among these skills, universities still identify their own sets of learning outcomes and in so doing, market themselves to and promise prospective students a worthwhile university experience. Clarke (2017) explains and summarises that skills such as communication, numeracy, information technology, learning how to learn, thinking skills, intellectual openness, curiosity, ethical standards, professionalism, self and time management, reliability, creativity, self-confidence, team work, problem-solving, and planning have dominated higher education institutions and government initiatives across the UK, Australia, and Europe, and serve to fulfil this purpose.

A myriad of terms have been used to describe such skills both synonymously and interchangeably; examples of such terms include skills, attributes, transferable, generic, employability-related skills, and graduate outcomes (Cumming & Kiley, 2009; Gilbert et al., 2004; Kiley, 2006). Compounding this is a lack of consensual theoretical clarity and agreement over the purpose and development of these skills (Bridgstock, 2009; Gilbert et al., 2004; Manathunga & Lant, 2006).

Criticisms also extend to the nature of skills and skills training, with concerns raised as to whether these skills are transferable at all, whether they are context-free, and whether this training would be at the cost of deep learning and the pursuit of 'truth' historically associated with academic scholarship, and therefore, threaten the traditional purpose of doctoral research (Kemp J. and Seagraves (1995), Marginson (1994) as cited by Jones (2009); Perkins and Salomon (1994) as cited by Jones (2009)).

Hyland and Johnson (1998) question the notion of skills transferability and cast serious doubts about it, pointing out that:

> There is no general routine, no one set of procedures, no algorithm that will *at the same time* facilitate the solving of a chess problem, show people the way out of difficulties in personal relationships, diagnose an electrical fault and help sort out a difficult passage in Hegel.

On the other hand, Jones (2009) offers an interpretation of 'transferability' anchored in the disciplines in which those skills are taught in her examination of the teaching of generic attributes in physics, history, economics, medicine, and law in two Australian universities.

Through semi-structured interviews with academic staff, the author finds that some skills have more commonality than others. For example, she argues that skills such as critical thinking share a number of similarities across disciplines, such as a general concern with evidence, argumentation, and being inquisitive:

> In terms of critical thinking and analysis, elements that run across most of the disciplines are: first, a concern with evidence, be that contextual, experimental, clinical, theoretical or technical; second, a concern with argumentation or logic in various forms, such as informal logic, mathematical logic and the ability to use a model within its boundaries; and, third, critical thinking in most disciplines is concerned with questions involving disciplinary theorising, assumptions, methodological questions, the frontiers of the discipline and areas of serious controversy within the discipline. (Jones, 2009, p. 95)

However, skills such as problem solving can be highly discipline-specific and dependent upon the knowledge of the discipline

> Problem solving, in contrast, is highly discipline specific and is tied to the technical or content knowledge of the discipline. As a consequence, the exact form that problem solving takes in each discipline is different. For example, in physics it will be problems to do with the physical world, will use mathematics and physics theory and may be experimental or theoretical. These forms of problem solving can be used in related fields, such as engineering, for example. In contrast, problem solving in law requires the understanding of legal principles, and the conventions of legal reasoning. Each form of problem solving requires particular disciplinary knowledge, and an understanding of the problem solving methods utilised by that discipline. (Jones, 2009, p. 96)

while other skills will have common elements but differ in their expression:

> Communication has some commonalities across the disciplines, in that there is an expectation that students will learn to express their ideas in a clear and well-organised manner. However, the forms and genres of communication vary between disciplines: for example, physics requires mastery of a laboratory report, whereas history and law may require essays. Even then the term 'essay' is a vague term, and the requirements of an essay in history are different from an essay in law. (Jones, 2009, p. 96)

Jones proposes that one might be able to apply these skills in different areas by having the willingness to inquire and reflect in other areas of knowledge, while simultaneously being aware and understanding the structures of knowledge within those areas. Her conclusions resonate with those of Craswell (2007), who argues that while some skills may 'transfer' smoothly, others may not and may need to be 'adapted' instead:

> There may be a smooth transfer of problem solving skills for an Engineering HDR student proceeding to an Engineering career. But then, a similarly qualified History student taking a position in, say, the Public Service, might well bring a fresh approach to identification and resolution of a problem by applying learnt skills out of context. Many skills developed by PhD graduates during candidature will transfer across sectors… However refined project design and management skills developed during the course of a PhD, these skills will need to be *adapted* to accommodate workplace exigencies, demands of the particular situation of production that will surely impact on overall design and management. Likewise, however sophisticated the communication skills attained in a doctorate (e.g. in writing proposals, reviews, theses, publishing articles or in presenting at conferences), these skills will also need to be *adapted* to situations where workplace imperatives impinge on the writing, where students encounter new genres, new styles of writing and presenting, new practices, new audiences (Craswell, 2007, p. 383).

The aim of this section of the literature review was to highlight the fraught nature of the HDR skills agenda and arising debate. This debate has generated lists and lists of skills in an attempt to address the different demands and criticism mounted over this topic. The ACOLA review alone (McGagh et al., 2016) produced a 'non-exhaustive' list of over 50 categories of skills and qualities expected of graduates in Australia. The conceptual congestion and complexity of definitions in this space posed a challenge for this research project in which the literature on doctoral education was being used to formulate the research tools and general framing necessary to be used within the discipline of chemistry.

For example, Cumming and Kiley (2009, p. 7) attempt to distinguish attributes at the HDR level into two broad categories – academic and employability skills:

> Academic skills typically include an understanding of a coherent body of knowledge, the ability to undertake research, and the ability to analyse information and apply

> knowledge. Employability skills such as communication, problem solving and teamwork are generally at or near the top of the list (Cumming & Kiley, 2009, p. 7).

But the definition is not without its problems. For example, communication, which is defined as an employability skill, is still a necessary academic skill for lecturing, researching, and supervising. The ability to analyse information, which is defined here as an academic skill, is also needed in the non-academic workplace.

To remedy this, the following skills classification and definitions is presented in Table 2-2, synthesised from the discussion above and informed by Monash University's Professional Development Website (Monash University, 2020):

Table 2-2 Reformulated Skills Classification System

Type of Skill	Definition
Closely Related to Academic Work	These skills are closely related to academic work.
Relevant to Academic Work & Beyond	These skills can be relevant to academic work. They are generally more closely related to non-academic work environments.

First of all, the term 'academic work' is defined in the broadest sense: these are the skills needed to succeed in academia, and that includes the skills needed in the work done to complete the PhD. Skills closely related to academic work can be skills such as interpreting NMR spectra. This is a skill very closely related to work done in the discipline of chemistry. That does not mean that it may not be of use in a niche chemical company – these are skills *closely* related to academic work, not *exclusive* to it. Skills relevant to academic work and beyond can be skills developed during science outreach activities to schools. These would be relevant for wide-ranging jobs that require evidence of public speaking and being able to communicate to generalist audiences. Not that these skills may not be *relevant* to academia, they are just more closely related to non-academic work. The language used here avoids exclusive categorisations, and recognises the 'grey spaces' surrounding the whole notion of skills. The value of this system is that it also resolves the issues when using terms like 'communication skills' loosely. So for example, writing a journal paper is a communication skill. So is writing a policy brief for the ACT Chief Minister. Both are examples of written communication skills. But writing journal papers is a skill more closely related to academic work. It may be of use outside of academia, but would likely need to be *adapted* to suit that environment. Writing policy briefs and reports to the ACT Chief Minister can be a skill relevant to academic work, but more closely related to careers that require short and succinct

forms of writing. This system of skills classification will be an important component in the coding and analysis of the data from this study.

2.6 Supervision of the Doctorate

The literature review so far has examined the main debates in the doctoral education literature relating to doctoral purpose and the paradigmatic shifts that have occurred in that space, as well as doctoral practice and the changes that have led to greater emphasis being placed on the candidate and their training for wide-ranging career pathways. This section of the literature review directs attention to doctoral supervision and supervisors. It examines the important role supervisors play in socialising students into the discipline, supervisory practice, and supervisory evaluation. It also acknowledges the actions universities have taken in response to the employability agenda. In so doing, this provides an argument that justifies selecting doctoral supervisors in chemistry as participants for this study.

2.6.1 Supervisors and their Role in Student Socialisation

Since supervisors are members of disciplines and subscribe to the norms, rules, and values that shape and validate disciplinary thinking and behaviour, it is useful to examine the role of supervisors and their practices from the perspective of disciplines. Perhaps some of the most recognised ways of disciplinary classification have been produced by the psychologist Anthony Biglan, who designed a system or typology that classified disciplines based on beliefs and self-perceptions of their own members. It divides and distinguishes disciplines into 'hard' or 'soft' disciplines, such as the differences between the physical sciences and the social sciences. Generally, academics in the 'hard' sciences were found to be socially connected, interested and involved in research, and more likely to focus on publishing in journals. Academics in the 'soft' sciences were more focused on teaching and publishing monographs, and were found to be less socially connected (Krishnan, 2009; Swarat et al., 2017; Taras, 2005). In similar terms, the work of Becher and Trowler (2001) mirrors that of Biglan (1973) in so far as it describes disciplines as 'tribes' and 'territories' where "academic cultures [are] (the 'tribes') and disciplinary knowledge [is] (their 'territories')" (Becher & Trowler, 2001, p. xv).

If disciplines are marked by cultural and knowledge parameters, this means that there are moral dimensions to disciplines that require people to think and act in certain ways. In this vein, the French philosopher Michel Foucault notably interpreted 'discipline' as a practice enforced on people to transform them into submissive and obedient individuals. This includes academic disciplines and their attempts at bringing about 'discipline' in society. The now

disciplined individual internalises these views and values as their own, so overt dominance is no longer required. Foucault viewed disciplining as a system of limiting an individual's freedom by constraining their discourses (Krishnan, 2009; Sugimoto & Weingart, 2015).

Perhaps Foucault's explanations are better clarified by socialisation theory. Socialisation is the process through which an individual gains the knowledge, skills, attitudes, characteristics, and the habits of mind necessary to function and be part of a social group, community, culture, or organisation (Bragg, 1976; Merton & Reader, 1957). Given that disciplines can easily be seen as social groups, communities, and cultures, socialisation theory can then be extended to disciplines. Austin (2002) explains that each discipline defines its research paradigms and the relationship among its scholars, and that makes a difference to the lives of these individuals:

> These disciplinary variations can make significant differences in the lives of faculty members. For example, a faculty member in English is likely to conduct research alone, while a professor of chemistry is more likely to have a team of colleagues and graduate students with whom he or she collaborates. Humanities scholars tend to value books and monographs as products of intellectual work, whereas natural and physical scientists, and many social scientists, tend to favour refereed articles (Austin, 2002, p. 97).

These ideas can be further extended to the socialisation of doctoral candidates, where the duration of candidature is seen as a period of socialisation in which they learn the knowledge, skills, attitudes, cultural rules, norms, and values, both explicitly and implicitly, that constitute belonging to and being a member of their chosen discipline (Austin, 2009; Gardner, 2007, 2010; Golde, 2005; Weidman & Stein, 2003). This is not dissimilar from the notion of apprenticeship whereby the master teaches the student the knowledge required to become a researcher, and the 'tricks of the trade' to become part of the discipline (Austin, 2009; Park, 2005). Therefore, it can be argued that supervisors, by virtue of their socialisation and apprenticing practices, are an important 'cultural reservoir' of the discipline, and perhaps arguably the "most powerful socialization agents of doctoral students" (Fogarty & Jonas, 2010, p. 304).

2.6.2 Supervisory Practice

Supervising doctoral candidates is a complex task in which supervisors play a critical role in socialising the student into the discipline, affecting the student experience, and affecting their career options (Barnes & Austin, 2009; Bøgelund, 2015; G. Gregory & E. Lovitts, 2003). The complexity of this task is further accentuated by the different interests to which supervisors

must attend. For example, as universities incorporate new knowledge production agendas, supervisors are expected to adapt to them in preference to traditional academic and professional aims (Bøgelund, 2015). The difficulty of this task is further compounded by the students' needs and the supervisor's own motivations (Wright, Murray, & Geale, 2007). Some researchers such as Ferris (2002) argue that a collaborative research partnership model most appropriately represents doctoral supervision, while others such as Vilkinas (2008) express that a corporate management model is more appropriate.

Supervisory practice is also characterised by individual 'approaches' to supervision. Sinclair's (2004) pedagogy of 'good' PhD supervision highlights key supervisory approaches that can lead to steady PhD completions. In his study, he argued that some supervisors take a 'hands off' approach to supervision and leave candidates to develop on their own. However, the author explains that only a minority of students enter their PhD with the ideal knowledge and skill base to undertake a project with a 'hands off' supervisory approach. But 'hands on' supervisors recognise this situation from the onset, and through a relatively interventionist supervisory approach, can assist students with faster completions (Sinclair, 2004). The author further sheds light on the importance of 'hands on' supervision by adding that these supervisors "demystify the PhD exercise" (Sinclair, 2004, p. vii) by helping students structure their candidature in its early stages. In particular, 'hands on' supervisors establish a bond of trust with their students, recognise the power imbalance in the relationship, and use their superior position to professionally develop the candidate as a peer (Sinclair, 2004). 'Hands on' supervisors recognise their own and their students' conceptions of research and supervision, and continually adapt and tailor their supervisory styles to help them progress in their candidature to develop to their fullest (Bills, 2004; Nulty et al., 2009; Sinclair, 2004). Western et al. (2007) provide similar commentary on supervisors who extensively monitor their students, finding that these students were less likely to be unemployed, and earned more, compared to students with less involved supervisors.

This means that in addition to being the 'cultural reservoirs of the discipline' and powerful socialising agents of students, supervisors also play an important role in the professional career development of their students.

2.6.3 Supervisory Evaluation

In this section on supervision of the doctorate, attention is given to the practice of doctoral evaluation. Two kinds of evaluative practices can be found in doctoral education: candidate

evaluation of their program through surveys and questionnaires such as the Postgraduate Research Experience (Graduate Careers Australia, 2015b) and follow-up surveys and studies on graduates regarding career outcomes such as the Postgraduate Destinations (Graduate Careers Australia, 2015a).

At the time of reviewing the literature, several issues had been raised regarding HDR supervision in Australia. Specifically, the ACOLA review (McGagh et al., 2016) paid close attention to the issues surrounding supervision in Australia by citing the Postgraduate Research Experience Questionnaire in their report, and pointed out that although survey data on supervisory experiences has been generally good, quality varies between supervisors, disciplines and institutions, with almost one in five graduating candidates being unsatisfied with the quality of their supervisory experience.

The absence of training for future supervision during candidature may account for this, coupled with most supervisors basing their supervisory practices on their own experience of supervision (McGagh et al., 2016; Probert, 2014). With no formal training, candidates who experienced poor quality supervision themselves are likely to perpetuate poor supervisory practices, unless they are alerted to supervisory 'best practice' as early career academics. Furthermore, universities assume that supervisors with years of experience require no training professional development, despite the expectations of candidates and the needs of employers constantly changing (Pearson & Brew, 2010). A lack of awareness of current employment outcomes can also compound supervisory effectiveness and quality.

Despite the relationship between supervisor and candidate being a very important factor in student attrition, there are no recognised best practice standards for HDR supervision in Australia (Kiley, 2011; Pearson, 2012). It has therefore been argued that universities must address how to supervise and support candidates in finishing on time and being work ready (McGagh et al., 2016). Supervisor training would better prepare supervisors to support the career development of their students, develop a wider range of supervisory skills tailored towards the needs of the discipline and the students, and clarify expectations between supervisor and candidate. The report also suggested that Australia's Research Training System would benefit from a national model of supervisory evaluation and accreditation. This would allow for the collection of performance data through measures such as candidate evaluation, completion time and rates, and career outcomes for graduates. It has been suggested that such data should be collected at the level of the discipline, and that the data within Excellence in Research Australia (ERA) reports or Quality Indicators for Learning and Teaching (QILT)

surveys. Through this data, benchmarks can be constructed and recognition given to supervisors who meet or exceed these benchmarks. Conversely, supervisors who are underperforming could be identified and investigated, and be provided with additional training and support or removed. Finally, a complaints system for students would further assist in the collection of performance data and help ensure quality supervision (McGagh et al., 2016).

The discussion so far has highlighted an existing dissatisfaction with the quality of supervision among HDR graduates. To remedy this, the discussion has noted the need for supervisory development interventions that improve the quality of supervision offered in Australia, including enabling supervisors to help prepare candidates for the workplace. In addition, the need to follow up on graduate career outcomes and using this kind of evaluation feedback to support the continual development of supervisors was underscored. This last point, in particular, is complemented by the early work of Pearson and Kayrooz (2004) who discuss the importance of critical reflection on research supervisory practice.

In their article, the authors object to the absence of attention given to enhancing supervisory practice through student feedback, citing that feedback is often informal and altogether problematic given the close nature of the relationship between the candidate and their supervisor and power difference between the two. Despite these issues, Pearson and Kayrooz (2004, p. 101) argue that in the absence of such feedback and follow-up, supervisors are "denied access to data about their practice as perceived by others" and specific, rich insights regarding the complex nature of supervision become obscured. The authors reinvoke Margot Pearson's (1999) argument that organisation-level surveys will not produce this kind of rich and nuanced feedback (Pearson & Kayrooz, 2004). Feedback presented in the aforementioned surveys in the beginning of this section tended to be generic in nature and did not provide the tools for supervisors to enable critical reflection on their practices. Therefore, this thesis argues for supervisory follow-up with graduates regarding their careers, but specifically in relation to supervisors' measures of self-success. In other words, how do supervisors know that they have succeeded with their students as supervisors, and how does this relate to their follow-up with students on career outcomes? This is an important question that will feature in the methodology underpinning this study.

2.6.4 University Responses to the Increased Focus on Student Employability

Section 2.6 of the literature review focused on the critical role supervisors play in the life of the doctoral candidate: in socialising them into the discipline, in developing their capabilities for

post-PhD careers, and in seeking and reflecting over feedback from them on their own practice in relation to graduate career outcomes. This final section sheds light on how universities have responded to this shift and increased focus on student employability. It acknowledges the work done by universities in this space, but argues for this research to be centred on chemistry PhD supervisors as study participants for the reasons argued so far.

University responses can be summarised under the main themes of changes to entry pathways into the PhD and changes in candidate skills training.

2.6.4.1 Changes to Entry Pathways into the PhD

Universities have responded to the changes within the doctoral education space in the way prospective candidates are admitted into research doctorate. What might have been the traditional "gold standard for entry", the Honours degree, faces decreasing enrolments (Kiley, 2017b, p. 82), as well as concerns over its short duration (nine months) and its lack of breadth and depth, which can result in underprepared candidates for HDR training, as well as difficulties in comparing it to other international qualification frameworks (Kiley et al., 2011; McGagh et al., 2016).

As described by McGagh et al. (2016), Coursework and Research Master's Degree have been regarded as alternative pathways to the PhD in Australia. The increasingly prevalent requirement for a research component within the Masters by Coursework degree is considered to have lifted its status as a valid entry pathway into the PhD, while the lower entry requirements for Research Masters compared to those of the Research Doctorate could help those from non-traditional backgrounds and those with industry experience to enrol in research degrees. Given the increases in prospective candidates' ages, part-time enrolments, and international enrolments, students are more interested in studying a Master's degree than an additional undergraduate year of Honours (Kiley, 2017b). This has led to an increase in the percentage of candidates entering a doctorate with a Masters by coursework compared with an Honours or a research master's (Kiley & Cumming, 2015). A few Universities have responded to this by introducing a four-year PhD which provides a year of coursework as part of the PhD followed by a three-year research project. Similar models include the 'Macquarie model' with a three-year undergraduate degree, two-year Master Degree, and a three-year PhD (Kiley, 2017b).

2.6.4.2 Increased Focus on Skills Training

Many universities have responded to the employability and HDR skills agendas by introducing transferable skills programs and internships for candidates. A general search of university

websites in Australia reveals research training offered in different ways, such as through Research Training Units running at the central level of university administration or through library workshops and online resources. While the ACOLA review (McGagh et al., 2016, p. 40) acknowledged that HDR graduates develop a range of skills, it also highlighted concerns regarding:

- the extent to which skills and transferable qualities are already being delivered, or need to be delivered, through existing HDR programs and/or other mechanisms
- the best ways to deliver both broader and specialist disciplinary skills through HDR training
- whether such skills development and/or assessment should be mandated for inclusion in HDR training.

These concerns were further compounded by the lack of data on graduate destinations and thus the reduced ability of universities to tailor skills training to candidates. Industry placements were commended for the delivery of industry-relevant experience and transferable skills either through formal, credited placements or encouraged as an opportunity for students to work on 'real-world' problems while building their industry networks (McGagh et al., 2016). Within that context, the Australian Cooperative Research Centres (CRCs) are intended to bring together universities, businesses, and governments to collaborate in interdisciplinary scientific research with an applied slant, although the programs are not without their contentions (Pitt, Cox, & Manathunga, 2009).

Despite the uncertainty regarding the extent to which skills training in Australia is delivered or needs to be delivered, Borthwick and Wissler (2003) offered some clarity over these concerns. While the data dates back to 2003, it gives a glimpse into the offerings in this area. As far back as the year 2000, universities were moving quickly to provide their HDR students with workplace-relevant skills development in addition to the research-based knowledge. Development focused on leadership and communication, project management, collaboration and team-work, commercialisation, entrepreneurship, career planning, self-development, globalisation and cultural awareness, public policy, and teaching.

Borthwick and Wissler (2003) also presented data on modes of delivery of such skills. Face-to-face presentations continued to be the dominant mode of delivery, including workshop programs. This was followed by online delivery, with the intention to build more extensive and

robust systems into the future. Programs also differed in duration, from half a day to three days or more.

Denicolo, Fuller, Berry, and Raven's (2010) work complements that of Borthwick and Wissler (2003) by showing how institutional changes within the university sector have facilitated the implementation of the HDR skills agenda. They explain that concerns over successful submission and completion rates of research degrees led academics and other stakeholders to consider the need to establish effective training and support for research students. This gave rise to a model known as the 'graduate school', an organisation within universities responsible for promoting high quality graduate education and administration. The authors argue that the advantages and added value of doctoral/graduate/research schools are that they (Denicolo et al., 2010, p. 17):

- Define a mission or vision shared by all partners that facilitates the process of turning doctoral candidates into excellent researchers;
- Provide a stimulating research environment and promote cooperation across disciplines;
- Provide a clear administrative structure for doctoral programmes, candidates and supervisors, and offer a clear profile and status for doctoral candidates;
- Ensure critical mass and help to overcome the isolation of young researchers;
- Bring junior and senior researchers together;
- Support and facilitate the task of supervising candidates and the role of supervisors;
- Organise admission with transparent rules and regulations;
- Provide teaching and transferable skills training;
- Provide enhanced career development opportunities, including advice on funding opportunities (scholarships, projects);
- Guarantee quality assurance and monitoring;

- Provide a framework allowing the development of codes of practice, procedures and mechanisms within the university structure and act as an independent arbitrator or ombudsman where necessary;

- Enhance opportunities for mobility, international collaboration and inter-institutional cooperation.

This section of the literature review has demonstrated some of the actions universities have taken in response to the increased focus on HDR student employability in Australia. It is expected that universities will take further actions as the recommendations of the ACOLA review begin to be translated from policy to practice. Despite the work done by universities at the central level to improve the skills of HDR candidates, the arguments presented in this section recognise the unique role that supervisors play as the 'cultural reservoirs' of the discipline and as the most powerful socialising agents of students. The section has explored the ramifications of supervision on postgraduate career opportunities, and the need for supervisors to reflect upon their own practice through evaluation and follow-up on graduate career outcomes positions supervisors as ideal participants for this study.

2.7 Summary

This chapter was the first of two literature chapters for this study in which the major debates in doctoral education were reviewed. A brief history of the research doctorate across the UK, US, and Australia provided the general backdrop for the study. Following this, the debates over the purpose of the PhD were covered, given that doctoral purpose underpins doctoral practice and to provide an understanding of the kinds of shifts in doctoral purpose that have occurred. This included covering key concepts related to knowledge production and the commodification of knowledge and skills in the knowledge economy, and the shift in focus that the doctorate has witnessed from preparing stewards of the discipline who keep the discipline alive by maintaining disciplinary knowledge production, to preparing knowledge workers with the necessary attributes and assets for employment. Changes in doctoral practices were then examined in which an increased focus on HDR skills training for greater student employability were observable across the UK, Europe, and Australia. This naturally flowed into inspecting the literature on employability, which synthetically showed two main constructs used to define employability: the knowledge, skills, and attitudes that the individual needed to accumulate to gain and maintain employment, and external factors that affect employment such as race, gender, age, and labour market conditions. This was followed by an

examination of the HDR skills agenda, in which critical debates on the very nature of skills and skills transferability were visited. The literature on doctoral supervision was also examined. This highlighted the important role that supervisors play in socialising students into becoming recognised and accepted members of their respective disciplines, thus acting as the 'cultural reservoirs' of the discipline. The literature underscored the impact of supervisors on students' post-PhD employment as well as the need for graduate follow-up on career outcomes as part of supervisors' self-reflective practice, making them appropriate study participants, despite university responses at the central level to the increased focus on student employability.

CHAPTER 3 – STEM & CHEMISTRY EDUCATION

This chapter constitutes the second literature review chapter for this study. Chapter 2 covered the most important debates that have been at the centre of attention within the scholarly literature on doctoral education. In this chapter, the major debates in contemporary STEM and STEM education are visited in order to provide the general backdrop of the state of science in Australia. The linkages between science, innovation, and HDR training and employability are observed, and arguments for infusing STEM education at the doctoral level with learning and inquiry related to the ethical, social, political, and economic issues pertaining to science are presented, as well as the need to expose students to areas of work and research beyond academia. Issues related to women in STEM and the academic workplace are also presented, in order to inform subsequent research decisions in this study. Following the review of the major issues in STEM education, the chapter then focuses on the discipline of chemistry, including a detailed examination of the state of research on chemistry doctoral education across the US, UK, and Australia between 2004 and 2016. Synthesis of this examination revealed the research landscape on chemistry doctoral education as barren, justifying the formulated research question.

3.1 Major Debates and Issues in STEM and STEM Education

Examining the major debates arising within the STEM education literature provides a richer understanding of the contextual issues surrounding chemistry education. In line with the employability theme featuring strongly in this study, STEM and the outcomes of STEM education are seen as providing economic growth and steering innovation in Australia, and become necessary focus points in the employability agenda of HDR candidates. The argument for the need for science graduates to be able to ask value-based questions related to the ethical, social, political, and economic issues relating to their disciplines specifically and science more broadly as they head out into the workforce, is drawn. In addition, the argument for exposing doctoral students to sites of work and research beyond the academy such as in the form of internships in order to maximise their employability, is also mounted. Major issues relating to women in STEM and academia more widely are visited to better inform the methodological and analytical choices made in this study.

3.1.1 STEM Education

Several reports describe science in Australia as being, more or less, in a state of crisis or 'unhealthiness' (Dobson, 2012b; Kennedy, Lyons, & Quinn, 2014; Tytler, 2007). Tytler (2007)

describes several dimensions of this crisis: the decreasing number of students studying science and particularly physical sciences during post-compulsory school years; the decreasing number of skilled science professionals in Australia compounded with science-based research and development shifting to developing countries; mounting evidence of student dissatisfaction and disapproval of school science in the middle years; the out-of-touch relationship between school science and contemporary society; and rising concerns with the lack of qualified science teachers in schools. Similarly, Kennedy et al. (2014) grapple with the science crisis at the upper secondary school level, highlighting the drop in student participation rates for most science and mathematics subjects as a proportion of the total Year 12 cohort, warning that while continuing declines may not amount to a crisis, they are cause for concern.

Dobson (2012) conducted a review, commissioned by the Office of the Chief Scientist, of tertiary student enrolments in natural and physical sciences in Australia between 2002 to 2009/10, casting light on greater numbers of students discontinuing their study of the enabling sciences after their first year at university. This means that students are less likely to complete majors in disciplines such as chemistry, mathematics, and physics than they are in biology and other specific disciplines within the Natural and Physical Sciences. Dobson found this concerning from the perspective of innovation and the drivers of innovation, given that science and technology were expected to drive and steer innovation, as opposed to subjects such as management, commerce, and health – fields that have been the most active in enrolment expansion this century.

The Australian Government has attempted to improve the robustness of science in Australia in a number of ways. For example, the Chief Scientist in Australia "provides high-level independent advice to the Prime Minister and other Ministers on matters relating to science, technology and innovation" and is a "champion of science, research and the role of evidence in the community and in government… [and] is a communicator of science to the general public, with the aim to promote understanding of, contribution to and enjoyment of science and evidence-based thinking" (Commonwealth of Australia, n.d.). The Office of the Chief Scientist has worked to realise the full potential of STEM in Australia by holding education round tables with a broad range of stakeholders from primary, secondary, and tertiary education to industry; STEM workforce supply and demand to investigate the demand and role for STEM skills in the workplace; science literacy and numeracy workforce to improve the teaching of numeracy and problem solving skills to meet workplace needs; and establishing the STEM Education and Industry Advisory Group with members from academia, education, and industry to develop a

clear strategic framework for building a high quality STEM foundation in the workforce and community (Office of the Chief Scientist, 2014).

Similarly, The National Innovation and Science Agenda aims to drive innovation and promote science to develop new sources of growth, maintain high-salary jobs, and inject economic prosperity in Australia (Department of Prime Minister and Cabinet, 2015). The Agenda (Department of Prime Minister and Cabinet, 2015) focuses on four key pillars, providing a framework for Australian innovation policy. The initiatives are worth $1.1 billion over four years, as summarised below:

Culture and capital – Providing new tax breaks to remove prejudice against businesses that are prepared to take risks and push the boundaries of innovation; supporting greater private sector investment and commercialisation of ideas through a CSIRO Innovation Fund and a Biomedical Translation Fund.

Collaboration – Changing funding incentives in order to better support university-industry collaborative research; providing long-term critical, world-class research infrastructure investment in order to achieve and maintain cutting-edge research.

Talent and skills – Ensuring all Australian students are digitally literate; promoting and supporting the teaching and learning of coding and computing in schools; changing the visa system to attract more international business and research talent.

Government as an exemplar – Leading by example by demonstrating innovative practices in the delivery of government and social services to Australians; providing open-access data to the Australian public; facilitating relationship with start-up companies and small businesses to sell technology services to government.

From the framework above, the government's focus on bolstering the state of Australian Science through industrial means becomes clear. The increased focus on strengthening the ties between university- and industry-type research, along with the increased funding of entrepreneurial, risk-taking businesses, marks that shift from Mode 1 disciplinary knowledge practices to Mode 2 knowledge production now co-produced and funded by government and industry actors.

Furthermore, the National Innovation and Science Agenda makes its way into the ACOLA review, where it is stated that:

> Recognising the introduction of the Government's National Innovation and Science Agenda, and the clear priority on improving the links between universities and industry, this working group would be empowered by strong links with Innovation and Science Australia… We also highlight the important roles that industry (in its broadest sense–businesses, governments, government business enterprises, non-government organisations, not-for-profit organisations, and community organisations) has to play, particularly in ensuring that HDR training makes its maximum contribution to national prosperity. This important work will be advanced by the Government's commitment to fostering research-industry collaboration through the National Innovation and Science Agenda. (McGagh et al., 2016, p. 7)

There is clear emphasis and a desire to seal the relationship between Australian HDR science and industry as the amalgamation of the two is perceived to drive the innovation and prosperity of the country. This marked a move in the doctoral education space and highlights concern about ensuring that HDR graduates were equipped with the skills and assets that allowed them to participate in the non-academic workforce fully. From the Australian Government perspective, this translated into the education and training of HDR candidates in terms of their generic skills. However, consideration of the scholarly perspective on this point can provide a more nuanced view on this issue.

Hancock and Walsh (2016) argue that the STEM PhD fails to adequately prepare students for their future complex careers. Their argument is based on the UK PhD but the reasoning can be extended to the Australian system. The authors point out that while the traditional purpose of acquiring a doctorate was admittance into academia, this has now become one of many career options for graduates. Particularly, the STEM PhD has been an apprenticeship in which the student learned the 'craft of the discipline', and was admitted upon production of a written thesis as proof of their disciplinary knowledge and skills. The STEM PhD has students join a research group under the supervision of a supervisor who "supports the student's enculturation" into the discipline and "its unique epistemic culture" (Hancock & Walsh, 2016, p. 40).

The crux of their argument states that:

> Pedagogic and occupation experience must include learning experiences beyond the university; since STEM doctoral graduates – whether they remain in academic science or not – are likely to be involved in knowledge creation and application with actors

> outside of academia. Similarly, social and locational experiences must anticipate the professional diversity and movement associated with the knowledge economy. Doctoral scientists must be guided to form working relationships with individuals from different disciplines and institutions to their own. They must possess a sound understanding of the economic and cultural context surrounding science; and be able to the negotiate political, economic, social and ethical values that now explicitly weigh in upon the processes of creating and applying knowledge. (Hancock & Walsh, 2016, p. 44)

The authors build their argument on several ideas. The first is related to knowledge, and specifically, the stronger shift seen towards Mode 2 interdisciplinary knowledge practices as outlined in Chapter 2. The authors argue that the STEM PhD has students work in singular, highly specialised research projects that primarily shape them into the moulds of their academic discipline, and therefore, are unlikely to adequately prepare them for today's workforce (Hancock & Walsh, 2016). Scientific evidence alone cannot address complex problems such climate change, GMO, and nuclear power because the answers to these problems are intrinsically linked to social, cultural, and political concerns that have traditionally been in the domain of inquiry of the Humanities and Social Sciences (HASS).

Attempts to inject STEM education with value-based questions from HASS are not novel. For example, in *Rethinking STEM Education: An Interdisciplinary STEAM Curriculum*, Madden et al. (2013) presented a model of a curriculum that infused traditional STEM teaching and learning with activities from the Arts and Humanities to foster creativity and sophistication in problem solving for today's wicked problems. The authors lament traditional science training for providing students with facts, but rarely examining creativity in science and interdisciplinary problem solving, despite industry leaders in the US valuing these skills in potential employees.

Similarly, Steele, Brew, and Beatty (2012) consider the different ways of strengthening science education by reflecting on the role of ethics teaching in the curriculum. The authors argue that "complex issues beg the need to engage in perspective taking, which is inherent in the exploration of ethics" (Steele et al., 2012, p. 122) and underscore the importance of the "understanding of the connections between human societies and the natural environments that sustain them…" (Steele et al., 2012, p. 129).

The Australian Council of Leaned Academies has worked on strengthening interdisciplinary research in Australia based on the recognition that the "real world does not always present its

problems and opportunities conveniently aligned with traditional academic disciplines so mechanisms are needed to facilitate interactions and collaborations between researchers working in widely different fields" (Bammer, 2012, p. 1) in order to achieve fruitful economic, social, and environmental results. This recognition reached the ACOLA review, in which McGagh et al. (2016) call for HDR candidates to be supervised by diverse, interdisciplinary panels in response to tackling complex problems.

Arguments for the infusion of STEM education with value-based considerations from HASS are increasingly substantiated when considering that science itself is not value-free since scientists use cultural values in their work and their day-to-day practices (Allchin, 1999; Demeritt, 2001; Douglas, 2000). Bahm (1971) argues that every step of the scientific process is saturated with value-based questions such as whether a research question is worthwhile and justified for spending time and funding on answering it, if the chosen methods are the best way to answer the question, and what attitude or work ethic is best suited to the approach.

In a more recent study, Lekka-Kowalik (2010) argues that the value-laden nature of science is a reality and essential in scientific research for several reasons. The first is that scientific research requires money, and funds are usually provided under certain conditions such as developing an answer to a particular question. This may lead to the "participation of science in the social division of power by providing knowledge and knowledge-based technologies" (Lekka-Kowalik, 2010, p. 35). Furthermore, scientific research has the capacity to change the way we view and evaluate the world around us: "Any decision to open a certain research project is at the same time a decision to bring about consequences in the form of new beliefs concerning values, people, the world, etc." (Lekka-Kowalik, 2010, p. 36).

There is also a moral evaluation that takes place in scientific research which, in some cases, can influence legal regulations and policies, and as a consequence, result in shaping social reality (Lekka-Kowalik, 2010, p. 37):

> A hypothesis that a certain substance is not lethal poison for human organisms requires stronger evidence than a hypothesis that a certain kind of flowers grows only in the Alps, precisely because the moral weight of consequences of making a cognitive error in the first case––i.e. killing a person by administrating the substance investigated––is greater than the moral weight of imaginable consequences of being mistaken about the place of finding a particular kind of flowers.

Lekka-Kowalik (2010, p. 40) concludes by calling for the scientific community to reflect more deeply regarding the relationship between science and society, the reshaping of the education of young scientists, and specifically:

> Scientists should understand science and this means not just giving them the latest knowledge and training skills necessary for research, but also developing the consciousness of what the rationality and responsibility of science consists in. And the recent development in organizational forms of science tends to include scientists into funding and policy-making bodies.

As Hancock and Walsh put it: "All career environments are rendered more complex, interconnected and uncertain by the convergence of the political, the economic and the social" (Hancock & Walsh, 2016, p. 44) and the STEM PhD, as argued so far, does not adequately attend to these complexities. To remedy this, the authors suggest that STEM PhD students be involved in interdisciplinary discussion spaces where students can focus and reflect on the political, economic, social, and ethical issues that the contemporary researchers are likely to encounter in the workplace. In addition, the authors propose that STEM PhD candidate experience sites of knowledge production outside of the university (Hancock & Walsh, 2016). This would afford students the chance to negotiate competing agendas of a number of stakeholders and better understand the full range of professional skills required by researchers working outside of academia. Their proposal closely mirrors the experience afforded when students participate in internships, which have been encouraged within the HDR space in Australia for improving potential job prospects for candidates, while also bringing new perspectives to problems faced by host organisations (Binder, Baguley, Crook, & Miller, 2015; McGagh et al., 2016).

This section of the literature review explored the main issues relating to STEM and STEM education. Considered in a state of 'unhealthiness', governments in Australia have sought to improve the condition of science through various means including the National Innovation and Science Agenda, the aims of which tie in with those of the ACOLA review, in a bid to better train HDR candidates in business skills and industry collaboration. The scholarly perspective shows, however, that doctoral students in the sciences need to be able to engage with and reflect upon value-based questions about the ethical, social, political, and economic issues relating to science, as the complex problems they will encounter in the workplace will seldom rely on scientific facts and expertise alone. This will need to be coupled with exposing

students to different work environments such as those experienced through internship programs.

3.1.2 Women in STEM

It has become increasingly common and prevalent, both within STEM disciplines specifically and academia more broadly, to hear about issues that women face in the workplace relating to inequity and underrepresentation. From that point of view, it is important to examine some of these issues from a scholarly perspective, and achieve a more nuanced understanding of these issues, to utilise this understanding in the methodological choices and analytical decisions made in this study.

Marginson, Tytler, Freeman, and Roberts (2013) authored a report titled *STEM: Country Comparisons - International comparisons of science, technology, engineering and mathematics (STEM) education.* The project aimed to examine skill shortages in STEM in Australia and draw comparisons to other countries to provide solutions for the Australian context; and hence, maintain Australia's STEM productivity and competitiveness. The report offers important contributions regarding women in STEM in Australia.

The report states that women are under-represented in STEM fields in Australia, in terms of both tertiary education and employment. Despite the equitable participation of women in tertiary education both in Australia and in other countries such as Argentina, Canada, Western Europe, Finland, and Russia, gender-based stratification of students exists at the disciplinary levels of STEM education. In Australia, "men outnumber women in mathematics, statistics, sciences (particularly physics), engineering, manufacturing, construction and computing, while women outnumber men in the study of health, welfare, education, humanities, arts, agriculture, life sciences, services, social sciences, business and law" (Marginson et al., 2013, p. 136). Women's participation in STEM employment is also low due to them leaving the disciplines in large numbers, particularly at the postdoctoral level. The report identifies a number of reasons that contribute to this:

> the perceived nature, organization and career pathways of STEM fields of study and employment, the availability and scope of parental leave, small numbers of women influencing and participating in senior roles on funding and other decision making bodies, the difficulty of breaking through existing disciplinary networks, as well as a

> lack of effective counter measures and policies within national systems (Marginson et al., 2013, p. 138).

The structure of career pathways in STEM poses challenges for young women who want to start a family in terms of work-life balance. Expectations students form about STEM careers during high school, coupled with stereotypes of who scientists are and what they actually do can also perpetuate this predicament.

Marginson et al. (2013) argue that gender balance in STEM aligns with gender balance and social justice in the real world, and leads to a more diverse and productive economy. Changes in the form of "political will, legislation, greater understanding of gender issues, mandated involvement of women on decision making bodies and to senior appointments, more appropriate human resource processes and funding systems" can help alleviate the aforementioned issues (Marginson et al., 2013, p. 140). Cultural change can also be achieved through including flexible working hours, childcare support, support for family mobility, and more generous maternity and paternity leave payments. Additionally, the provision of mentoring and support can bolster female participation in STEM education and employment, especially making highly successful women in STEM more visible in society.

Marginson et al's. (2013) work successfully draws attention to the state of women in STEM. Since this study examines the responses of academic supervisors in chemistry, understanding the condition of employment of women from the perspective of academia bolsters the discussion. The work of Baker (2016) discusses the persistent gender gap in universities by reviewing over 40 years of research across Australia, Canada, New Zealand, USA and the UK (Baker, 2016).

The author argues that because governments in Australia, New Zealand, and the UK have financially rewarded universities based on research productivity, this, by extension, has privileged permanent academic research staff and tenured academics who are usually male, senior, and able to attract research funds and postgraduate students, raising the research profile and prestige of the university. Teaching activities, which are usually undertaken by women, are downplayed and become underprivileged in the process.

Baker (2016, p. 890) sheds light on the gendered nature of funding that favours:

> large-scale projects with multiple collaborators using quantitative research methods… When academics focus on qualitative research and particularly when they choose

> feminist or qualitative projects, they are less likely to be awarded external grants but women are also less likely than men to apply for grants.

The competitive process of publishing in prestigious journals, the growing focus on international networking, coupled with academia's stressful work culture skews the work-life balance of individuals, and is especially disadvantageous for those with duties of care (Baker, 2016).

Traditional cultural factors are at play as well, with men usually encouraged to aspire to a lifelong professional career, while women are usually socialised to become wives and mothers, and carers of elderly parents. Because more women than male academics are single, separated, divorced, or parenting alone, the burden of the responsibility falls upon them to care for children and complete household work. Coupled with lower average salaries, many female academics cannot afford childcare services or additional support. This tends to reduce the time available for research activities, further disadvantaging women in the workplace. Even when a father is present in the relationship, male academics can be:

> … good fathers by working hard at their research and publications, which would enable them to gain promotion, increase their earnings, and support their family at a higher income. They would still be viewed as 'good fathers' if they performed some childcare during evenings and weekends. In contrast, 'good mothering' is more often socially defined as providing daily emotional and 'hands-on' care (Baker, 2016, p. 894)

Baker (2016, p. 893) explains this by looking at how men think of their career ambitions:

> Men tend to search for permanent tenure-stream and tenured positions in high-prestige research universities, which provide them with more opportunities to carry out funded research, gain scholarly publications, and attain high salaries and peer esteem. In contrast, women doctorates tend to express more ambivalence about striving for high-pressure careers and sometimes accept jobs that pay less but are closer to parents, partners and friends, or enable them to manage care work.

The author concludes that despite the emergence of equity and family initiatives for women, the gendered nature of work and family life privileges men by default, and especially so when the work of male academics is preferentially rewarded, suggesting that the gender gap will persist despite the rise in female employees (Baker, 2016).

This section of the literature review has shed light on some of the major issues facing women in the workplace, both within the STEM context and in academia more broadly. The understanding of these issues will inform the methodological and analytical choices made in this study.

3.2 The Case of Chemistry

Reviewing the literature on STEM education provided the general backdrop for this chapter. This section of the literature review focuses on the case of chemistry, and examines what the discipline of chemistry is and its nature and the contemporary debates within the doctoral education space in chemistry. This includes a detailed look at the state of research on chemistry doctoral education in the US, UK, and Australia. This will provide the scaffolding required and help build the argument justifying the research question: 'What are the Positions of Chemistry PhD Supervisors in Australia in Relation to Contemporary Debates and Practices in Doctoral Education?'

3.2.1 What is Chemistry?

Chemistry is the study of matter and its transformation. It allows us to create new materials and improve the quality of our life. Chemistry is often described as 'the central science' since it is central to new breakthroughs in fields like medicine, pharmacology, genetic engineering, and more (RMIT, 2016; The University of Sydney, 2015).

The Australian Academy of Science concisely defines of what chemistry is:

> Chemistry is the central science. In sharp contrast to other major science disciplines such as physics, mathematics and biology, chemistry is the only 'fundamental' science that has a specific industry attached to it. It spans basic science and education through to advanced manufacturing, and is the most significant contributor to the wealth, prosperity and health of the human species. Over the last 5,000 years it has been chemistry, more than any other discipline, which has made our global civilisation possible… Amongst the physical sciences, chemistry remains the largest single scientific discipline. (Australian Academy of Science, 2016, p. 3)

Having explored the meaning of chemistry, attention is turned to the structure of chemistry at a disciplinary and academic level.

3.2.2 The Structure of Chemistry

There is a marked deficit in descriptive data about the structure and organisation of chemistry as an academic discipline in Australia. For these reasons, when attempting to explore the structure of chemistry in the context of disciplines at universities, the American literature was consulted. However, a quick examination of university chemistry websites in Australia generally shows that the organisational structure of chemistry as a discipline in Australia is not dissimilar from the structure described in the US literature below.

In Golde & Walker (2006, p. 135), the work of chemists is described as "'the three m's' – making molecules, measuring their properties, and modelling". Based on the US context, the discipline is described as being male dominated, with one third of doctoral recipients working in academia, and two thirds in industry and government labs. Most chemists in the US enter a doctoral program directly after receiving their undergraduate degree, and the median age for receiving the doctorate was slightly under thirty. Students study a year or two of coursework to begin their specialisation, but this is specific to the US environment, as highlighted in Chapter 2.

The discipline has subdivisions, with the largest being organic chemistry, followed by general chemistry, physical chemistry, analytical chemistry, biochemistry-biotechnology, and inorganic chemistry. Students are expected to join a chemist's research group or laboratory. This raises important considerations, as expressed by Golde and Walker (2006, p. 137):

> Often the student's own research and the research he or she conducts as a research assistant are indistinguishable. This practice raises several important issues, including (1) the ability of students to develop and perform original, independent research, (2) the potential subordination of the student's interests (including time-to-degree) to the lab's interests, (3) the quality if advising, and (4) the problems of overspecialisation.

Joining a research group also involves attending group meetings where researchers at all levels share their results, ideas, and experiences. The informal nature of group meetings facilitates student socialisation in to the discipline, and serves as a training ground for learning public speaking, dealing with constructive criticism, and learning to ask good questions (TheScientist, 1991; Vincent, 2009).

Different group leaders will manage these meetings differently. Some will have their students talk about their research findings and problems while also discussing new literature. Others

may use the group meetings to discuss of new research presented at a conference which only a few members attended. Some group leaders meet with their students frequently while others suspend them when they are away (TheScientist, 1991; Vincent, 2009).

Academic hierarchy also shapes the nature of group meetings. For example, some group leaders hold separate weekly meetings with their postdoctoral fellows in addition to larger meetings including graduate students. Postdoctoral fellows are especially valued for the different perspectives they bring to the group. However, while they are more independent thinking, they may be less experienced in the lab compared to students who have been there for several years (TheScientist, 1991).

3.3 Examining the State of Research on Chemistry Doctoral Education

The previous section of this literature review observed the organisational structure of the discipline of chemistry, and highlighted the prominent role the supervisor plays as the Group Leader within the discipline. This section of the literature review examines the state of research on chemistry doctoral education. It covers the state of research done in this area across the US, UK, and Australia between 2004 and 2016.

3.3.1 The USA

In the US, discussions on doctoral reform in chemistry can be traced back to 2004. These debates have been led by the American Chemical Society (ACS), which represents the discipline of chemistry and advances its cause, and are published in the *Journal of Chemical of Education*. In 2004, Charles P. Casey, president of the ACS at the time, sponsored the presidential symposium *Responses to Changing Needs in Doctoral Education* to help deliver a focus on graduate education in chemistry. The symposium coincided with the *Carnegie Initiative on the Doctorate* (CID) mentioned earlier in this review (Golde & Walker, 2006), of which Casey was a committee member, re-examining doctoral programs and requirements (Casey, 2004).

Casey states that the increasingly multidisciplinary nature of chemistry, and its quick expansion into other science-related fields, warranted an examination of its graduate education programs (Casey, 2004). The committee decided that graduates should possess depth and breadth of scientific knowledge, be problem solvers, have excellent oral and written communication skills, be able to work in teams, be confident and independent scientists, and have the persistence to work at the low end of the learning curve repeatedly (Casey, 2004). Similar sentiments were expressed in the December 2004 meeting report and the October

2006 editorial of the same journal, where it was stated that the increased interdisciplinarity of chemistry necessitated that the education of graduate chemists change in response to it (Caserio et al., 2004; Moore, 2006).

Moore (2006) describes some changes in doctoral education in chemistry that took place during the *Carnegie Initiative on the Doctorate* (CID). For example, Howard University offered a more flexible curriculum, earlier assessment of students' capabilities, and integration of professional development into the curriculum for their students. The University of Colorado developed a program that supported students who wanted to apply their chemistry knowledge to research in other areas such as public policy, education, philosophy, or law (Moore, 2006). However, what is most striking is the editorial's acknowledgement of the scarcity of research done on chemistry doctoral education (Moore, 2006, p. 1415):

> Out of nearly 100 articles that involve graduate education published during the past decade in this *Journal* [Journal of Chemical Education], only about half a dozen deal with organizational and curricular issues such as those described above. Many of these were clustered in the December 2004 issue, which reported on new ACS initiatives.

Perhaps the most seminal work that has occurred within this space is in Golde and Walker's (2006) *Envisioning the Future of Doctoral Education*, where three prominent chemists produced essays on the problems with doctoral education in chemistry in the US at the time and proposed respective remedies.

Kwiram (2006, p. 142) notably conceived the purpose of the chemistry doctorate as scholarly research aimed to develop the "habits of mind" of experts in the field. Professional skills development for students does not feature strongly within his discussion, as evidenced by these two quotes:

> Most of the recent discussions of reform for doctoral education in chemistry have focused on functional improvements that would give new Ph.D.'s a more complete repertoire of professional skills. Although professional skills are not the core or essence of the Ph.D., these skills are considered important for all graduates of chemistry doctoral programs, especially those planning to work in industry and government. (Kwiram, 2006, p. 143)

> Although we might agree in a global sense that professional skills need more emphasis, this area will probably not receive serious attention until industry, as the major

> employer of chemistry Ph.D.'s demonstrates its seriousness by preferentially hiring graduates who have such training. (Kwiram, 2006, p. 146)

The author then moves on to the "major structural problems" of the chemistry doctorate in the US: Time-to-Degree and Preparation for a Faculty Career (Kwiram, 2006, p. 146).

Kwiram viewed the increasing time-to-degree as a concern because it discouraged bright students from joining chemistry doctoral programs and lengthened the delay in achieving earning status for graduates. Increased time-to-degree opened up exploitation of student labour and reduced opportunities for other students both in terms of program enrolment and access to resources.

Furthermore, Kwiram (2006, p. 150) criticised chemistry doctoral education in its "failure to provide an integrated and comprehensive training program – graduate study plus postdoctoral work – for those planning an academic career", and dedicated the rest of his essay to the following topics that new faculty members should have been exposed to before supervising students in the field:

> Education as a profession; apprenticeship in teaching; history of the discipline; exposure to other [scientific] disciplines; management and personnel skills; institutional structure and governance; tenure and the tenure clock; ethics, conflict of interest and sensitivity training; importance of diversity; leadership skills; grant writing; regulatory and compliance issues.

Breslow (2006) centred his concerns about the US chemistry doctorate in terms of increasing the depth and breadth of knowledge of the student, and provided three proposals to achieve this:

- Developing breadth of knowledge through courses, seminars, exams, and interdisciplinary research. It is important to note here that interdisciplinarity for chemists is conceived as working with other physical and natural scientists such as biologists, physicists, and engineers.
- Developing depth of knowledge through doctoral research, stimulating creativity, developing research proposals, lecturing, and journal publishing.
- Developing professional skills in oral and written communication, teaching, good scientific practice and ethics, and professional service.

The third and final essay in the series, *Training Future Leaders,* is by Angelica Stacy, who conceives of chemistry graduates as not only leaders of the discipline, but also leaders in industry, science education, and public policy; that is, leaders across society (Stacy, 2006).

Her concerns for improving the doctoral student experience stem from several students leaving the program despite being:

> …among the best, brightest, most talented and promising, with the very kinds of skills and interests that the field needs. Yet they are saying, "This is not for me." They are creative people with wide-ranging interests, and they feel constrained in our doctoral program. (Stacy, 2006, p. 187)

Her argument for supporting students with interests in chemistry and other fields such as education, public policy, and politics is because of her view that a diversity of perspectives enriches the discipline of chemistry and provides society with individuals who can think in diverse ways (Stacy, 2006, p. 189):

> Because cutting-edge research requires cooperation – a team of people pooling their extensive knowledge of many disciplines – it also calls for new ways of negotiating, working with others, and communicating. And because our work now involves educating other experts, educating the public, and advocating for certain directions to be taken by a team, chemists must be able to consider the implications of their work well beyond the lab and understand psychology, sociology, education, communication, policy, and politics.

To remedy this, Stacy (2006, p. 190) proposes education reforms to develop students into leaders who are more collaborative in nature and appreciate the need for a diversity of knowledge and perspectives – an "expert learner" who can learn the important things in the field and connect to other fields. These reforms begin with reflection over and examination of the following questions (Stacy, 2006, p. 191):

- "Who enters and completes our programs?
- What might we do differently in the programs?
- What stands in the way of the changes we need to make?"

At the time of writing, Stacy (2006, p. 191) stated that "white men who are about twenty-eight years old" predominantly enter and complete their programs. She proposes more flexibility in the degree structure to encourage women to occupy academic positions in chemistry, and allow students who have worked for while outside of the university to be admitted into doctoral programs and enrich the discipline with their workplace experience.

Stacy (2006, p. 194) expresses "the challenge we face is how to orient our programs to build on strengths that individual students bring rather than constraining them to meet our needs" and highlights the work done at University of Michigan at the time that allowed chemistry doctoral candidates to pursue research in both chemistry education and traditional chemistry research topics, commenting on the enthusiasm of the students, the success of the program, its structure, and the attitudes that informed it.

However, Stacy (2006, p. 195) takes this one step further and proposes that the discipline of chemistry consider what the humanities and social sciences do with their research students:

> Consider, for a moment, our approach in contrast to that of other disciplines. Students in the humanities and social sciences choose the topics of their dissertations. Consequently, they spend a lot of time trying to figure out what constitutes a good question. (Indeed, many say that students in these fields spend too much time stalled at this stage of their training). However, there is something to be learned here. For as frustrating and time-consuming as this process might be, it teaches the students to think at much higher levels. They must, for example, compare and contrast to figure out what is a good question to ask, and they learn a lot about how to design research projects. In the sciences we could give our students more independence.

In addition, one important reform that Stacy suggests is sectioning the thesis in such a way that it includes both research traditionally done in chemistry and a section with research reflecting the student's interest within or related to chemistry, or the humanities and social sciences.

Stacy (2006) sheds light on some of the barriers to these changes and highlights that the supervisory relationship and the reward structures in academia would be the two main factors here. She argues that for successful candidature to occur, the researcher not only needs to be a good mentor and have the resources in their laboratory to support their students, but the researcher also needs to have an attitude that allows and supports the student to pursue learning as described by Stacy above. She also acknowledges the power imbalance in favour of

the supervisor in the student-supervisor relationship, and suggests that flattening the power imbalance could be achieved by allowing students to work with more than one supervisor on their project, and allowing them to rotate their work through more than one laboratory.

Stacy (2006) also notes that the reward structure in academia largely based on research outputs, the strenuous competition for research grants, and the dominance of white men in the discipline, are unconducive to these proposed changes. She further questions the value of the standard measures of success in the discipline – the number of publications and awards received – in helping produce the colleagues and leaders that chemistry and society need (Stacy, 2006, p. 204):

> In a field that is devoted to results, we are oddly uninterested in the result of our efforts with graduate students. Can we find new ways to measure success that are based on results?... What if, similarly, departments were ranked, based on where their graduate students were placed and how well they were doing in their careers? What if we regularly gathered and used information and feedback from our graduate students about what works and what doesn't in our programs? What if we were to solicit their ideas about courses, projects, and even the structure and pace of graduate education?

In 2011, Loshbaugh, Laursen, and Thiry (2011) explored how US chemistry departments had responded to calls for increased focus on chemistry graduate employability at the doctoral level. The authors interviewed 22 chemistry department chairs, graduate program leaders, and administrators across 14 well established chemistry departments, specifically asking (Loshbaugh et al., 2011, p. 709):

> • What issues do departments identify as important for the future of their graduate programs?
>
> • To what extent do these issues align with or respond to issues identified in recent research and national initiatives on graduate education?
>
> • What departmental or institutional structures and common faculty practices support graduate students' career selection and preparation, and what additional unmet needs are reported?

A major aim reported by participants was to develop independent thinkers with transferable skills. Participants indicated that interdisciplinary collaborations had become more common

in their departments; that younger staff members were driving change and producing new social practices; and that departments were implementing new professional and leadership programs with a major aim of developing graduates with independent thinking and transferable skills (Loshbaugh et al., 2011).

The authors commented that while respondents were broadly aware of the issues in the chemistry doctoral program mentioned by the ACS and had attempted to address them, the changes did not appear to be driven by evidence from those sources. In fact, the authors noted low faculty awareness of these initiatives and stated that changes "tended to be somewhat piecemeal in nature" (Loshbaugh et al., 2011, p. 714). Also absent from all 14 departments was a systematic way of measuring the impact of those practices.

In another US-based study, Thiry, Laursen, and Loshbaugh (2015) turn their attention to doctoral students in chemistry. The authors invoke the argument that despite the reality that most doctoral students do not aspire to pursue academic careers, alternative career pathways are often discouraged by supervisors in science (Fox & Stephan, 2001; Nerad, 2009; Sauermann & Roach, 2012). Additionally, they conducted interviews with 32 late-stage students and 25 early-stage students exploring the career decision-making processes and preparation of doctoral students, and the results show some important findings. In the absence of systematic career development resources for students, Thiry et al. (2015, p. 251) explain that:

> the void was often filled by rumor, hearsay, and word of mouth from peers. Thus, a cycle of misinformation perpetuated itself as students had no clear way to develop the wide range of networks that they needed to prepare for careers.

This was also confounded by a number of students who felt that their advisor was unsupportive of career exploration, especially if it was non-academic. This stemmed from the belief that the advisor 'needed' the student for their own research agenda and would not allow for distractions.

Thiry et al. (2015, p. 250) assert that the study challenges the "taken-for-granted notion that doctoral advisors are, and should be, students' most important source of career development", especially that advisors are usually unaware of the importance of peers and socialisation in doctoral students' career development (Gardner, 2010). The authors propose that students actively look for a diversity of networks and role models to allow them to try out 'possible selves'. They also suggest that departments and institutions expand professional learning

opportunities so that students are exposed to a spectrum of career paths and the knowledge and skills required, and that career exploration should begin early during candidature.

One important study on chemistry doctoral education was published in 2012 by the ACS titled *Advancing Graduate Education in The Chemical Sciences* (American Chemical Society, 2012). The report stated that graduate education in chemistry does not sufficiently prepare students for their careers after graduate school, emphasising that while a doctoral program in the chemical sciences must focus on depth, mastery, and specialisation, it should also help develop students' critical professional skills. The Commission recommended that departments better monitor their graduate students and that programs offer specific activities that would help students enhance their ability to persuasively communicate complex ideas to both technical and nontechnical audiences; to learn new science and technology; to collaborate with teams and/or clients; to manage technical work towards an outcome; and to perform research in an ethical manner. Interdisciplinarity is noted again here, with the Commission explaining that contemporary problems in chemistry are increasingly complex and arise at the interface of scientific disciplines and sub-disciplines; therefore, necessitating that their solutions require a collaborative interdisciplinary approach (American Chemical Society, 2012).

3.3.2 The UK

In the UK, Purcell et al. (2008) investigated the postgraduate employment of chemistry graduates, a report that was commissioned by the Royal Society of Chemistry (RSC) – a society for the advancement of chemistry, similar to ACS, but in the UK.

Perceptions of the narrowness of chemistry doctoral education that resounded in the US are similarly echoed here. Purcell et al. (2008) report that despite one large employer employing people with doctorates for their maturity, a handful of employers were cautious of PhD graduates and what was needed to recruit them. One employer who did recruit a small number of them remarked that PhD graduates performed poorly at interviews, and that their [employer's] rigorous interview process revealed this (Purcell et al., 2008). Others raised concerns as to how easily graduates from the chemical sciences with such an academic background could transition into a new work environment, and the report mentions alongside this the following quote: "'Potentially, someone who has been in education that long may not have developed the competencies that we look for. They may pitch themselves a little too high'" (Purcell et al., 2008, p. 101).

The report further mentions that a small number of employers were concerned about standards at PhD level. One employer quote was: "'PhDs lack the fundamentals and lack breath of experience compared to previously. It's not confined to certain universities'" (Purcell et al., 2008, p. 105).

Another employer felt surprised at the low numeracy level of some PhD graduates, but added that his experience might have been incidental (Purcell et al., 2008).

The only other publication in the UK that examined any issues relating to chemistry doctoral education was that of Hanson and Overton (2010) in *Skills Required by New Chemistry Graduates and their Development in Degree Programmes*, a report in collaboration with and financially supported by the RSC. The report surveyed recent chemistry graduates in the UK to examine which generic skills were useful and well developed.

The study surveyed 196 graduates, of whom 40 were PhD graduates. These respondents considered both chemical knowledge and skills to be equally important as generic skills, and would have liked more opportunities to develop skills such as experimental design and interpretation, oral communication, skills in chemical instrumentation, numeracy and computation, and independent learning skills.

3.3.3 Australia

In Australia, Harding (2004) presents a framework for successful supervision in chemistry, including timely completions, through structured communication in a research program based on collaboration. The author puts forth that in contrast to the social sciences and humanities, the planning and execution of research projects in experimental-based disciplines such as chemistry allow well-defined research goals and research skills to be developed. Her framework focuses on collaboration, open communication, and scientific writing development as essential factors for the successful completion of the dissertation. Harding proposes that treating a PhD student as a 'research collaborator' holds a more positive connotation compared to 'supervisor', which can imply a leader/subordinate type of relationship. By clearly communicating expectations, and promoting respectful open dialogue, the author provides means of preventing the difficulties that arise during candidature such as poor communication between the supervisor and student.

Harding (2004) also pays attention to the soft skills expected of chemistry graduates going into industry or academia, such as "advanced research planning skills, occupational health and

safety, intellectual property, scientific writing skills, communication, ethics, professionalism and scientific integrity" (Harding, 2004, p. 8). She concludes her piece by concurring that there exists no unified set of guidelines for good supervision, and that excellent supervision is intrinsically difficult to define and to evaluate, highlighting the equal importance of supervisor development and supervision skills (Harding, 2004).

The only other time that doctoral education is mentioned within AusJEC is in Varella (2012), in which the author describes The European Chemistry Thematic Network Association (ECTNA) which aims to promote the international recognition of chemistry qualifications, including the chemistry doctorate. In compliance with Bologna Process, ECTNA awards what it calls the *The Chemistry Doctorate Eurolabel®* to chemistry doctoral programs that meet its accreditation framework, in which the following criteria are considered:

- Fitness for purpose;
- Entry to the programme;
- Length of studies;
- Study programme structure, *i.e.* coursework and credits considered in the widest possible sense;
- Teaching and training in generic competences;
- Transcripts;
- Graduate schools;
- Supervision;
- Examinations;
- Assessment;
- Quality assurance (Varella, 2012, p. 19)

In 2005, the Royal Australian Chemical Institute (RACI) published the *Future of Chemistry Study - Supply and Demand of Chemists*:

> The report examines the complete pathway that chemists travel from education to employment with an emphasis on the important role our primary and secondary teachers play in sparking an interest in science in the hearts and minds of our young people (Royal Australian Chemical Institute, 2005, p. 1).

The report only touches on doctoral education issues and somewhat hints at the themes of narrowness mentioned in the US and UK literature. For example, the Australian University Heads of Chemistry Survey in the RACI report reveals comments by five respondents regarding skills developed in a PhD in chemistry including chemical skills, generic skills, and skills relevant to industry. Two respondents suggested that the skills a doctoral candidate develops during candidature depend on the particular research project undertaken. Another two respondents suggested that the skills developed during the PhD were far too narrow and specialised. One respondent suggested better industry engagement to alleviate this problem:

> In my view the traditional PhD does not adequately prepare students for industry. I should like to see explicit coursework subject matter in issues relating to business management, personnel management, accountancy and the law included in the PhD, or the construction of a new doctorate which comprises 2.5 years of research project and the subject matter of a Grad Dip in Business. All PhD graduates will need to manage budgets and personnel, yet we do very little formally to equip students to do this. (Royal Australian Chemical Institute, 2005, p. 50)

However, the report then provides a contrasting view to the one above: "'the business models for many industries are widely different, and … we might do our students a disservice by over-emphasising a small number of business models at the expense of others'" (Royal Australian Chemical Institute, 2005, p. 50).

Another respondent suggested that a doctoral candidate's research experience hinged upon the number of academic staff at that university. This factor was often cited as a disadvantage for institutions with smaller numbers of academics. The respondent further said:

> This can often lead to unfair competition and potential p/g students are a jealously guarded resource. A culture of 'free trade' between institutions and where a movement between institutions for p/g study from u/g is the expected norm, would be a healthier environment for chemistry training in this country. (Royal Australian Chemical Institute, 2005, p. 50)

The RACI report summarised that for universities, the main challenge is ensuring that chemistry graduates have both core chemistry skills and the skills needed to move to related areas; a matter likely be increasingly important as the labour market becomes more mobile (Royal Australian Chemical Institute, 2005).

In 2016, the Australian Academy of Science released *Chemistry for a better life - The decadal plan for Australian chemistry 2016–25*. While not strictly concerned with chemistry education per se, the report does offer some coverage on this area. The purpose of the review was to "ensure a coordinated effort across the discipline and to maximise the benefit of chemistry for all Australians—leading to improved economic and social prosperity, greater wealth creation and better integration with the long-term sustainability needs of the natural environment" and to "guide Australian investment and activity to add to the global body of chemistry knowledge. It will efficiently deliver knowledge and improved products and services for national and international markets" (Australian Academy of Science, 2016, pp. 3–4).

The report focuses on five strategic goals in order for Australian chemistry to enable economic, social and environmental prosperity (Australian Academy of Science, 2016, p. 6):

> **Strategic goal 1**: Raise chemistry knowledge and skills
>
> **Strategic goal 2**: Improve the capabilities of the research sector
>
> **Strategic goal 3**: Raise the level of innovation efficiency and enhance the capacity of industry to innovate
>
> **Strategic goal 4**: Improve the image of chemistry
>
> **Strategic goal 5**: Implement the decadal plan.

However, despite the report's strategic goal to raise chemistry knowledge and skills, its treatment of chemistry education issues at the doctoral level is lacking. In its examination of academic research issues, the report focuses on ARC funding structures that do not lend themselves to 'ambitious and higher risk research' and that disadvantage women in STEM. Focus is also cast on the lack of university-industry engagement and poor career prospects for young researchers in the academic sector. The report's remedies for this centre on promoting chemistry teaching (presumably school teaching), given the comment:

> - currently the career path of a chemistry or science teacher is not sufficiently promoted at universities. Students are generally directed towards an academic or research career first, an industry career second and only into teaching as a last and less desirable option. (Australian Academy of Science, 2016, p. 33)

Other solutions include establishing more diverse research funding sources and creating more incentives for university-industry engagement and commercialisation. As far as doctoral education in chemistry is concerned, the report makes passing reference to it. It is cited that 97% of PhD graduates find employment within 3 months of completion, but only 20% of chemistry graduates will pursue a PhD in chemistry to begin with and, of those, only 80% will complete. Industry employment is lamented again, with the report noting that "the dearth of industry investment in R&D has resulted in 70% of [PhD] graduates being employed in academia and just 30% in industry" (Australian Academy of Science, 2016, p. 26).

3.4 Formulation of the Research Question

This section of the chapter has mapped out the state of the literature on chemistry doctoral education across three regions: the US, the UK, and Australia between 2004 and 2016. Having made this detailed examination, this section of the literature review aims to synthesise these discussions and consequently, provide the justification for the research question.

Of the three regions examined, the US features most prominently in terms of debates on chemistry doctoral education; however, this is a relative statement made in relation to the state of the fields in the UK and Australia. In other words, over a duration of 12 years in the US, apparently only three essays on chemistry doctoral education reform (Breslow, 2006; Kwiram, 2006; Stacy, 2006) were produced in one seminal text (Golde & Walker, 2006), one major ACS review took place in 2012 (American Chemical Society, 2012), and a couple of scholarly research articles were published (including editorials) (Caserio et al., 2004; Casey, 2004; Loshbaugh et al., 2011; Moore, 2006; Thiry et al., 2015).

Qualitatively, most of the work here has articulated the need for chemistry doctoral programs to strike both breadth and depth of knowledge. The need for student professional career awareness and skill preparation is also acknowledged. Interdisciplinarity is conceived as working with other STEM disciplines. However, the section on STEM education in this thesis underscored the need for STEM students to engage with questions of values in science; only Stacy (2006) envisioned this for the discipline of chemistry. Loshbaugh et al. (2011) examined chemistry departments' reactions to the increased focus on student career preparation and

professionalisation by interviewing heads of departments, program convenors, and administrators. But given that supervisors are the 'cultural reservoirs' of the discipline and powerful socialising agents as argued in Chapter 2, it is necessary to examine their conceptions of chemistry doctoral purpose, their subsequent educational practices, and their ways of self-evaluation. Once again, only Stacy (2006) manages to pose these self-reflective questions about the discipline of chemistry and its doctoral programs.

Examining the state of the field in the UK paints a dimmer picture. With only two reports commissioned by the RSC and only passing reference made to the perceived narrowness of chemistry doctoral education and the need for both depth and breadth of knowledge, the UK falls behind the debates despite the presence of the RSC – the UK equivalent of the ACS.

Lastly, Australia appears to be below the par in terms of its engagement in contemporary debates on chemistry doctoral education. Examining RACI's 19 journal publications in *The Australian Journal of Education in Chemistry* (AusJEC) between 2001 and 2016 yields only two articles that mention doctoral education in chemistry: that of Harding (2004) and Varella (2012), with the latter merely describing doctoral education accreditation practices in Europe. As with the UK, scholarly research on doctoral education is unrecognised and even the seminal work of the *Carnegie Initiative on the Doctorate* (CID) is not picked up in any of AusJEC's journals. The 2005 RACI report on the future of chemistry education glosses over chemistry doctoral education in Australia and so does the Academy of Science's 2016 Decadal Plan for chemistry, despite the latter's commitment to bolstering chemical knowledge and the general image of chemistry in Australia.

Stepping back, the research landscape on chemistry doctoral education appears to be barren. The field has largely ignored the scholarly research on doctoral education that has existed for 30 years now. This absence of scholarly research raises a number of key issues:

Given that contemporary debates on doctoral purpose as well as practice have become more strongly concerned about developing the student into a knowledge worker and less so about developing 'stewards of the discipline', it is unclear what chemistry doctoral supervisors think the purpose of the chemistry doctorate is, especially within the Australian context. Furthermore, it is unclear what the educational practices of chemistry PhD supervisors in Australia look like in relation to contemporary doctoral debates and practices in Australia. Lastly, the measures used by chemistry PhD supervisors in Australia to gauge their own

supervisory success with their students, specifically in relation to follow-up on graduate career outcomes, is not clear. This requires asking the following questions:

- What are the conceptions of doctoral purpose held by chemistry doctoral supervisors in Australia?
- How do their educational practices relate (or not) to their conceptions of doctoral purpose? Specifically:
    - What knowledge and skills do they ensure their students have upon graduation?
    - Do they encourage their students to reflect upon contemporary issues pertaining to the discipline of chemistry?
    - Do they encourage their students to experience work during their degrees?
- How do chemistry PhD supervisors evaluate their success in terms of follow-up on graduate career outcomes?

These questions can be encapsulated in the following overarching research question:

'What are the Positions of Chemistry PhD Supervisors in Australia in Relation to Contemporary Debates and Practices in Doctoral Education?'

Therefore, this analysis necessitates and justifies the research question: 'What are the Positions of Chemistry PhD Supervisors in Australia in Relation to Contemporary Debates and Practices in Doctoral Education?' By drawing upon the key concepts mentioned above, this study will turn to doctoral supervisors in chemistry in Australia as the 'cultural reservoirs' of the discipline and examine their influence on their students. Their fundamental conceptions of the purpose of the chemistry PhD, their respective educational practices, and their measures of self-evaluation in relation to graduate career outcomes will be explored, and the appropriate research methods to answer this question will be outlined in the next chapter.

3.5 Summary

This chapter was the second chapter of the literature review for this study. Having looked at the prominent scholarly debates that have occupied the doctoral education space in Chapter 2, this chapter aimed at constructing the case study in chemistry. The major debates in STEM and STEM education sketch an image of 'unhealthy science' in Australia, with governments

attempting multiple strategies to remedy this. One remedy has been The National Innovation and Science Agenda, which has aimed at injecting economic growth and national prosperity by supporting science through increased funding and business ventures. This agenda and its aims happen to tie in with those of the ACOLA review, extending the urgency of improving the employability of HDR candidates. The scholarly literature showed that in addition to transferable skills training, STEM graduates needed to be able to engage in and reflect upon the ethical, social, political, and economic issues pertaining to science, since scientific expertise alone will unlikely be sufficient to address the complex problems of today's workforce. Exposing students to areas of work and research beyond academia were also argued as improving candidate employability. Issues related to women in the STEM and academic workplaces, such as underrepresentation, were also covered, in order to inform subsequent research decisions in this study. Following the review of the major issues in STEM education, the chapter focused on the discipline of chemistry, including the general nature and structure of chemistry as an academic discipline. This was followed up with a detailed examination of the state of research on chemistry doctoral education across the US, UK, and Australia between 2004 and 2016. This detailed examination revealed the research landscape on chemistry doctoral education as barren. It thus became necessary to invigorate the field of scholarly research in chemistry by initiating the scholarly debates in the field. Based on this, the unique and key role supervisors play as the 'cultural reservoirs' of the discipline, and the concepts derived from the doctoral education literature on doctoral purpose, practice, and evaluation, the following research question was formulated: 'What are the Positions of Chemistry PhD Supervisors in Australia in Relation to Contemporary Debates and Practices in Doctoral Education?'

CHAPTER 4 – METHODOLOGY & RESEARCH DESIGN

This chapter discusses the methodology adopted for this research project. The chapter sections generally follow a structure in which supporting literature is provided followed by the research choices made based on that literature. First, my philosophical position is established and situated in critical realism. The critical realist philosophy states the presence of reality independent of our acknowledgment of it, but that our understanding of that reality is based on the different perspectives and meanings we bring forth into the research. From there, the qualitative research approach is presented and argued as the most appropriate research methodology for answering the research question, given the interest and research goals of formulating a deep and sophisticated understanding of chemistry doctoral supervisors and their conceptions of doctoral purpose in chemistry, their educational practices, and self-evaluation of supervisory success in relation to their follow-up on graduate career outcomes. A quantitative research approach is argued as inadequate in achieving those goals. The semi-structured interview technique is then argued as the data collection instrument of choice due to its usefulness in allowing a researcher to cover a set of predetermined interview questions, while also keeping the space open for new ideas and insights to be discovered and explored. In relation to methods of data analysis, qualitative content analysis is argued to be the most adequate data analysis tool due to its flexibility in allowing analysis of the data both deductively based on pre-existing themes from the literature review, and inductively through emergent themes from the data. The interview design is outlined and reasoning is provided behind the questions asked. Thirty-one supervisors participated in this study, spanning universities in Australia across the Go8, ATN, and IRU groupings, as well as both genders, a number of sub-disciplines in chemistry, different levels of supervisory experience, and a number of geographic states in Australia. This approach provided a culturally diverse and varied sample to conduct the data analysis. The data analysis approach and reasoning behind it is also provided.

4.1 Philosophical Position

All research is influenced by a particular research philosophy, mine being critical realism. Critical realism is a philosophy that "stresses the primacy of being over thought" (Joseph, 1998, p. 76). In research terms, this means that ontology (theory of being) takes precedence over epistemology (theory of knowledge) (Joseph, 1998; Steinmetz, 1998).

Fleetwood (2004, p. 26) defines ontology as the "study or theory of being, not to being itself. To have an ontology is to have a theory of what exists". He further explains that critical realists "do not, for example, think that mountains, buildings, computers and kidneys are real, but ideas, beliefs, concepts, language and discourse are non-real" (Fleetwood, 2004, p. 27). Something is considered real if it has an effect or can make a difference and have consequences. Realism, in general, holds the view that there is an external social reality that exists independently of our knowledge of it and that it can be measured, however accomplishing this can be difficult (Gray, 2014; Schwandt, 2007). Where ontology is concerned with theory of being, epistemology is the study of theory of knowledge and what constitutes legitimate knowledge (Gray, 2014).

Critical realists, according to Maxwell (2010) and Mingers (2006), maintain an ontological realism; that is, there is a real world that exists independently of our understanding, perceptions, theories, and constructions of it, while accepting a form of epistemological relativism; that is, our understanding of this world is unavoidably a construction from our own lens and point of view. This relationship between reality and our interpretation of it is best captured below:

> There is no theory-neutral observation, description, interpretation, theorisation, explanation, or whatever. There is, in other words, no unmediated access to the world: access is always mediated. Whenever we reflect upon an entity, our sense data is always mediated by a pre-existing stock of conceptual resources, which we use to interpret, make sense of and understand what it is, and take appropriate action. This stock may be individual (e.g. a subjective belief or opinion) and/or social (e.g. an accepted theory, perspective or social norm) and/or rooted in practice (i.e. the result of previous encounters with entities other than ourselves). (Fleetwood, 2004, p. 28)

In other words, critical realism reconciles "a realist view of being in the ontological domain whilst accepting the relativism of knowledge as socially and historically conditioned in the epistemological domain" (Mingers, 2006, p. 19). In relation to this study specifically, being a critical realist means that the conceptions of doctoral purpose that chemistry PhD supervisors have, their consequent educational practices with their students, and their self-evaluation of success in relation to follow-up on graduate career outcomes are all real entities, and all other social and cultural functions are all seen as real and operating independently of our understanding of them. But our understanding of their conceptions, their practices, the ways

they self-assess their success, is conceptually mediated and dependent upon our views and understanding of the world.

In terms of methodology, critical realism encourages the use of different methods as appropriate for the research and different theoretical interpretations and explanations (Pawson, 2006; Pawson & Tilley, 2001).

As stated by Sayer (2008, p. 168):

> It advocates a 'critical methodological pluralism', i.e. pluralistic not in the sense that any method goes in any situation, but that different methods are appropriate to different situations, according to the nature of the latter. Therefore, methodological issues cannot be resolved without a prior consideration of ontology.

This implies that while critical realism guides the whole research process, the choice of data collection and analytical methods is determined by their utility in answering the research question, and by the various ontological assumptions of the parts of the social reality under investigation (Vega, 2010).

4.2 Methodology – Qualitative Research

Since the methodology is chosen based on how well it can answer the research question, it is then useful to revisit the research question:

> 'What are the Positions of Chemistry PhD Supervisors in Australia in Relation to Contemporary Debates and Practices in Doctoral Education?'

Given the interest in formulating a deep and rich understanding of chemistry PhD supervisors' conceptions of doctoral purpose in chemistry, their subsequent educational practices, and self-evaluation of supervisory success in relation to follow-up on graduate career outcomes, it is argued here that the qualitative research approach would be the most suitable and appropriate methodology to answer the research question above and realise these research aims.

Qualitative research is a type of scientific research. It is a "naturalistic, interpretative approach" (Snape & Spencer, 2003, p. 3) which seeks to answer a question according to a described method, collects the evidence, and produces new findings that can be applied to contexts beyond its own. Furthermore, it attempts to answer a given research problem from the viewpoint of the participants in which it is involved. Qualitative research is particularly effective in obtaining deep, rich, culturally specific information about the values, thoughts, and

feelings of specific populations and the meanings that they attach to phenomena within their social worlds (Gray, 2014; Mack, Woodsong, MacQueen, Guest, & Namey, 2005; Snape & Spencer, 2003).

While a quantitative research instrument such as a survey could have been used to collect the data, it would not have satisfied these research aims. Quantitative research methods are usually appropriate when trends, relationships, and probabilities are needed to answer the research question, usually in the form of a hypothesis and generally unambiguous; qualitative methods are generally used to deeply explore and understand the experiences and perspectives of participants and thus produce data that is "usually not amenable to counting or measuring" (Denzin & Lincoln, 1998; Hammarberg, Kirkman, & de Lacey, 2016, p. 499).

According to Mack et al. (2005) and Ritchie (2003), qualitative research methods are particularly effective in recognising and handling abstract entities, such as social norms and traditions, gender, and ethnic background, the roles of which may not be immediately apparent in the research problem. Even though findings from qualitative research can often be extended to individuals and cultures with characteristics and attributes similar to those in the population being studied, attaining rich and in-depth understanding of the phenomenon under study usually takes precedence over producing findings that can be generalised to other geographies or populations (Cooksey & McDonald, 2011; Mack et al., 2005). This is a defining difference between qualitative and quantitative research. It is not essential to collect data from every individual in a community or social group in order to get meaningful and convincing results – only a sample of the population is needed. The study's research goals and the attributes and nature of the population being studied, such as its size and how diverse it is, determine which and how many people to recruit (Mack et al., 2005).

In adopting a qualitative research methodology, this study establishes an original opportunity to interact with chemistry PhD supervisors in Australia – the cultural reservoirs of the discipline – and uncover deep, rich, and novel insights about what they think the purpose of the chemistry PhD is, what they report educational practices look like, and how they view their own success as supervisors, in addition to facilitating the inspection and probing of new emergent insights.

4.3 Research Methods – Interviews

Having determined the qualitative research approach as the underpinning methodology of the study, the next step is to determine the appropriate methods to answer the research question. For this study, the semi-structured interview technique is the method employed as it allows for a deep and detailed understanding of the social reality under investigation, while also providing the flexibility to gather data in different ways.

Interviews are a verbal exchange and have often been described in the literature as a type of conversation (Brinkmann, 2008; Burgess, 1982, 1984 as cited by Legard, Keegan, & Ward, 2003; Gray, 2014). Essentially, they are a means of constructing knowledge about the social world through human interaction (Gray, 2014; Mack et al., 2005).

Many different styles of interviewing exist, such as through the internet, over the telephone, and face-to-face. The interview itself is conducted to enable the researcher to answer one or a number of research questions, designed in advance before entering the field (Brinkmann, 2008). It is also useful to highlight the differences between some of the interview techniques available. As Cook (2012, p. 2) explains:

> A distinction can be made between structured interviews where a list of preconceived topics are responded to by the participant, unstructured interviews where no preconceived topics or questions are devised, and semi-structured or in-depth interviews where the conversation oscillates among the researcher's introduction of the topic under investigation, the participant's account of his or her experiences, and the researcher's probing of these experiences for further information useful to the analysis.

Additionally, the in-depth interview is used to produce nuanced knowledge about the social world. In contrast to in-depth interviews, surveys are more restricted in their ability to produce detailed accounts of reality, and are better geared towards larger samples with fixed or structured questions (Curtis & Curtis, 2012; Travers, 2010).

In semi-structured or in-depth interviews, a researcher has the flexibility to cover topics through a series of "predetermined, but open-ended questions" (Ayres, 2008, p. 3), allowing for in-depth probing aimed at acquiring a fuller and more detailed understanding of the participant's response, and the potential to produce new knowledge (Legard et al., 2003).

In general, a participant information sheet, along with a consent form are sent to the potential participant, explaining what the research study entails and the purpose of the interview, and

asking whether they would consent to participate. Good questions are usually brief and simple, with the researcher often being interested in descriptions and reflections of the respondent's experiences. Concrete descriptions are attained by posing questions such as 'what' and 'how', rather than 'why'. A debrief may be provided at the end of the interview and may include giving the interviewee a chance to add comments or ask questions (Brinkmann, 2008).

Brinkmann (2008) adds that interviews are usually audio-recorded and then transcribed, with the transcription being used as the primary data source for the researcher. Interview transcription is a demanding process that requires experience and attentiveness to the many differences between oral and written communication.

4.4 Pilot Study and Refinement of Interview Questions

It is common practice in qualitative research to conduct pilot studies to improve various aspects of the research study (Lewis-Beck, Bryman, & Liao, 2011; Schreiber, 2012). Five supervisors in chemistry participated in a pilot study. The interviews with them were used to improve the quality of the research before beginning the data collection phase. In addition to refining the interview questions, the pilot study offered the chance to leave the 'theoretical space' of the project, and to pragmatically enter the field and interact with chemistry PhD supervisors within this space. It meant engaging with them over their thoughts, concerns, and needs emerging as a result of these discussions. It also meant making use of their expertise within the discipline and seeing how it could improve the sophistication of the study. Besides the five pilot participants, two other academics in chemistry were consulted in an advisory manner. The interviews and discussions with these seven participants formed the 'expert consultation' phase for the project.

4.5 Interview Design

As explained in Chapters 2 and 3, the aim of the literature review was to draw upon the key concepts and understanding from the literature on doctoral education in order to provide the necessary framing for this study. The literature review was organised around three overarching themes: doctoral purpose, doctoral practice, and doctoral evaluation. By extension, the interview questions were designed based on these more specific themes: Supervisory Conception of Doctoral Purpose in Chemistry, Supervisory Educational Practices, and Supervisory Self-Evaluation. These themes and their corresponding interview questions have been summarised in Table 4-1 below:

Table 4-1 Interview Design Based on the Conceptual Framing Provided by the Literature Review

Themes	Corresponding questions
Theme 1: Supervisory Conceptions of Doctoral Purpose in Chemistry	What do you think is the purpose of a chemistry PhD?
Theme 2: Supervisory Educational Practices	What knowledge do you ensure your students have when they graduate? What skills do you ensure your students have when they graduate?
	Do you encourage your students to reflect about the discipline of chemistry in the broader scheme of things? (e.g. the ethical, social, economic, & political issues pertaining to the discipline of chemistry?)
	Do you encourage your students to get work experience, paid or unpaid, during their PhD? (e.g. tutoring, university admin, industry, government?)
Theme 3: Supervisory Self-Evaluation	How do you know that you have succeeded as a supervisor with your students?
	Have your PhD graduates ever reported how their PhD, or aspects of it, have best prepared them for the careers they have chosen? Conversely, have your PhD graduates ever reported how their PhD, or aspects of it, could have better prepared them for the careers they have chosen?

Under Theme 1: Supervisory Conceptions of Doctoral Purpose in Chemistry, participants were asked 'What do you think is the purpose of a chemistry PhD?' in order to establish what conceptions of doctoral purpose underpinned their reported practices.

Several questions were asked under Theme 2: Supervisory Educational Practices. 'What knowledge do you ensure your students have when they graduate?' opened up the opportunity to gain insight into the knowledge that supervisors valued the most and saw as fundamental for graduates to have. On the other hand, the question 'What skills do you ensure your students have when they graduate?' allowed insight into the skills that supervisors valued as crucial for students to learn in the program and possess upon graduation. These questions were informed by the literature on knowledge and skills reviewed in Chapter 2.

Continuing under Theme 2: Supervisory Educational Practices, participants were asked, 'Do you encourage your students to reflect about the discipline of chemistry in the broader scheme of things? (e.g. the ethical, social, economic, & political issues pertaining to the discipline of chemistry?)'. This question was informed by the literature reviewed in Chapter 3 on STEM and the need for science graduates to be able to engage with such value-based questions in the face of today's complex problems that will unlikely be solved using scientific expertise alone. The question explored whether supervisors in chemistry allowed space for such discussions during the PhD program. Similarly, the question 'Do you encourage your students to get work experience, paid or unpaid, during their PhD? (e.g.: tutoring, university admin, industry, government?)' was aimed at seeing whether supervisors were open to encouraging their students to engage in these sites of experience that would improve the employability of

students entering the wider workforce, given the structural issues raised in the discipline of chemistry in Section 3.2.2 of the STEM and Chemistry Education chapter.

Finally, under Theme 3: Supervisory Self- Evaluation, supervisors were asked, 'How do you know that you have succeeded as a supervisor with your students?' to uncover, through self-reflection, the different measures they employed in characterising their success as supervisors. The question also allowed for an exploration of whether their self-evaluation measures of success aligned with their reported educational practices and conceptions of doctoral purpose. Under the same theme, supervisors were asked, 'Have your PhD graduates ever reported how their PhD, or aspects of it, have best prepared them for the careers they have chosen?' and 'Conversely, have your PhD graduates ever reported how their PhD, or aspects of it, could have better prepared them for the careers they have chosen?' to explore whether follow-up discussions existed with their graduates, and how that might relate to and link with their self-evaluation measures of success. With all questions asked under the three themes, follow-up questions for clarification were asked, where needed. For example, asking a participant to clarify their measures of success when they were talking about their measures of supervisory failure, 'So that's the measure of failure though… so then the measure of success would be a…' Please see Appendix A for the interview questions and Appendix B for an interview transcript.

4.6 Participant Recruitment

Having designed the interview questions for the study, the next step in the research methodology turned to the sampling and recruitment of study participants. Mack et al. (2005) and Marshall (1996) explain that as one of the most common sampling approaches, purposive sampling actively categorises participants, based on predetermined criteria, to produce the most productive sample to answer a specific research question. Sample sizes, which may or may not be determined before data collection, depend on resources, time available, and research aims. In practice, the number of required participants usually becomes clearer as the study progresses or as new themes or explanations stop emerging from the data. This is called data saturation – "the point in data collection when new data no longer bring additional insights to the research questions" (Mack et al. p. 5, 2005; Marshall, 1996). Purposive sampling is hence most successful when, ideally, data analysis is done in conjunction with data collection.

Distinction between various methods for selecting samples is fundamentally based on producing either a probability sample or a nonprobability sample. With probability samples,

"each member of the population has a known chance of being included in the sample… Probability samples are required for statements about either the accuracy of sample estimates or the statistical significance of results" (Morgan, 2008, p. 2). On the other hand, one of the most accepted ways of selecting a nonprobability sample is maximum variation sampling, which inspects a widespread array of diverse cases within the population (Morgan, 2008).

Most qualitative research in reality relies on nonprobability samples because it is frequently difficult to find data sources that meet the eligibility criteria, notwithstanding quantifying the total size of the population from which the sample is taken. The need to collect very rich and detailed, in-depth data often leads to small sample sizes where statistical analysis is futile. Therefore, using nonprobability samples in qualitative research corresponds to an approach to data collection and analysis that normally depends on carefully interpreting of a small number of very rich sources of data (Morgan, 2008). Quantitative research often struggles to understand the utility of studying small samples due to the misunderstanding that generalisability is the ultimate objective of all good research (Marshall, 1996).

Based on the reasoning above, maximum variation sampling was chosen for this study as providing the greatest sample diversity. The research was national and based in Australia. Fourteen universities were chosen in the following states/territories: Australian Capital Territory, New South Wales, Victoria, South Australia, Queensland, and Western Australia. These amounted to the eight universities from the Group of Eight (Go8) universities, five universities from the Australian Technology Network (ATN) universities, and one university from the Innovative Research Universities (IRU).

Selecting supervisors from a range of universities and contexts offered the greatest potential for participant diversity and richness. The Go8 represents Australia's most research intensive universities while ATNs represent Australian universities with an industry collaboration focus. IRUs represent a network of universities in Australia committed to excellence in research and teaching.

In terms of states and territories, NSW was chosen as it houses universities from all three of the aforementioned networks, facilitating the data collection process while reducing monetary and time expenses. Meanwhile, Melbourne and Brisbane house research institutes and companies that employ chemists. South Australia has a wine industry that attracts chemistry research graduates. Western Australia has a petroleum industry that may employ chemistry PhD graduates. These different sites offer research breadth and diversity of participants.

For this study, potential participants were identified from their respective institutional web pages, starting with 332 potential participants. Deans/Heads of Schools of the respective universities were contacted for approval to undertake the interviews within the Schools/Centres. All relevant staff were contacted to see whether they would participate in my study. A week after sending out the invitations, those who had not responded were recontacted via email or phone. Each potential participant was emailed a copy of the participant information sheet (see Appendix C for the Participant Information Sheet).

Those who agreed to have face-to-face interviews were asked regarding a suitable date and time sometime between February and July 2017. Those who agreed to have Skype or telephone calls participated as immediately as possible.

4.7 Ethics

ANU's Human Research Ethics Committee provided unconditional approval for the project. Deans or Heads of Schools of the respective universities were contacted for approval to undertake the interviews within their Schools or Departments (see Appendix D for the Ethics Approval).

For interviews done via Skype or telephone, consent forms were sent to the participant's email address and were signed before the Skype/telephone interview (see Appendix E for the Consent Form). Following the transcription of the interviews, the names of participants and any other mentioned names were replaced by pseudonyms. As far as the law allows, the confidentiality of the results will be preserved.

Data is stored on my password-protected PC and on ANU's cloud storage. The data must be stored for a period of at least five years from the date of any publication arising from the research.

4.8 Actual Sample

Deans or Heads of Schools needed to be contacted for their approval to conduct the research at their universities. Before doing so, it was decided that I would have someone as a 'sponsor' during this process. The role of the sponsor was to support me and improve my credibility when approaching the Deans or Heads. A well-known director of a chemistry research school was selected to fulfil this role, given his position within, and his visibility across the discipline of chemistry. He agreed to draft a letter in which he outlined and explained his reasons for his support. He advised that I contact Heads of Chemistry as opposed to the Deans or Heads of

Schools. This was for two reasons: the request to conduct research with chemistry PhD supervisors was most likely going to be redirected to the Heads of Chemistry nonetheless; and to avoid having the request be forgotten and subsequently followed up.

Fourteen emails were drafted to the target universities. Heads of Chemistry were chosen, wherever possible. In the absence of a Head of Chemistry, a Head of School (of Science, for example) was chosen instead. My supervisor, Dr Margaret Kiley, emailed each of them, explaining who we were and what the research was about, and included the director's letter of support as well as the participant information sheet as attachments.

Eleven out of 14 Heads of Chemistry/Schools gave approval to conduct the research at their universities. Some Heads provided approval to immediately conduct the research with their supervisors. Others passed on the research details to their supervisors and I contacted them reiterating the research details while providing the information sheets and consent forms. Some Heads provided lists of their chemistry supervisors which I cross-referenced with my own list. Other Heads asked to see my own contact list and they updated it appropriately.

A total of 332 potential participants (including pilot participants) existed. Following the approval of the Heads, supervisors were invited via email to participate in the study, with follow-up calls made to those who did not respond to the email invitation within a week of the initial contact. Some email invitations bounced back and some supervisors' phone numbers simply were not operational. Others declined to participate while some did not reply to either their email invitations or follow-up phone calls. Several supervisors mentioned upon contact that they were not chemists.

A total of 31 interviews were conducted in this study, which consisted of eleven face-to-face interviews, one Skype video call, and nineteen telephone calls. After conducting the first thirteen interviews, including nine face-to-face interviews in NSW, preliminary data analysis was conducted to examine the data for emergent themes and insights. Following this, some additional interview questions were incorporated into the interview schedule for further probing of emergent themes. This is outlined in detail in Chapter 5.

Thirty-one interviewees provided enough data to reach the point of data saturation for the study, at which no new insights were arising from the interviews. Women were oversampled in the recruitment process to address and ameliorate issues relating to underrepresentation indicated by the literature review. When asked about the ratio of men to women of chemistry academic staff at their universities, participants gave responses that ranged between 20 and 30%

female representation. This sampling strategy provided 13 females out of 31 participants, which equals a 42% representation.

4.9 Participant Demographics

This section of the methodology covers the demographics of the actual study participants, as summarised in Table 4-2 below:

Table 4-2 Participant Demographics

Universities	**9**
Go8	6
ATN	2
IRU	1
Participants	**31**
Go8	21
ATN	7
IRU	3
Gender	
Male	18
Female	13
Sub-discipline	
Organic	7
Inorganic	4
Physical	8
Other	12
Number of Completions	
Fewer than 5	11
Between 5 and 10	5
More than 10	15
State	
NSW	15
VIC	3
SA	4
WA	9

Nine universities ultimately participated in this study, including six Go8s, two ATNs, and one IRU. The 31 participants consisted of 21 supervisors from the Go8 universities, seven supervisors from the ATN universities, and three supervisors from the IRU university. The study consisted of 18 males and 13 females. Seven supervisors identified themselves as organic chemists, four identified as inorganic chemists, eight as physical chemists, and 12 supervisors identified were from sub-disciplines that did not fall into the 'classic three'. Eleven supervisors had supervised fewer than five PhD students to completion, five supervisors had supervised

between five and ten PhD students to completion, and 15 supervisors had supervised over 10 PhD students to completion. In terms of geographic location, 15 supervisors were in NSW, three in VIC, four in SA, and nine in WA. These participant demographics demonstrate that the sample consisted of a rich and diverse variety of participants for the study.

4.10 Data Collection and Analysis

4.10.1 Data Collection

Data was collected in three ways: eleven face-to-face interviews, one Skype video call, and nineteen telephone calls. Face-to-face and Skype video interviews were audio-recorded using a smartphone. Telephone calls were recorded using either a smartphone or an audio recorder. Audio-recorded data was fully transcribed using Dragon NaturallySpeaking software via voice writing or 'parroting' – listening to the audio recording and verbally reuttering the dialogue into a microphone so that it is recognised by the software and transcribed. This accelerated the transcription process and saved valuable time.

4.10.2 Data Analysis – Qualitative Content Analysis

Following completion of the interviews, the data were analysed. Qualitative data analysis focuses on the analysis of talk and text, with particular attention to the "work done by words" (Denscombe, 2010, p. 279). In other words, while text and talk can be analysed at a surface level for the information and descriptions they contain and convey, social scientists appreciate that words can do much more than this, and analyse them in such a way in order to reveal the assumptions, meanings, and constructs held 'in between the lines'.

For this study, qualitative content analysis was chosen as the data analysis tool. Qualitative content analysis is a research method for the controlled analysis of text within its context, and can make sense of volumes of textual data through systematic coding and identification of themes (Bengtsson, 2016; Hsieh & Shannon, 2005; Mayring, 2000; Patton, 2002)

According to Zhang and Wildemuth (2009, p. 1), qualitative content analysis "emphasizes an integrated view of speech/texts and their specific contexts" and "goes beyond merely counting words or extracting objective content from texts to examine meanings, themes and patterns that may be manifest or latent in a particular text".

To condense the raw data into manageable themes for interpretation, qualitative content analysis draws upon both inductive and deductive reasoning to achieve this. Inductive reasoning produces themes which emerge directly from the data through close inspection and

comparison, while deductive reasoning uses concepts and themes from theory or prior relevant studies in the literature. This flexibility of qualitative content analysis holds great analytical utility for the researcher (Zhang & Wildemuth, 2009).

Bengtsson (2016) explains that because qualitative content analysis does not adhere to a particular scientific paradigm, there are fewer rules to follow and therefore, a smaller risk of confusion regarding philosophical concepts and discussions. Zhang and Wildemuth (2009), however, do offer a general procedure for conducting qualitative content analysis, summarised in Table 4-3 below:

Table 4-3 General procedure for conducting qualitative content analysis (adapted from Zhang and Wildemuth (2009))

Qualitative Content Analysis Process	
Step 1: Prepare the Data	Transform the data into written text.
Step 2: Define the Unit of Analysis (Basic Unit of Text)	These are usually themes that might be expressed as a single word, phrase, sentence, paragraph, or an entire document. The theme is an expression of an idea or issue relevant to the research question(s).
Step 3: Develop Categories and a Coding Scheme	Develop themes either through induction or deduction. Units of analysis can be assigned to more than one theme.
Step 4: Test Your Coding Scheme on a Sample of Text	Test your coding scheme with another researcher. If the results show low consistency, then the coding rules need to be revised.
Step 5: Code All the Text	Once consistent, apply the coding scheme to the whole text. Be prepared to add new themes to the scheme as new data is analysed.
Step 6: Report You Findings and Draw Conclusions from the Coded Data	Report your processes as completely and truthfully as possible. Make sense of the themes by exploring them themselves and in relation to other themes in the data. This will rely on the researcher's reasoning abilities.

NVivo 11 was used to manage and help analyse the data. Themes were categorised based on the number of respondents and the codes allocated to them, rather than the number of times a particular code was mentioned. This strategy is arguably more conceptually robust than mere code counting. Respondents were given shorthand pseudonyms such as G08M31 where G08 = university grouping, M = gender, and the number represents the order in which the 31 participants were interviewed. In this study, the data analysis approach consisted of two stages: Stage One: Deductive Analysis of the Semi-Structured Interviews, and Stage Two: Inductive Analysis of Emergent Themes.

A coding manual was built for the analysis of the data. Stage One of the analysis consisted of deductively analysing the data based on pre-existing themes derived from the literature review. Stage Two consisted of inductively analysing the data based on emergent themes from the data. The manual underwent multiple revisions and was finessed as the data was analysed and

reviewed within the research group several times. Once confidence regarding the analysis was reached within the research group, intercoding took place with a member external to the group to ensure coding consistency.

Stage One provided the space for the deductive analysis of the interview responses guided and framed by the concepts and understandings arising from the literature review of the major debates in the scholarly literature on doctoral and STEM education. For example, Theme 1: Supervisory Conceptions of Doctoral Purpose in Chemistry was produced from the deductive analysis of the debates in the doctoral education literature. Given that doctoral purpose underpins practice, this was an important starting point in the interview question schedule.

The coding of responses under this theme was informed by the concepts arising from the literature on doctoral purpose: supervisors who thought the chemistry PhD was about developing students in terms of their knowledge, skills, and attitudes, were coded under the conceptions of purpose relating to developing the candidate as a person (or 'Person' as shorthand) and which is underpinned by the paradigm of developing knowledge workers. For those who saw the purpose of the chemistry PhD as conducting and executing research and creating knowledge, their responses were coded under conceptions of purpose relating to the product and artefacts of doctoral study (or 'Product' as shorthand), which is underpinned by the paradigm of preparing stewards of the discipline concerned with creating knowledge for the sake of the discipline.

It was crucially important at this stage of the analysis to code the responses by question. For example, the response to the question on doctoral purpose in chemistry is coded under the theme of Supervisory Conceptions of Doctoral Purpose in Chemistry, and the responses to questions relating to educational practices were coded under the corresponding theme of Reported Educational Practices. The reason for this was to address the research aims and draw linkages to see (if) and how supervisors' conceptions of doctoral purpose were underpinning their reported educational practices and so on. If a whole interview was coded for the theme of doctoral purpose, that would have meant coding responses related to educational practices under that theme and would have consequently produced adverse conceptual problems in the analysis, and failed in addressing the aim of trying to see the linkages between supervisors' conceptions of purpose and their reported practices.

This is where the flexibility and utility of the chosen data collection method and analysis come forth in Stage Two of the analysis, which opened up the space for inductive reasoning and the

exploration of new and interesting emergent themes. Chapter 5 discusses these stages of analysis in greater depth and detail.

4.11 Summary

This chapter of the thesis discussed the methodology adopted for this study. First, my philosophical position is established and anchored in critical realism which states the presence of reality independent of our acknowledgment of it, but that our understanding of that reality is conceptually mediated. From there, the qualitative research approach is argued as the most appropriate research methodology for answering the research question, given the interest and research aims of formulating a rich and sophisticated understanding of chemistry doctoral supervisors' conceptions of doctoral purpose in chemistry, their educational practices, and self-evaluation of supervisory success in relation to follow-up on graduate career outcomes. A quantitative research approach would have been inadequate in realising these research aims. The semi-structured interview technique is selected as the data collection instrument for its flexibility and hence its utility in allowing a researcher to cover a set of predetermined interview questions, while also allowing for new topics and insights to be discovered and explored. In terms of methods of data analysis, qualitative content analysis was the analytical tool of choice as it provided the flexibility to analyse the data both deductively based on pre-existing themes from the literature, and inductively through emergent themes from the data. The interview design was outlined, including justification behind the questions asked. Thirty-one supervisors participated in this study, spanning universities in Australia across the Go8, ATN, and IRU, as well as both genders, multiple sub-disciplines in chemistry, different levels of supervisory experience, and a number of geographic states in Australia. This provided a culturally diverse and rich sample to conduct the data analysis. The approach and justification behind the data analysis was also provided.

CHAPTER 5 – FINDINGS

Stage One: Semi-structured Interview Analysis

The previous chapter on Methodology and Research Design outlined the approach needed to analyse the data. This chapter details the main findings arising from the Stage One analysis of the 31 interviews conducted in this study. This analysis, as detailed previously, is based on interviewee responses to the semi-structured interview questions asked in the study, such as, "What do you think is the purpose of the chemistry PhD?" The chapter is structured into three main themes: Supervisors' conceptions of the purpose of the chemistry doctorate; Supervisors' reported educational practices in the doctoral program; and Supervisors' self-evaluation of success in relation to their graduates and their career outcomes.

5.1 Supervisors' Claimed Conceptions of the Purpose of the Chemistry Doctorate

Supervisors were asked what they thought the purpose of the chemistry PhD was. As explained in the literature review, debates in the doctoral education literature provided the necessary framing for this study. In Section 2.2 of the Literature Review, the major paradigms that have underpinned doctoral education purpose were discussed, as have been 'preparing stewards of the discipline' and 'developing knowledge workers'. It was argued that the paradigm of preparing stewards of the discipline was essentially one that kept its discipline 'alive' and relevant by maintaining a steady influx of individuals (stewards) who ensured the knowledge creation practices of the discipline remained ongoing. It was then argued that that kind of paradigm cast the focus and purpose of doctoral education as being about the 'Product' – the cutting-edge research, the knowledge produced, the written thesis, and so on. It was also argued that the paradigm of developing knowledge workers shifted the focus of an outcome of a period of doctoral study from the 'Product' to the 'Person', and specifically, to the knowledge, skills, and qualities with particular relevance to workforce employability. To analyse the data and report the findings, these two broad terms of 'Person' and 'Product' were used to categorise the responses of interviewees in this study, with the shorthand of 'Person' encompassing those meanings of doctoral purpose related to and focused on candidate development, and 'Product' encompassing meanings of doctoral purpose related to and focused on conducting research and the creating disciplinary knowledge. These shorthand terms will be related back to the doctoral paradigms of preparing stewards of the discipline and developing knowledge workers later in the Discussion chapter.

Supervisors' comments were classified under 'Person' if their conception of doctoral purpose was focused on the student and the importance of the student developing knowledge, skills, and attitudes during the PhD. But if a supervisor conceived the purpose as focused on the research itself and the contribution to knowledge, for instance, then these conceptions were classified under 'Product'. A third category of 'Person & Product' covered supervisors whose views overlapped both of these categories. It is important to mention that these conceptions are what supervisors report or claim to be what they think and believe. There is essentially a reliance on supervisors providing an honest account of what they think, provided they have a reasonably clear understanding of what is being asked of them. These main themes, along with their corresponding number of persons and coding rule is provided below in Table 5-1:

Table 5-1 Supervisory conceptions of purpose of chemistry PhD, including number of persons, and coding rule

Main theme		Number of Persons	Coding rule
Person	To Develop Knowledge, Skills, & Attitudes (KSA)	18	Supervisor's conception of purpose is focused on the knowledge, skills, and attitudes a student develops. These could be also be related to research.
Product	To Do Research & Contribute to Knowledge	4	Supervisor's conception of purpose is focused on the research itself and the contribution to knowledge.
Person & Product	To Develop Knowledge, Skills, & Attitudes and To Do Research & Contribute to Knowledge	9	Supervisor's conception covers both categories above.

Eighteen supervisors conceived the purpose of the chemistry PhD as focused on the student developing knowledge, skills, and attitudes. For example, Go8M13 conceives the purpose as focused on the training of the student, but also highlights the importance of this 'training regime' in preparing the student for broad professional roles in the workplace: "I think it's a training program, like any PhD in many ways, and that's what it's become across-the-board… This is a really great training regime for being a professional in the broader sense". (Go8M13)

Likewise, Go8F1 conceives the chemistry PhD as providing students with 'generic' skills that can be used for a range of careers: "Providing students with general skills, generic skills in independent research and critical analysis that can then be used in a whole lot of careers". (Go8F1)

However, the purpose or what this knowledge, these skills, and attitudes were meant for was of interest and needed to be analysed. This was done to better compare the reported conceived purpose of supervisors with their reported practices in the rest of this chapter. Therefore, the comments of these 18 supervisors were further investigated regarding the intended utility (if any) of these KSAs. Two categories emerged here: 'KSA for Jobs' and 'KSA in General', as summarised in Table 5-2:

Table 5-2 Intended use of KSAs for supervisors whose conceptions of doctoral purpose related to 'Person'

Sub-theme		Number of Persons	Coding Rule
To Develop Knowledge, Skills, & Attitudes (KSA) for What?	KSA for Jobs	11	Supervisor sees the knowledge, skills, and attitudes as intended for and to be used for jobs.
	KSA in General	7	Supervisor sees the knowledge, skills, and attitudes to be developed for indefinite purpose.

Under 'KSA for Jobs', 11 supervisors appeared to see the knowledge, skills, and attitudes a student develops as meant for and to be used for employment purposes. For example, Go8F1 reported seeing the skills the student gains as having utility for the purposes of student employment: "Providing students with general skills, generic skills in independent research and critical analysis that can then be used in a whole lot of careers" (Go8F1).

Under 'KSA in General', seven out of 18 supervisors did not anchor the knowledge, skills, and attitudes students were to develop to a specific purpose or utility, and remained indefinite and unbounded. For example, ATNM3 does not link independence of mind to a specific purpose: "I guess really to promote independence of mind" (ATNM3). For Go8F4, the knowledge and skills are not tied up with a purpose, and appear to be the end result in themselves:

> So I think the purpose of chemistry PhD is to one, learn more about a particular area of chemistry, more than anyone else in the world knows about that particular area of chemistry. But in doing that, in learning how to research, you develop lots of other skills as well, and I think that those other skills are actually quite important, the analytical problem-solving, critical thinking type skills.

Returning to Table 5-1, the category of 'Product', and in contrast to those under 'Person', four supervisors conceived the purpose of the chemistry PhD to be the process of conducting the research itself and contributing to knowledge. In the case of Go8M8, his conception of doctoral purpose in chemistry centres on the discovery of new knowledge and its anticipated

publication: "I guess all PhDs have the purpose of trying to discover new knowledge… We would hope that it would result in the publication of the new knowledge gained, but it doesn't always". Go8M12 similarly echoes Go8M8's sentiments and sees the chemistry PhD as ultimately the means to do more chemistry research: "When I did it, it was this thing you did to do more chemistry. Honours wasn't enough, if you wanted to get into research properly you did a PhD".

Finally, nine supervisors provided conceptions of doctoral purpose in chemistry that spanned both categories of training and developing the knowledge, skills, and attitudes of the candidate as well as focusing on doing chemistry research and producing new knowledge in the field. As can be seen in the comments of ATNM2, his conception covers both research training and also the research itself – conducting it, writing it, presenting it, completing it:

> Obviously it's about research training… The process of conducting research, writing about research, presenting research… To give people a foundation in the research process… How to have an idea, explore an idea, and develop that to a completed research idea. (ATNM2)

Similarly, Go8M9 articulates a conception focussed on both learning how to do original research and the associated skills needed, as well as doing the research itself and developing original knowledge in the discipline: "I would say the purpose is to learn or to do original research, to develop an original body of work in chemistry, to learn analytical skills that are transferable to a range of careers".

5.1.1 Comparisons of Conceptions of 'Purpose' against Main Demographics

Having explained the different conceptions supervisors claimed in terms of doctoral purpose, the three main conceptions of 'Purpose' are examined against the main demographics of the sample to investigate if any of the group of respondents under 'Person', 'Product', and 'Person & Product' stood out in comparisons against those main demographics and whether any patterns could be drawn. In each of the tables below, the percentage in the main demographics column is based on the number of that certain demographic divided by the total number of supervisors in the sample – thirty-one. For example, 21 supervisors are from Go8 universities, so the percentage of Go8 respondents is 21/31×100=67.7%. Similarly, the percentage in the main theme column is based on the number of that certain demographic divided by the total number of supervisors under that main theme. For example, 18 supervisors fell under the

category of 'Person' for doctoral conception, 13 of whom were from the Go8 universities. Therefore, the percentage of supervisors who conceived the purpose of the PhD under 'Person' and who were from the Go8s is 13/18×100=72.2%. This allows us to see whether the percentage of respondents under a main theme is representative of the sample. In the two examples given previously, 67.7% and 72.2% are largely similar and the latter could be described as representative of the sample. This comparison is in the analysis in the following tables, where the percentage of respondents under 'Person', 'Product', and 'Person & Product' is compared against the type of university, gender, sub-discipline, supervisor's number of student completions, and geographic state of Australia. While it is recognised that 31 interviews do not allow for substantial comparisons within the sample, the following do allow for some tentative suggestions regarding these variations. In Table 5-3 below, the number of supervisors who conceived the purpose of the chemistry doctorate under 'Person', 'Product', and 'Person & Product' were compared with the number of respondents based on university type:

Table 5-3 Comparison of respondents under 'Person', 'Product', and 'Person & Product' by university type

		Main Demographics		Person		Product		Person & Product	
		n	%	n	%	n	%	n	%
University Type	Go8	21/31	67.7	13/18	72.2	4/4	100.0	4/9	44.4
	ATN	7/31	22.6	2/18	11.1	0/4	0.0	5/9	55.6
	IRU	3/31	9.7	3/18	16.7	0/4	0.0	0/9	0.0

Most percentages were representative of the sample, with the exception perhaps of 'Person: ATN'. While the percentage of ATN individuals is 22.6% under the main demographics, under 'Person' it is 11.1%; that is, around less than 50% of ATN supervisors are in this category despite ATN universities having a traditional focus on developing candidates for industry. In fact, they are doubly represented under 'Person & Product' at 55.6% and appear to have mixed conceptions regarding doctoral purpose in chemistry. The other noteworthy finding is of 'Product: Go8', where 100% of respondents are from the Go8, which may echo the research-intensive philosophies of these universities.

Table 5-4 below examines the same themes by gender. All percentages are roughly representative of the sample, except for 'Person & Product': Female at 22.2% compared to the main demographic of 41.9%:

Table 5-4 Comparison of respondents under 'Person', 'Product', and 'Person & Product' by gender

		Main Demographics		Person		Product		Person & Product	
		n	%	n	%	n	%	n	%
Gender	Male	18/31	58.1	9/18	50.0	2/4	50.0	7/9	77.8
	Female	13/31	41.9	9/18	50.0	2/4	50.0	2/9	22.2

In Table 5-5, the three themes are now examined against the different sub-disciplines of supervisors:

Table 5-5 Comparison of respondents under 'Person', 'Product', and 'Person & Product' by sub-discipline

		Main Demographics		Person		Product		Person & Product	
		n	%	n	%	n	%	n	%
Sub-discipline	Organic	7/31	22.6	3/18	16.7	2/4	50.0	2/9	22.2
	Inorganic	4/31	12.9	2/18	11.1	1/4	25.0	1/9	11.1
	Physical	8/31	25.8	6/18	33.3	1/4	25.0	1/9	11.1
	Other	12/31	38.7	7/18	38.9	0/4	0.0	5/9	55.6

Noteworthy figures are 'Product: Organic', 'Product: Inorganic', and 'Person & Product: Physical'. Supervisors under 'Product: Organic' are almost double that of the sample (50% and 22.5% respectively). This is somewhat surprising given that Organic chemistry supervisors produce the bulk of graduates needed in the pharmaceutical industry, and hence, a less exclusive focus on the research and contribution to knowledge might have been anticipated. In contrast, supervisors under 'Product: Inorganic' make up 25% of the respondents compared with 12.9% in the Main Demographics. This is expected given the greater theoretical nature of the sub-discipline. However, it is important to be careful with these conclusions as with only four respondents in that category a change of categorisation of only one person would shift the distribution by 25%. Finally, 'Person & Product: Physical' comprises 11.1% of supervisors compared with the main demographics at 25.8%. This marks a diminished number of physical chemists under this category but it is difficult to explain why.

Below, in Table 5-6, these three themes are now examined against the number of PhD students supervisors had supervised to completion:

Table 5-6 Comparison of respondents under 'Person', 'Product', and 'Person & Product' against number of completions

		Main Demographics		Person		Product		Person & Product	
		n	%	n	%	n	%	n	%
Number of Completions	Fewer than 5	11/31	35.5	8/18	44.4	1/4	25.0	2/9	22.2
	Between 5 & 10	5/31	16.1	1/18	5.6	2/4	50.0	2/9	22.2
	More than 10	15/31	48.4	9/18	50.0	1/4	25.0	5/9	55.6

In this table, three figures that do not represent the sample can be found. Under 'Person: Between 5 & 10', there is 5.6% of supervisors compared with 16.1% representation in the sample, perhaps suggesting that an early career academic (with fewer than five completions, 44.4%) or a later career academic (with more than ten completions, 50.0%) is more likely to conceive the purpose of the chemistry PhD as being focused on the student. Those under 'Product: Between 5 & 10' – consists of 50% versus 16.1% in the sample, which may suggest that a supervisor is more likely to conceive the purpose of the chemistry PhD as being focused on the research itself if they are mid-career, compared to 25% with fewer than five completions and 25% with over 10 completions. Once again, it is important to take care with these remarks due to there being only four respondents in that category.

Table 5-7 below examines these three themes by geographic state:

Table 5-7 Comparison of respondents under 'Person', 'Product', and 'Person & Product' by state

		Main Demographics		Person		Product		Person & Product	
		n	%	n	%	n	%	n	%
State	NSW	15/31	48.4	12/18	66.7	1/4	25.0	2/9	22.2
	VIC	3/31	9.7	2/18	11.1	1/4	25.0	0/9	0.0
	SA	4/31	12.9	2/18	11.1	0/4	0.0	2/9	22.2
	WA	9/31	29.0	2/18	11.1	2/4	50.0	5/9	55.6

In this table, no comparisons particularly stand out, perhaps except for 'Person: WA' where there is one third less respondents compared to the main demographic of 29%; 'Product: NSW' with 25% compared with 48.4% in the sample; and 'Person & Product: NSW' at 22.2% compared to 48.4%; but once again it is difficult to add meaning to these observations.

Section 5.1 explained the different conceptions of doctoral purpose that chemistry PhD supervisors claimed in this study. Three main conceptions were produced: 'Person', 'Product', and 'Person & Product'. Eighteen supervisors under 'Person' conceived the purpose of the chemistry PhD as focused on developing the knowledge, skills, and attitudes of the candidate. This group of supervisors was further investigated to see what the knowledge, skills, and

attitudes students develop were meant for. Eleven supervisors and their comments indicated that they conceived the knowledge, skills, and attitudes to be eventually used for the purposes of graduate employment, whereas seven supervisors did not appear to link the knowledge, skills, and attitudes to a particular purpose or utility, and were unbounded and undefined in these terms. On the other hand, four supervisors fell under the category of 'Product', that is, those who expressed a conception of purpose focussed on the research itself and the contribution to knowledge, while nine supervisors under 'Person & Product' presented a mix of both conceptions. Overall, it was found that almost all the supervisors interviewed (27 of the 31) mentioned that the purpose of the PhD included developing the knowledge, skills, and attitudes of the students.

Further detailed examination was conducted to see if any of the group of respondents under 'Person', 'Product', and 'Person & Product' stood out in comparisons against the main demographics of university type, gender, sub-discipline, number of completions, and geographic state in Australia. Different results ranged from being representative of the sample to not so, with several being difficult to explain, and maybe needing to be further investigated using larger sample sizes. However, a result that did stand out under university type was the under representation of the supervisors from the ATN in 'Person: ATN' despite the technical nature of the university, and supervisors under 'Product: Go8' being all from the Go8 universities.

5.2 Supervisors' Reported Educational Practices

Section 5.1 detailed the supervisors' conceptions of doctoral purpose in chemistry, which were categorised based on whether their conception of purpose focused on developing the candidate in terms of their knowledge, skills, and attitudes (the 'Person' category); whether their conception of purpose focused on conducting research and the creation of knowledge (the 'Product' category); or whether their conception of purpose spanned both of the previous conceptions (the 'Person & Product' category). In this section, the educational practices of chemistry PhD supervisors are examined to make linkages between the different categories of conceived doctoral purpose and supervisors' reported education practices. Similar to the analysis of the conceptions of purpose of the chemistry doctorate in section 5.1, the analysis here relied on the review of the literature related to doctoral education practices and the concepts arising from that review that framed the data analysis.

Once again, supervisors were asked about their educational practices with their students. What they actually do with their students in the laboratory and other research spaces can only be brought to light if a researcher visits those 'sites' and conducts some form of observational research there. This is methodologically challenging, however, and for this reason, reports of what supervisors' educational practices were sought instead.

Four main categories were used from the literature in framing the analysis of the data: knowledge that supervisors report they ensure their students have; skills that supervisors report they ensure their students have; supervisors' reported comments on how they encourage their students to reflect upon the ethical, social, political, and economic issues pertaining to the discipline of chemistry; and reports on whether chemistry PhD supervisors encourage their students to get work experience during the PhD. These main themes and their coding rules are provided below in Table 5-8 below:

Table 5-8 Reported educational practices of chemistry PhD supervisors and the corresponding coding rule

Main theme		Coding Rule
Knowledge Ensured	Disciplinary Knowledge	The knowledge appears to be disciplinary, bounded, contained.
	Interdisciplinary Knowledge	The knowledge appears to be multidisciplinary, shares its boundaries with other disciplines.
Skills Ensured	Closely Related to Academic Work	Supervisor appears to be ensuring skills closely related to academic work and needed to finish the PhD.
	Relevant to Academic Work & Beyond	Supervisor appears to be doing more than what is required for PhD completion and academic success. These skills are related to academic work and beyond.
Reflection on Ethical, Social, Political, & Economic (ESPE) issues pertaining to the discipline of chemistry	No – Not really	Supervisor indicates that this has either not happened or not happened formally.
	Reflecting on Applications of Research	Supervisor encourages students to reflect upon the potential applications and effects of their research in society.
	Reflecting on Science & the Public	Supervisor encourages students to reflect on the relation between science and the public. Examples could be reading science related news in the newspaper and reflecting on that.
Encouraging Work Experience	Academic Teaching & Work	Supervisor encourages students to demonstrate in labs, tutor, or do work related to academia such as spending time in a lab overseas.
	Industry Work	Supervisor encourages students to work with industry. Industry is meant here as chemical industry.
	Government Work	Supervisor encourages students to work with government.

5.2.1 Knowledge Ensured

This section of the analysis covers the types of knowledge supervisors reported they ensured their students have upon completion, framed based on the literature review and the debates on knowledge and knowledge production. A supervisor is deemed to be ensuring the learning

of disciplinary knowledge for their students if that knowledge appears to be closely linked to the discipline of chemistry and largely contained within those boundaries. The reported ensured knowledge is deemed interdisciplinary knowledge if it appears to share its boundaries with other disciplines. Table 5-9 provides the overall view of the number of supervisors and the types of knowledge they ensured their students had:

Table 5-9 Type of knowledge ensured by chemistry PhD supervisors

Type of Knowledge Ensured	Number of Supervisors
Disciplinary Knowledge	27
Interdisciplinary Knowledge	2
Disciplinary & Interdisciplinary Knowledge	2

Based on their reported knowledge practices, 27 supervisors were found to be ensuring that their students exited with disciplinary knowledge of the field, while two were found to be focusing upon interdisciplinary knowledge, and two were covering both.

An example of ensured knowledge being disciplinary is best exemplified by Go8F2's quote on the importance of her students mastering a specific area of chemistry: "So they have to have really mastered an area of chemistry that they were focusing on, they have to be experts for that particular little area of chemistry, so that's about technical knowledge". Similarly, Go8M9 highlights the importance of his students having a deep understanding of his fundamental fields of knowledge: "My research is on the fundamental areas of statistical mechanics and quantum mechanics and so I ensure that my students have a deep understanding of those particular areas of theory".

On the other hand, the following respondents presented themselves as examples of supervisors ensuring their students developed interdisciplinary knowledge:

> They're not going to graduate from a PhD if they haven't demonstrated knowledge in an area. Of course they need to understand their project, and their project is big and broad and they need to know the chemistry of it and they need to know the biology of it, I guess they wouldn't graduate if they didn't have that. (Go8F1)

For Go8F1, it is necessary that a student demonstrate knowledge of the area of research and in her case, that includes knowledge which spanning both the disciplines of chemistry and biology. Similarly, ATNM3 puts an effort into his students learning knowledge that crosses the boundaries of chemistry, physics, and biology: "I am pushing them toward getting more

multidisciplinarity in science in general. So rather than stopping at chemistry, look at disciplines such as physics, and biology and so on" (ATNM3).

Table 5-10 shows on the other hand provides more detail of the reported knowledge ensured based on supervisors and their conceptions of doctoral purpose:

Table 5-10 Type of knowledge ensured by chemistry PhD supervisors based on their corresponding categories of conceived doctoral purpose

Type of Knowledge Ensured	Person	Product	Person & Product
Disciplinary Knowledge	16	3	8
Interdisciplinary Knowledge	2	0	0
Disciplinary & Interdisciplinary Knowledge	0	1	1

What is apparent in the table above is the predominance of discipline-focused teachings across the categories of supervisory conceptions of doctoral purpose: 'Person', 'Product', and 'Person & Product'. Sixteen out of 18 supervisors who conceived the purpose of the chemistry PhD as developing student knowledge, skills, and attitudes, report developing their student's disciplinary knowledge while only two reported to be developing students' interdisciplinary knowledge. In Section 5.1, these 18 supervisors were found to be either envisaging the student knowledge and skills to be used for employment purposes, or the utility of these KSAs were left unbound and undefined. This marks a disconnect between their conceptions of doctoral purpose and reported practices. Also, the definite practice of developing disciplinary knowledge does not align with the purpose of developing knowledge in an indefinite sense.

However, for supervisors who conceived the purpose of the PhD in chemistry as to do research and create knowledge (the 'Product' category), their conceptions of purpose and reported practice developing disciplinary knowledge align. Indeed, those reported practices better serve that conceived purpose.

As for those whose conceptions of purpose covered both the development of the candidate's KSAs and conducting research ('Person & Product'), it would have been anticipated that their reported practices would offer a greater mix of disciplinary and interdisciplinary knowledge development, given their reported conception of purpose being a mix of both.

5.2.2 Skills Ensured

While the previous section examined the knowledge that supervisors reported they ensured their students have when they graduate, this section examines the skills these supervisors claimed they ensured with their students. The different categories of skills were deductively

used from the literature review on HDR skills. Table 5-11 below presents these skills and the number of supervisors who reported ensuring them:

Table 5-11 Type of skills ensured by chemistry PhD supervisors

Type of Skills Ensured	Number of Supervisors
Closely Related to Academic Work	24
Relevant to Academic Work & Beyond	1
Closely Related to Academic Work & Relevant to Academic Work & Beyond	6

Based on their reported skills practices, 24 supervisors were found to be ensuring that their students exited with skills closely related to academic work, one was found to be making sure their students had skills relevant to academic work and beyond, and six supervisors were reportedly ensuring both types of skills.

If a supervisor, based on their comments of reported practices, appears to be ensuring skills which are needed to complete the PhD and are closely related to academic work, then those skills are coded under Closely Related to Academic Work. If a supervisor's comments suggest they are taking further steps and appear to be doing more than what is needed for thesis completion and academic success, then these skills are coded under Relevant to Academic Work & Beyond.

In the quote below, Go8M8 explains in depth the skills that he thinks his students need:

> So all my students have to know how to interpret NMR spectra, that's a very specific skill that many of them won't use again if they go out and get a job in industry for example. They need to be able to follow through the course of the chemical reaction, using TLC, maybe sometimes other methods, gas chromatography, or NMR spectroscopy. They need to know how to work up and purify a compound, using column chromatography, sometimes HPLC, crystallisation. They need to know how to do risk assessments, and to carry out essentially hazardous procedures in a safe way.

The evidence that Go8M8 reports here suggests his commitment to providing his student with the technical and experimental skills they need to possess in his research group. These skills are directly related to obvious requirements of the PhD and possible academic work and may not even, as pointed out by the participant, be used in a job in industry. Additionally, he covers communication skills, but these skills are closely related and highly contextual to the needs and work practices of academics:

> They learn how to present their work, in both oral and written formats, and in posters as well, and they get a practice at that. They get intensive one-on-one in how to write scientifically in a format that's appropriate for a thesis and/or journal articles.

Not only do the comments made by Go8M8 sketch a training environment highly geared for academic success, but they also show the absence of any work done by the supervisor to prepare students for the workforce beyond the confines of academia. These reported practices also resemble those of Go8F4:

> So I run group meetings where we do organic chemistry problem-solving, mechanism-type problems to try make sure they are on top of the chemistry, but importantly, I like to get them to do presentations on their research in group meetings but also then at a conference, all of my students when I can get them into a conference to do a talk… So get them to do an actual oral presentation but also poster presentations. I want them to write their own research papers, so to learn the skills of how to write a scientific research article, which is not something I got to learn as a PhD student and I regret that.

Go8F4's skills training covers discipline-specific chemistry requirements. These include problem-solving skills needed in their work, and also communication skills typically relevant for doctoral and academic success such as conference presentations and journal-article writing.

In contrast, supervisors who claimed they ensured their students graduated with skills relevant to academic work and beyond appeared, based on their responses, to put an effort into teaching their students skills that were of utility to academic work and other workplaces such as industry or government, or emphasised the importance of students developing skills from other disciplines including the social sciences and humanities.

For example, Go8F3 focuses on developing skills in her students such as being able to construct an argument, work with evidence, and communicate it – constantly emphasising her focus on breadth of skills that would be useful for her graduates whether they stay in academia or go into industry:

> The key thing is how to put together an argument, working from facts, looking at data objectively and then being able to construct a critical argument around those facts. An evidence-based article. And that could include for graduates who have gone into industry, include writing reports, so I mean in the broadest context not just a piece of

> academic work that ends up in a journal, I mean like broadly speaking reports, or being able to present that data as well that's the critical skill, communication skills that is to come out, but I'm talking broad here it's not specific skills in chemistry.

In addition to the above, Go8F3 has had some of her students present to the public and participate in the Three Minute Thesis Competition:

> Some of my students have had a little bit to do with presenting work to the general public as well, so the skills of being able to talk about science more generally, and also to talk about science to younger students as well, so a lot of them do demoing or do outreach with schools and stuff like that… So there's a few different things going on. There's these Three Minute Thesis competitions and stuff around the place. (Go8F3)

Similarly, Go8F1 appears to make an effort to develop her students' skills that are beyond the immediate requirements for PhD completion and academic success:

> A good understanding of not only their project and how it fits into scientific research, but how scientific research fits into the broader scheme of society. Development of presentation skills, which I think are key. Development of leadership skills, so I make all my students lead different things particularly in the third year of their PhD, leading group meetings, planning things. Ability to talk to different types of people, so I'm very strict on making my students talk to different people at conferences, not just talk to their friends, I make them talk to visiting seminar speakers so they can get an understanding of how to talk to professors or people who may seem more knowledgeable than them. And I also really seek to develop my students as citizens of whatever organisation they're working in. So contributing to the organisation, for our university, it's contributing to societies, and helping support their fellow peers. Being more outward looking than inward looking.

These skills are broken down into greater detail, based on supervisors' different conceptions of doctoral purpose in chemistry, in Table 5-12 below:

Table 5-12 Type skills ensured by chemistry PhD supervisors based on their corresponding categories of conceived doctoral purpose

Type of Skills Ensured	Person	Product	Person & Product
Closely Related to Academic Work	12	3	9
Relevant to Academic Work & Beyond	1	0	0
Closely Related to Academic Work & Relevant to Academic Work & Beyond	5	1	0

What is noteworthy in the findings in Table 5.12 is the predominance of the development of skills closely related to academic work across the three categories of supervisors and their conceptions of purpose. Despite there being 18 supervisors who conceived the purpose of the chemistry PhD as being about student development (the category of 'Person') with 11 reportedly adhering to the purpose of the chemistry PhD being student development of knowledge, skills, and attitudes for jobs, and seven keeping the utility of the latter undefined, 12 out of 18 supervisors appear to exclusively focus on the development of skills that are closely related to academic work. Only five supervisors report ensuring that their students develop skills that are both closely related to academic work and relevant to academic work and beyond. This means that for those who linked the purpose of the chemistry PhD to developing skills for a range of careers, they are actually largely preparing their students in the skills for academic work, based on their reports. As for those who left those skills unspecified in terms of utility, they are seemingly specifically skilling-up their students for academic work pathways.

For supervisors whose conceived purpose for the chemistry PhD was about the execution of research (the category of 'Product'), the results of their claimed practices are anticipated and align with their conceived purpose as being focused on the research itself, with three out of four supervisors seemingly being focused on conferring skills closely related to academic work.

Those whose conceptions of doctoral purpose in chemistry covered both candidate development and the execution of research and production of knowledge ('Person & Product') surprise again in their exclusive focus on the first set of skills, with all supervisors appearing to be ensuring skills closely related to academic work.

5.2.3 Reflection on the Ethical, Social, Economic, and Political Issues (ESPE) Pertaining to the Discipline of Chemistry

The previous section in this study examined the skills that supervisors reported they ensured their students had upon completion. This section of the analysis turns to whether and how

supervisors encourage their students to reflect upon the ethical, social, political, and economic issues pertaining to the discipline of chemistry. From the review of the literature, reflecting on broader world issues related to science was argued as a necessary practice for science research students in order for them to appreciate the connectedness of science to these world issues as they go in to the wider workforce. This was described as allowing students to think about the relevance of their discipline beyond the confines of the laboratory and walls of universities.

In terms of the analysis, supervisors tended to not respond to individual items in the question on ESPE issues. Rather, it was more useful analysing their responses to this question in terms of emergent themes. The emergent themes were supervisors reporting that they did not or did not really encourage their students to reflect upon these issues; supervisors reporting that they encouraged their students to reflect on how their research could be applied; and supervisors reporting that they encouraged their students to reflect on the relationship between science and the public. These themes have been summarised in Table 5-13 below, along with a detailed explanation of their analysis.

Table 5-13 Supervisor's encouragement of their students to reflect upon ESPE issues pertaining to chemistry

Encouragement to Reflect on ESPE Issues	Number of Supervisors
No – Not really	13
Reflecting on Applications of Research	14
Reflecting on Science & the Public	2
Reflecting on Applications of Research & Reflecting on Science & the Public	2

Thirteen supervisors reported that they did not encourage their students to reflect upon ethical, social, political, and economic issues pertaining to the discipline of chemistry. In response to the question, 14 supervisors reported encouraging reflection upon the applications of their research, while two reported encouraging reflection upon issues related to science and the public. Two supervisors reported reflecting both on the applications of their research and on matters related to science and the public.

Table 5-14 below presents these findings in terms of supervisors' conceptions of doctoral purpose:

Table 5-14 Supervisor's encouragement of their students to reflect upon ESPE issues pertaining to chemistry by supervisors based on their conceptions of doctoral purpose

Encouragement to Reflect on ESPE Issues	Person	Product	Person & Product
No – Not really	8	3	2
Reflecting on Applications of Research	8	1	5
Reflecting on Science & the Public	1	0	1
Reflecting on Applications of Research & Reflecting on Science & the Public	1	0	1

Half the respondents whose conceived purpose for the PhD focused on developing of the person ('Person' category), reported they did not or did not really encourage their students to reflect upon the ESPE issues pertaining of the discipline of chemistry. Similarly, three quarters of supervisors whose conceived purpose for the chemistry PhD focused on research and the creation of knowledge ('Product' category) and one third of supervisors whose conceptions of purpose covered both of the aforementioned focuses ('Person & Product' category) reported the same response, which can be characterised as: "I would say probably not, no" (ATNF3).

Almost half of the respondents who characterised the purpose of the chemistry PhD as being about student development ('Person') and almost half within the category of 'Person & Product' whose conceptions of purpose spanned both candidate development and execution of research were more likely to encourage their students to reflect on the applications of their research, with only one supervisor within the category of 'Product' to do so. Reflection could include supervisors encouraging students to reflect on the impact of their research on society, as is the case with Go8M7 and ATNM4 respectively:

> Well that's what I mean by training them for life. So, yes of course, we regularly have discussions about the impact that our research can have or could have, and we also discuss that, for example, the reason that I choose to do the research that I'm doing reflects the fact that I want the chemistry to have an impact across society. (Go8M7)

> We try to get them to reflect upon how their work fits into the broader context in the research area… We try to get them, being a technical university, we try to have at least an underpinning, not in every case, but in many cases, there's an underpinning application or potential application or rationale for the research. (ATNM4)

Lastly, encouraging students to reflect upon chemistry or science more generally and its relation to the public appeared to take place, but seldom in the sample, with only one supervisor within the category of 'Person', zero supervisors under the grouping of 'Product', and two out of nine supervisors within the category of 'Person & Product' doing so. This practice can be best captured by the comments made by ATNF2, whose response shows the effort she puts into getting to her students to think about the linkages between chemistry and the public:

> I try to encourage my students to actually listen to the news and interact with the news constantly. Constantly talking with them about aspects that have occurred, if I see an article in the paper, I forward it to them. (ATNF2)

Of those interviewees who focused on their reported purpose of the PhD being the development of the person, nine out of 18 reported that they did not encourage their students to reflect upon the ESPE issues relating to the discipline of chemistry, despite their reported intentions of doctoral purpose in chemistry as developing students' knowledge, skills, and attitudes for employment purposes (11/18) or in an undefined sense and for no specific utility (7/18). However, the remaining nine out 18 supervisors did report encouraging their students to reflect upon these issues, at least in the form of thinking about the potential applications of their research and its effects in and on society, as well as thinking about the relationship between science and the public.

Supervisors who conceived the purpose of the chemistry PhD as being focused executing research (the 'Product' category) prove again to be demonstrating practices that appear to align with their professed purpose of being focused on the research itself, with three out of four supervisors indicating that they did not encourage their students to reflect upon these issues.

Reported ESPE practices of supervisors whose conceived purpose for the PhD in chemistry focused on both the development of the person and the product aspects of the PhD ('Person' & 'Product') are more difficult to analyse in terms of alignment with their conceived doctoral purpose. One third said that they did not encourage their students to reflect upon these issues, yet almost half seemed to encourage their students to reflect upon their research and its applications. This is perhaps one instance where the mix of conceptions on doctoral purpose are manifesting as a mix of practices.

5.2.4 Encouraged Work Experience

The final section on reported educational practices examines supervisors' encouragement of their students to take on work experience during the PhD. One of the key arguments arising from the review of the relevant literature for this study was for science doctoral researchers to experience sites of research and knowledge making beyond those in the university. For these purposes, supervisors were asked whether they encouraged their students to partake in work experiences such as university tutoring, university administration work, industry work, or government work. These different responses have been summarised in Table 5.15:

Table 5-15 Reported supervisors' encouragement of their students to undertake work experience during the PhD

Encouraged Work Experience	Number of Supervisors
Academic Teaching & Work	31
Industry Work	10
Government Work	5

All thirty-one supervisors reported that they encouraged their students to engage in academic teaching and work, ten reported encouraging industry work, while five reported encouraging government work. It is important to note that because respondents were coded as reporting more than one kind of work, if mentioned, these numbers add up to more than 31.

All supervisors reported encouraging their students to undertake academic teaching and work. That typically includes laboratory demonstration, tutoring, or collaborating with another lab, as summarised by Go8F6 and ATNM3 respectively: "I normally encourage them to do some tutoring, whether that's going to be a lab or just assisting other students. And I normally encourage them to spend six months in a lab overseas" (ATNM3). "It is expected of our PhD students that they would undertake paid laboratory demonstrating, and many are offered tutorial work, which I encourage". (Go8F6)

Encouraging work experience in industry could take shape in the petroleum industry for example: "Yes, we do work with the oil industry. That's quite aligned with our area as well. Particularly the petroleum sector" (ATNF1), while government work could be in a Government Department such as Geoscience Australia: "Yes. We have projects with Geoscience Australia. And students go and work with Geoscience Australia". (ATNF1)

Table 5-16 examines these findings based on supervisory conception of doctoral purpose:

Table 5-16 Reported supervisors' encouragement of their students to undertake work experience during the PhD supervisors based on their corresponding categories of conceived doctoral purpose

Encouraged Work Experience	Person	Product	Person & Product
Academic Teaching & Work	18	4	9
Industry Work	5	0	5
Government Work	1	0	4

The reported encouragement of academic teaching and work featured heavily for supervisors who conceived the purpose of the PhD as developing the person ('Person'), despite their claimed doctoral purpose. With supervisors in this category reportedly seeing the knowledge, skills, and attitudes developed as either serving employment purposes or being widely defined with no specific utility, these findings suggest development strongly situated within the academic sphere and for it.

All supervisors whose conceived doctoral purpose in chemistry was focused on carrying out research ('Product') reportedly encouraged their students to participate in academic teaching and related work experience. And finally, supervisors within the category of 'Person & Product' show once more some distribution in encouraged work experiences, which tends to align with their reported conceived doctoral purpose.

Section 5.2 of this chapter examined the respective reported educational practices of supervisors under the three main strands of doctoral purpose ('Person', 'Product', 'Person & Product'). The practices were organised around the themes of knowledge ensured (whether it was disciplinary or interdisciplinary), skills ensured (whether closely related to academic work or relevant to academic work and beyond), reflection of the ethical, social, political, and economic issues pertaining to the discipline (which emerged as reflection of applications of research and reflection on science and its relation to the public), and finally, the encouragement of work experience.

The finding that was most unexpected in this section is the reported practices associated with those under the category of 'Person'. Under this category, it was observed that of the 18 supervisors who claimed that the purpose of the chemistry PhD was about the student developing knowledge, skills, and attitudes, 11 saw these elements as having an employment utility, while seven did not anchor the conception for a particular use. Based on this, the linkages made in this section between the claimed purpose and reported practice show a marked disconnect between the two for supervisors under this category.

The findings here show that the reported knowledge ensured is very largely disciplinary, rather than being focused on jobs or being widely broad and undefined. The reported skills ensured are largely closely related to academic work, rather than being related to academic work and beyond. In terms of encouragement to reflect upon the ESPE issues of the discipline, half the respondents reported that they did not reflect on these issues with their candidates, while the other half reported reflecting on applications of the research and the relation of science and the public. Finally, work experience encouraged is reportedly largely focused on academic work such as laboratory demonstrating and tutoring, as opposed to a greater mix of experiences including industry and government, to better align with the conceived purpose.

The purported educational practices of supervisors under the category of 'Product', who saw the purpose of the chemistry PhD as being about the execution of research, appear to be most expected and in alignment with the conceived doctoral purpose. Whereas supervisors under the category of 'Person & Product', whose conceptions of doctoral purpose spanned both person development and research execution, seem to encourage their students to reflect upon ESPE issues relating to the discipline and to participate in an array of work experiences, they still appear to be heavily focused on imparting knowledge and skills and encouraging work experiences closely situated within the discipline.

Having examined chemistry PhD supervisors' conceptions of doctoral purpose in chemistry and how well their described practices align with their conceptions of purpose, the final element of the study that remains is examining their own evaluation of supervisory success in relation to their follow-up with their graduates on their career outcomes.

5.3 Supervisors' Self-Evaluation of Success in Relation to Graduate Career Outcomes

Section 5.1 examined supervisors' reported conceptions of doctoral purpose in chemistry. From that analysis, three main categories of conceptions of doctoral purpose were formed: 'Person', 'Product', and 'Person & Product'; with supervisors within the category of 'Person' conceiving doctoral purpose in chemistry as being focused on the developing the student's knowledge, skills, and attitudes; those under 'Product' seeing the purpose of the chemistry doctorate as being about execution of research and expanding the boundaries of the discipline through the contribution to knowledge; and those within the category of 'Person & Product' covering both of the previously mentioned conceptions of doctoral purpose in chemistry.

Following this, Section 5.2 examined the reported doctoral educational practices of chemistry PhD supervisors. These were organised around the knowledge supervisors reported they ensured their students had upon completion; the skills supervisors reported their student had upon completion; whether supervisors reportedly encouraged their students to reflect upon the ethical, social, economic, and political issues pertaining to the discipline of chemistry; and whether supervisors reportedly encouraged their students to engage in work experience such as academic teaching and related work, industry work, and government work. This was done in order to observe the links between supervisors' claimed conceived doctoral purpose and whether and how it aligned with their subsequently reported doctoral practices. This section examines supervisors' comments about their own evaluation of supervisory success in relation to follow-up with their graduates in terms of career outcomes, as it was argued in the literature review that supervisors need to be able to critically reflect upon their practices through follow-up with graduates regarding their careers. Categorisation of the data, including formulation of the coding rules, was framed through the review of the literature. These are summarised in Table 5-17 below:

Table 5-17 Supervisory self-evaluation of success and follow-up with graduates

Main theme			Coding Rule
Supervisory Self-Evaluation of Success	Graduate is Employed		Supervisor considers themselves having succeeded if graduate is employed.
	Graduate Development		Supervisor considers themselves having succeeded if graduate has developed through the process.
	Graduate Wellbeing		Supervisor considers themselves having succeeded if graduate enjoyed their PhD or their jobs later.
	Student Completes		Supervisor considers themselves having succeeded if student completes
Graduate Follow-Up	How PhD Best Prepared for Career	No – Not Really	Supervisor and graduates have not had a discussion on how PhD has best prepared the graduate for chosen career
		PhD Helped Skill Up Student	Supervisor perceives that the PhD has helped skill up the student for their jobs
	How PhD Could have Better Prepared for	No – Not Really	Supervisor and graduates have not had a discussion on how PhD could have better prepared the graduate for chosen career

	Career	Need for Work-Specific Training	Supervisor indicates that student had suggested the need for the PhD to have provided more specific work-related training

5.3.1 Supervisory Self-Evaluation of Success

Supervisors were asked about how they knew that they had succeeded as supervisors with their students. One of the key arguments that came out of the review of the literature was the need for supervisors to critically reflect upon their own practices, especially in relation to their graduates and their career outcomes. This research project investigated supervisory reflection but from the specific angle of supervisory self-evaluation of success. Supervisors reported different measures for self-success: seeing their graduate employed, having witnessed their student go through some form of development, seeing their graduate well and happy, and having their student complete. These categories have been summarised in Table 5-18 below:

Table 5-18 Supervisors' reported self-evaluation measures of success

Supervisor's Self-Evaluation of Success	Number of Supervisors
Graduate is Employed	22
Graduate Development	9
Graduate Wellbeing	7
Student Completes	6

Twenty-two supervisors reported having their graduate being employed as a measure of supervisory success, nine reported that they had succeeded as supervisors with their students if they saw their student had gone through some form of development, seven felt that they had succeeded if the graduate was in a state of wellbeing, and six if they saw their student complete. Since respondents were coded as reporting each measure of success, if mentioned, these numbers add up to more than 31.

Supervisors who reported that they felt they had succeeded if their students had a job after the PhD were coded under Graduate is Employed. The following comments by ATNM3 and ATNF2 typically represent this: "Well mainly I look at what they're doing in their career, whether they're progressing really well, or whether they struggle, I guess". (ATNM3)

> So my graduates, both of them have now got postdoc positions, one of them in Oxford. And so the other students, the co-supervised ones, they all have, one has a postdoc, one has a job at a chemical company, and the other one went back to Malaysia to work as a

> lecturer. So I think if you look at successes and what they're doing after the PhD, then I'd say it's quite successful. (ATNF2)

Other supervisors considered themselves successful if their students had developed, in a broad sense, during the PhD:

> If I see them developing with the time of their PhD. So remembering what they were like at the beginning and kind of seeing the skills that they have developed but more importantly probably is the personal development they have gone through. (Go8F1)

In the case of Go8F1, skills development is rather separated from personal development; with she suggesting that she valued the latter more highly. For ATNM4 in contrast, the development appears to be more focused on the candidate having built the aptitude and independence to conduct research: "Scientifically speaking, I succeeded by the end of the PhD if they are telling me what we should be doing in terms of completing the research, rather than me". (ATNM4)

Some supervisors measured their success in terms of student happiness and wellbeing: "They're happy, I guess, in what they're doing. I mean to me that's a key thing and they're making a contribution, a positive contribution. I have no quantitative way of assessing that whatsoever!" (Go8F3) and "… but they all seem relatively happy. I put being happy in life a pretty important requirement. So I think that's one of the criteria that I would use". (Go8M11)

Finally, others measured their success in terms of student completion: "Everybody who earns a PhD is a primary measure of success" (Go8M1), and "I see their theses go through with effectively no corrections". (Go8M4)

Table 5-19 examines these responses in terms of supervisors and their conceptions of doctoral purpose:

Table 5-19 Supervisors' reported self-evaluation measures of success based on their corresponding categories of conceived doctoral purpose

Supervisor's Self-Evaluation of Success	Person	Product	Person & Product
Graduate is Employed	14	2	6
Graduate Development	4	1	4
Graduate Wellbeing	4	2	1
Student Completes	2	2	2

From the table above, it is observed that the supervisors' responses are quite diverse. Measures of success are spread across the different categories of conceived doctoral purpose. What is most noteworthy, however, is the measure of success that supervisors whose conceived purpose for the PhD in chemistry focused on student development of knowledge, skills, and attitudes ('Person') most strongly report. Fourteen out 18 supervisors believe they have succeeded as supervisors if their graduate is employed, along with other measures. For those respondents who conceived the purpose of the chemistry PhD as being about carrying out research ('Product'), the small number of respondents under this category poses some difficulty in making assessments in isolation, but what is certain is that the condition of their student – whether employed, whether having gone through a developmental curve, whether happy, or simply having submitted – means something to these supervisors. This is similarly observed for the responses of supervisors whose conceptions of doctoral purpose covered candidate development and execution of research ('Person & Product').

5.3.2 Graduate Follow-Up

Having sought their views on self-evaluation of success, supervisors' responses were also examined for evidence of follow-up discussions with their graduates and specifically on how the PhD had best and could have better prepared their students for their chosen careers. In terms of how the PhD had best prepared their graduates for their careers, these responses are categorised in Table 5-20 below:

Table 5-20 Supervisory follow-up with graduates regarding how PhD had best prepared them for their careers

Graduate Follow-Up		Number of Supervisors
How PhD Best Prepared for Career	No – Not Really	20
	PhD Helped Skill Up Student	11

Twenty supervisors reported not having had such an engagement with their graduates, while eleven reported, through informal feedback mechanisms with their graduates, that the PhD helped skill up the student in some way. This is explored in greater depth below based on supervisors' conceptions of doctoral purpose in Table 5-21:

Table 5-21 Supervisory follow-up with graduates regarding how PhD had best prepared them for their careers based on supervisors' different conceptions of purpose

Graduate Follow-Up		Person	Product	Person & Product
How PhD Best Prepared for Career	No – Not Really	10	4	6
	PhD Helped Skill Up Student	8	0	3

In terms of how the PhD has best prepared students for their chosen career, ten out of 18 supervisors whose reported purpose for the PhD was focused on developing the person's knowledge, skills, and attitudes ('Person'), all supervisors whose claimed purpose for the PhD was focused on conducting research and the creation of knowledge ('Product'), and six out of nine supervisors whose conceived purpose for the PhD focused on developing the student's knowledge, skills, and attitudes as well as the execution of research ('Person & Product'), responded that they did not have such discussions with their students: "Not particularly" (Go8F4) and "No, I've never really had that discussion with them" (Go8F5).

For supervisors within the category of 'Person', eight reported that the PhD helped skill up their students, while no supervisor indicated so under the category of 'Product', and three out nine supervisors reported this under the category of 'Person & Product'. However, this feedback appears to have generally been obtained informally, from one or a couple of graduates. The data provided little evidence that the supervisors demonstrated concerted effort to explicitly or formally collect such feedback from their graduates:

> Have your PhD graduates ever reported how their PhD, or aspects of it, had best prepared them for the careers that they have chosen? (Interviewer)
>
> I can't say any of them had ever explicitly said that. (Go8M11)
>
> Implicitly? (Interviewer)
>
> When they say they've got a job and it was because of the skills that they learnt they assumed that's because of... Actually they say that when they got the job, especially the guy that's now at [a university], he was saying it is all due to the project that we had... (Go8M11)

In relation to how the PhD could have better prepared their graduates for their careers, supervisors' responses are categorised in Table 5-22 below:

Table 5-22 Supervisory follow-up with graduates regarding how PhD could have better prepared them for their careers

Graduate Follow-Up		Person
How PhD Could have Better Prepared for Career	No – Not Really	29
	Need for Work-Specific Training	2

Twenty-nine supervisors reported not engaging with their graduate over the topic, while two reported that their graduates had suggested better work-specific training during the PhD. These points are explored in more detail in Table 5-23 based on supervisors' conceptions of doctoral purpose:

Table 5-23 Supervisory follow-up with graduates regarding how PhD could have better prepared them for their careers based on supervisors' different conceptions of purpose

Graduate Follow-Up		Person	Product	Person & Product
How PhD Could have Better Prepared for Career	No – Not Really	16	4	9
	Need for Work-Specific Training	2	0	0

In terms of how the PhD could have better prepared students for their chosen career, 16 out of 18 supervisors who conceived the purpose of the chemistry PhD as being about developing the candidate in terms of their knowledge, skills, and attitudes (the 'Person' category) responded that they did not have these sorts of discussions with their students, as well as all respondents who conceived the purpose of the PhD in chemistry as being focused on conducting research and creating knowledge (the 'Product' category), and those whose reported purpose for the chemistry doctorate covered both of the aforementioned conceptions: "No, not really. I've never had any feedback…" (IRUM1).

Only two out of 18 respondents within the category of 'Person' felt that the PhD should offer work-specific training for candidates, because of some informal feedback gained by the supervisor from the graduate:

> I think to a little degree, informally. As a postdoc, and particularly becoming at the end of his postdoc, he is now having to apply for things like scholarship funding, grant proposals and all that kind of thing, and I think he's kind of reported that having the skills to take that step into more independent research probably hasn't been pretty well developed. Developing the networks, or understanding of grant funding bodies, process for applications of grant funding scholarships, that kind of thing. So probably that's an area that he was underprepared for. (Go8F6)

Section 5.3 reported supervisors' self-evaluation of success in relation to their follow-up with their graduates on their career outcomes. Specifically, supervisors' responses were examined in terms of their self-evaluation of success as well as evidence of follow-up discussions with their graduates on how the PhD had best prepared and could have better prepared them for their chosen careers. The most noteworthy observation is that, despite the fact that graduate

employment was strongly considered to be a measure of supervisory success, a number of supervisors expressed not having follow-up discussions with their graduates regarding how the PhD had best prepared them for their careers. This number was even larger for follow-up discussions on how the PhD could have better prepared these graduates for their careers, with almost no one reporting that they had such discussions with their students. Even when feedback was garnered, it was through informal mechanisms.

5.4 Summary of Stage One of the Analysis

Stage One of the Findings chapter covered the data analysis of the semi-structured interview questions for this study. The chapter was organised around supervisors' conceptions of the purpose of the chemistry PhD, supervisors' reported educational practices, and supervisors' self-evaluation of success in relation to graduate career outcomes. The findings indicate that the majority of chemistry PhD supervisors reported that the purpose of the chemistry PhD included the development of the candidate's knowledge, skills, and attitudes. Despite this, their reported educational practices largely gravitated towards focusing on disciplinary knowledge and skills which were closely related to academic work, the encouraging of work experience such as tutoring and lab demonstrating. A number of supervisors reported not encouraging their students to reflect upon the broader world issues related to chemistry, however, when reflection did take place, it was concerned with the potential applications of their research. Several supervisors reported that graduate employment meant that they had succeeded as supervisors with their students. But despite this, follow-up with graduates regarding graduate career outcomes was highly uncommon. These issues will be synthetically discussed in Chapter 6. The following section of the chapter interrogates the data using an inductive analytical approach.

Stage Two: Inductive and Semi-structured Interview Analysis

The analytical approach in Stage 1 of this chapter primarily focused on analysis of direct responses to the semi-structured interview questions. However, and as described in Chapter 4, using the semi-structured interview method not only allows the researcher to cover a specific set of questions and their responses, but also provides them with the opportunity to ask new questions and uncover new insights. This stage of the analysis explores the emergent theme which I term: Academic Career Privileging. It also later explores the 'trigger points' or 'Points of Inflection' that could explain the shift in supervisors' conceptions of purpose from the

traditional underpinning paradigm, to one more concerned with the candidate and the development of the candidate's knowledge, skills, and attitudes.

5.5 Academic Career Privileging

After conducting preliminary data analysis of the first 13 interviews in this study, it was found that some supervisors held preferential views towards academic careers and considered them superior to other career pathways. These views emerged organically in this first set of interviews, and were not part of the original semi-structured interview questions. Following this observation, supervisors in the subsequent 18 interviews were asked "What kind of career expectations did your supervisor have of you?" and "What kind of career expectations do you have of your students?" in order to examine whether responding supervisors hold such views with their students, and to see if any possible links can be made with their own supervisors when they were still students, elucidating this emergent theme further. The responses, based on the inductive and subsequent interview data analysis, form three main themes which organise this chapter: Shepherding 'Bright' Students into Academia; Default Expectations for Academic Careers; Student Guilt & Supervisory Disappointment, as summarised in Table 5-24 below. Some supervisors' comments may appear more than once across these themes – it is normal for a statement to be coded under more than one theme in qualitative content analysis.

Table 5-24 The manifestation of Academic Career Privileging among chemistry doctoral supervisors

Main theme	Number of Persons	Coding rule
Default Expectations for Academic Careers	6	Evidence of either the supervisor being aware of default career expectation to become an academic or enforcing it on their own students.
Shepherding 'Bright' Students into Academia	7	Evidence of supervisors enacting this behaviour with their students.
Student Guilt & Supervisory Disappointment	4	Evidence of either the supervisor being aware of students feeling guilty and their supervisors disappointed when student does not become academic, or having experienced this themselves.

These different themes will be explored in more detail in the sections that follow.

5.5.1 Default Expectations for Academic Careers

Default expectations for academic careers refers to a reported behaviour among doctoral supervisors whereby they expect that their students, by default, will be joining the academic ranks after completion. This expectation manifests in this study in two ways: the first where an interviewee expresses this expectation of their students, and the second where the respondent reports awareness of other supervisors enacting this with their students.

In the discussion below, Go8F1 expresses a number of concerns related to these expectations, starting with the disregard towards considering and seeing the value in chemistry PhD graduates pursuing careers outside of academia:

> I am very aware, particularly through the EMCR [Early- and Mid-career researchers Forum], of the lack of considering other scientific careers and the value of PhD graduates going into many different areas and the challenge of people feeling like they've failed if they don't stay in academia. (Go8F1)

It is clear from the comments by Go8F1 of her awareness and recognition of the value of PhD graduates embarking on careers outside of academia, but faces the challenge of convincing students that they have not failed if they have left academia. This becomes more evident as she continues her discussion:

> So often PhD graduates will say to me, "Oh well, even though I haven't stayed in academia, I'm still doing okay". You know there's always this... It's funny right? Because my interpretation is kind of like 'Well they're lucky they kind of escaped from this crazy world that is academia!' I don't really have anything to say about it but I think it's a helpful thing to keep in mind. (Go8F1)

As Go8F1 goes further into voicing her concerns, she sheds light on the issues graduates express when talking to her post-graduation: "'Oh well, even though I haven't stayed in academia, I'm still doing okay'". The comment illuminates a sense of disappointment on behalf of the student, and in so doing, exposes the default career expectation of becoming an academic. Furthermore, Go8F1 displays a sense of cynicism and irony about her own job as an academic, yet struggles as to how to address those student concerns.

> When you talk to people, I think there is still this feeling amongst many academics that they're training their students to be researchers, and if they don't make it, then they've fallen off the path. I don't I think that's true, and I think the younger generation of supervisors are certainly not seeing that, but I don't know how we fix it as a perception. (Go8F1)

Despite saying 'researchers', it is argued here that within the context of the interview and Go8F1's previous comments, that she is implying 'a researcher within academia' rather than, say, someone conducting research outside of the university sector. Following through Go8F1's comments above draws further emphasis on the problem of supervisors and their assumptions

that their students will become academic researchers just like them, as well as supervisors' disappointment and disapproval if their students do not remain in academia and "fall off the path". Once again, Go8F1's struggle to address that becomes apparent in the conversation, as well as a sense of conflict regarding her own career, as voiced below:

> The other thing that I would say is, my concern would be, in my group, that I'm actually turning people off an academic career because they see me working so ridiculously hard and being so stressed. I wouldn't look at my career and want to have it. It's great, and I have an amazing opportunity, but seriously who would sign up for thirteen-hour days forever? I guess that's the flipside of making it sound like everyone should want to be academics, it's encouraging anyone to want to be academics. I don't know how you do that. (Go8F1)

From her finishing comments, it appears that Go8F1 faces a situation where she feels that she not only needs to encourage students to see the value in careers outside of academia, but also that she cannot bring herself to encourage students to work in academia, given such prevailing work conditions. It is almost as if she is questioning the appropriateness of the default career expectation of becoming an academic in terms of work ethic and employment wellbeing.

On the other hand, the discussion with Go8F3 below highlights the issue of student voice and ownership of their own post-PhD career choices:

> A number of my colleagues, and I'm not sure I understand why, the discussion about what comes after a PhD seems to be shrouded in secrecy, and I'm not sure I really understand why. And even for myself as a PhD student I was always a bit worried about talking about that with my PhD supervisor because I think he had a very set vision about where he thought I should go. (Go8F3)
>
> Was he expecting you to be an academic? (Interviewer)
>
> I think he was and I didn't want to be… And for me, I've taken a bit longer, but I figured my own roots and ended up I guess in the end here! (Laughs). (Go8F3)
>
> But you figured it out for yourself. (Interviewer)
>
> To me, I had to do that for myself. (Go8F3)

The discussion with Go8F3 draws attention to her experience as a doctoral student herself, where her supervisor assumed that she would become an academic, to the extent that she felt worried about openly discussing her career ambitions with him. It can be argued that that experience, as a result, alerted Go8F3 to this very situation among her colleagues and their reluctance to discuss post-PhD life with their students, keeping what comes after a PhD, as Go8F3 describes, "shrouded in secrecy". And while Go8F3 did eventually remain in academia, her comment "To me, I had to do that for myself", clearly captures how necessary it was to make that decision for herself; to have the authority herself to make that call.

Like her colleague, Go8F4 shows awareness of the assumption and expectation that completing a chemistry PhD equates to becoming an academic, and attempts to address this by exposing students to chemistry doctoral alumni who have jobs in areas unrelated to chemistry, showing them the different career possibilities available to them:

> Making sure that students are aware that there are opportunities out there, but they don't have to be buttonholed into 'I'm a chemist. I've spent eight years training to be a chemist, therefore I must be a chemist in the future'. We get a couple of ex-students or even just people who we happen to know who have done PhDs in chemistry but have jobs in different places to actually just come in and give a little presentation about what it is that they do and how they got there, to try and give students some evidence that there is something else down there! (Laughs). (Go8F4)

The reported beliefs and behaviours of Go8F4 stand in stark contrast to those of Go8M9, who considers himself to be preparing his students for a potential career in academia: "Well, I encourage my students to do lab demonstrating partly because I consider that I am training them potentially for an academic career and that's a useful experience, teaching experience for an academic career". (Go8M9)

Finally, Go8M1, in acknowledging his disappointment when some students did not remain as researchers in the field (this concept of supervisory disappointment will be explored in greater depth in section 5.5.3), demonstrates the default career expectations he held for his students, until he later changed his views upon reflection:

> I mean I would have at the start been quite disappointed if someone hadn't gone into a research job after doing a PhD with me. But now, many years later after reflection and understanding, I'm very relaxed about that, it's very good to see PhD students, good to

> see scientists in the social sciences, you know, it's a very good mix to have that crossover. (Go8M1)

Once again, it is argued here that the 'research job' is an academic job, when viewed in the context of Go8M1's previous interview comments: "So this is something that I think academics hadn't thought about at all at the time I started my research career. They thought people will be trained to be like them" (Go8M1).

5.5.2 Shepherding 'Bright' Students into Academia

If the previous section demonstrated how chemistry PhD supervisors held preferential default expectations that their students would become academics, then this section demonstrates how supervisors expect and may shepherd their 'bright' students who are up for the job, into academia. In this study, the finding became manifest as supervisors reported enacting this behaviour with their own students.

In the comments made in response to the career expectations she holds of her students, ATNF2 starts by saying that her students should just find a job and she would place them in different networks based on their interests: "To find a job. No, I don't really have very many. I try to be as open-minded as I can, and if they come up with an interest, I try to connect them with someone" (ATNF2). However, her ensuing comments reveal her encouragement of students to take on a postdoctoral position "if" (with emphasis by participant) they are up for it:

> I'd encourage them to do a bit of travelling now they've got a PhD, try to encourage them to do a little bit of a postdoc, if they're, IF, I think that they're up for it because I think that such an exciting opportunity, it helps with jobs, but after that I think finding a job is probably the hardest thing. (ATNF2)

In other words, it is the students whose attributes constitute them as 'up for it' who are encouraged to join academia. Interestingly, this view ATNF2 holds might be related to the views her own supervisor had of her and her own potential adequacy as a supervisor:

> What kind of career expectations did your supervisor have of you? (Interviewer)
>
> (Laughs). Very little! No, I actually have no idea. I think he thought that I should probably work in the wine industry I reckon, just be a lab tech I think! (ATNF2)

Another participant, ATNF3, expresses similar views to those shared by ATNF2:

> So I suppose the expectation would be if they obviously do really well and they can get a permanent academic job, then fantastic, otherwise maybe try to encourage them into a slightly more stable career, either maybe industry, or teaching, because I know from experience as well that it's very difficult to get an academic job, so not that I would discourage it, I would say if after a few years you're finding it difficult maybe, look into doing something that's got a bit more of a long-life career.

Once more, there is a perception that the students who do really well would be applying for academic positions in the first instance and that this is considered the pinnacle of career achievements. This reaffirms the default career expectation of academic careers. Furthermore, it is only when all avenues of potential academic jobs have been exhausted that other careers in industry or teaching would then be considered.

Likewise, ATNM2 demonstrates very similar views, and begins by emphasising the importance of graduate wellbeing and happiness:

> I obviously hope they go on to become successful in whatever they enjoy, and I always emphasise to them that what matters is that you do something that you really enjoy, and have fun, just like we do in our work. (ATNM2)

However, his continued response brings forth his inner preference:

> I don't try to push them too overtly one way or the other, I don't try to say, 'Oh you should all go on and become academics'. Because I know it's not realistic, it's not even an easy career to have any more. I think it's getting harder and harder. However, if I see a student who has that special kind of potential, you think to go on in that way, then obviously I'll do what I can and encourage them, but I don't want to push them in one way or the other too much. I think it has to be their choice. (ATNM2)

Not only does ATNM2 show an inner preference for academic careers, but also that it is students with that "that special kind of potential" that are encouraged to join.

In the case of ATNM3, it is those with an "aptitude for research":

> If I see that the student has got an aptitude for research, I try to encourage them to go towards academia, and maybe postdoc. I try to tell them that, even if you want to work in industry, having a few years of postdoc is not going to damage your skill base set.

> The difficult thing that I find is that they're very well aware that getting jobs in academia nowadays is very complicated, even if you have the skill set, that might not be enough to guarantee you a job. (ATNM3)
>
> So do you hope that they become academics? (Interviewer)
>
> The ones that have the skills for it, yes. (ATNM3)

With this supervisor, it is quite clear that for those students who have an "aptitude for research", the recommended and encouraged pathway is the academic one. Moreover, applying for postdoctoral positions, despite the aforementioned complicated application process, is encouraged even for those who want to go into industry.

In addition to the previous characteristics of 'bright' students, the discussion with G08M10 adds being "cut out" to the list:

> I think I probably still, for my students, to have a fairly conservative view that they either are or aren't cut out for an academic research position. (G08M10)
>
> So do you anticipate, in general, that a PhD in chemistry or in your field leads to a job in academia? Is that the anticipation? (Interviewer)
>
> I think that's probably my default position. Which isn't necessarily correct, but that's probably where I still sit. (G08M10)

Noteworthy is the participant's ability to identify his view as not "necessarily correct", but maintaining it nevertheless.

In the example below, G08F8 makes the following response to the question on the career expectations she has of her students: "I just want them to be happy. I really just want them to be happy" (G08F8). But what starts as intentions for graduate happiness and wellbeing in their careers eventuates into an exhaustive list for academic career success:

> Okay, I'll take that back. I want them to be happy but I also want them to reach their potential. And their potential, in my mind, I try to make sure that even the students that I think are not so good can reach a place… as I feel I get more experienced, I can help people find the right fit for the right job. I have one student who got 12 papers in 3 years. And obviously I have very high expectations of her, and she's a superstar. And then I have other students, and if they are not up to snuff, I try to catch it in the middle

> or early on, and say, 'Okay, look, you know, pull your socks up, I can see where're you're gonna go here, I think you need to do this, this, and this. And if you don't do that, that's okay, but then this is the type of career path you might end up taking'. So I try to help them figure out their fit and how much they can push themselves versus how much they feel like they're gonna die. I try to say, 'If this is too much, then you need to do something differently, then let's slow down, you realise that you only get two papers instead of six, that's going to impact your career'. And that's one of the reasons I tell them, 'Don't go demonstrate too much'. Because no one's going to care how much you demonstrated when you're getting a job. They're going to say, 'Wow, she got six papers, as opposed to two'. (Go8F8)

Despite her initial comments on happiness, Go8F8 is clearly envisaging academic careers when thinking about post-PhD careers. It is the students with a publication record who are "superstars" – these are presumably the 'bright' students' – and then those who have a less glamorous record are warned of the "type of career path" they might take. Students are pushed to produce papers, under an assumption that the path following the PhD is an academic one, and that the careers of those with fewer papers will be adversely affected. Demonstration is discouraged because "no one's going to care how much you demonstrated when you're getting a job", insinuating that that job is a postdoctoral position. Perhaps in this special case, with this participant, most students are being shepherded into academia, and not just the bright 'superstars'. It does not negate that she wishes her students be happy, but rather, her understanding of graduate happiness seems to be inherently infused with being employed as academic.

Finally, in Go8M9's discussion below, he reports that he does not expect his students to become academics, despite considering himself to be preparing them for a potential career in academia in Section 5.1.1 previously:

> Well I don't expect them all to become university academics, that's for sure. (Go8M9)
>
> Why is that? (Interviewer)
>
> I don't think most of them are capable (laughs) to be blunt! (Go8M9)

When asked in what sense he considers them not capable, he provides the following response, quoting the competitive nature of the sector, lack of student motivation, and the requirement

for a "certain level of passion" to qualify, and hopes that his students are gaining a range of skills that could be useful for non-academic jobs:

> Well it's a very competitive area to get into, only a small percentage of PhD graduates can possibly get an academic position, and so just based on the statistics and only the top 10% or so of PhD graduates will get an academic position, I think it's really just the best students that do, and also a lot of my students don't seem to be motivated in that direction. It requires a certain level of passion for the research that only a few students seem to have. I hope that I would be teaching my students a range of transferable skills in quantitative analysis, computer programming, that there are a range of jobs that they would be able to find.

5.5.3 Student Guilt and Supervisory Disappointment

The previous two sections of Stage 2 of the findings focused on the manifestation of supervisors' default expectations for academic careers for their students, and the shepherding of 'bright' students into academia. Instances of supervisory disappointment when a student did not join the academic ranks were detected in the previous analysis. Descriptions of student guilt were also apparent.

This section on Academic Career Privileging examines the occurrences of student guilt, when they do not join academia after completion, and the consequent supervisory disappointment in greater detail. The analysis here followed the same approach as the previous two sections, that is, observing evidence of a responding supervisor reporting awareness of other students feeling guilty and their supervisors being disappointed when the student did not become an academic, or the responding supervisor expressing disappointment themselves in their students who would depart or have departed academia.

The comments made by G08M1 from Section 5.1.1 are reviewed again in terms of their relevant content on supervisory disappointment, with G08M1 making explicit remarks about his disappointment when a student did not remain as a researcher in the field:

> I mean I would have at the start been quite disappointed if someone hadn't gone into a research job after doing a PhD with me. But now, many years later after reflection and understanding, I'm very relaxed about that, it's a very good to see PhD students, good to see scientists in the social sciences, you know, it's a very good mix to have that crossover. (G08M1)

Based on his previous comment, "so this is something that I think academics hadn't thought about at all at the time I started my research career. They thought people will be trained to be like them" (G08M1), it is argued that his disappointment would have been in relation to his students not becoming stewards of the discipline.

In the case of ATNM4, however, supervisory disappointment is not something he expresses himself if his students have left academia:

> So I try to communicate clearly, but I don't have any, I certainly don't, I know there's this stereotype of equating successful supervision equalling becoming an academic, and I'm certainly seeing plenty of US-based supervisors who think like that. But for me, getting a job that the student finds enjoyable and pays the bills is a successful outcome. And at the moment, that's been achieved certainly for the vast majority. (ATNM4)

Rather, he reports his recognition of a stereotype whereby supervisors considering successful supervision has been achieved when a student becomes an academic. The reported stereotype itself is about what counts as successful supervision for those supervisors. But what can be inferred from it is a student leaving academia equalling failed supervision for those individuals, and by extension, disappointment in the student (and presumably supervisors being disappointed in themselves in this case).

This is similarly seen with G08F1, whose comments were analysed before in relation to default expectations for academic careers, but are presented here again for the perspective they provide on student guilt and supervisory disappointment:

> So often PhD graduates will say to me, "Oh well, even though I haven't stayed in academia, I'm still doing okay". You know there's always this... It's funny right? (G08F1)

> When you talk to people, I think there is still this feeling amongst many academics that they're training their students to be researchers, and if they don't make it, then they've fallen off the path. (G08F1)

Finally, G08M9 describes the cycles of disapproval and approval he felt his supervisor went through as G08M9 left then came back to academia:

> What kind of career expectations did your supervisor have of you? (Interviewer)

> Well I think his expectation was that I was gonna be an academic at a university, I think that's what a lot of supervisors (laughs) hope of their students. After my PhD, I left academia briefly, and I think my supervisor was disappointed and he was happy when I returned. (G08M9)

This section of the Findings chapter has examined the emergent theme of Academic Career Privileging. Three themes constituted this overarching theme: Default expectations for academic careers; Shepherding 'Bright' Students into Academia; and Student Guilt & Supervisory Disappointment. The theme of default expectations for academic careers examined the manifestation of supervisors envisaging their students becoming academics upon completion of their doctoral degree, by default. This came about in the data in two ways: either responding supervisors assuming and expecting their own students to join academia upon completion, or being aware and observing this phenomenon taking place in the discipline among other supervisors. Closely related to this assumed default career expectation was supervisors shepherding of 'bright' students into academia. This occurred in the data as the responding supervisors directing and persuading their students into becoming academics. 'Bright' was used here as a generic placeholder to capture the various terms supervisors used that could fall under it, such as 'up for it', 'has that special kind of potential', and so on. Finally, and unsurprisingly, with such expectations from supervisors of their students, descriptions of supervisory disappointment and student guilt were also observed when a student did not live up to the expectation of becoming an academic, leading to the disapproval of their supervisor.

In discussing the emergent theme of Academic Career Privileging, it is also problematised. It sketches a situation in which students are expected to become academics, just like their supervisors, and join academia. Specifically, it is the 'bright' students who are of interest, and they are the ones who are chosen to pursue the pinnacle of career pathways. By extension, this means that students who are less 'bright' are meant for the other careers – unless a 'bright' student cannot make it into academia (at least permanently), then they can join the others in the search for non-academic careers. It is likely, that at this point, that students who have left academia will begin to feel the shame and guilt, while their supervisors cast their disappointment for 'falling off the path'.

It is important to explicitly state that this thesis does not argue for the dissolution of academic careers. Academic research is an integral part of a healthy society. But it does argue that Academic Career Privileging is highly problematic, as it appears to be a constraining set of ideas and behaviours: it constrains the student by forcing them into academic straitjackets, it

constrains the supervisor and their own definitions of supervisory success, and it constrains the various contributions that graduates can potentially make in multiple workplaces. This theme will be further examined against additional new literature in order to bring the findings into fuller meaning and draw out the implications for this study.

5.6 Points of Inflection

In the previous Stage One analysis in this chapter, supervisors were categorised into three main group based on their conception of doctoral purpose in chemistry: those who thought the purpose of the chemistry PhD was about developing the candidate's knowledge, skills, and attitudes (the 'Person' category); those who thought that the purpose of the chemistry PhD was about conducting research and creating knowledge (the 'Product' category); and those whose thoughts covered both of the previous conceptions (the 'Person & Product' category).

But given that the doctorate, as discussed in the literature review, has historically been the means through which candidates became stewards of the discipline, and has ensured the longevity and sustenance of the discipline, this raised the following question: What had caused several supervisors in this study to have had their conceptions of doctoral purpose shift from the traditional underpinning paradigm, to the one more concerned with the candidate and the development of the candidate's knowledge, skills, and attitudes? What might be the points of inflection or 'trigger points' that could explain this and how might they be integrated into future research and development programs or workshops for supervisors?

The responses of the 27 supervisors under 'Person' and 'Person and Product' were revisited, since these two categories of respondents had a strong focus on candidate knowledge, skill, and attitude development in their conceptions of doctoral purpose. In revisiting these interviews attention was paid to the points that might have elicited their conceptions of purpose being coloured by ideas related to the doctorate as preparing knowledge workers. The responses of ten supervisors provided these points most evidently, from which four themes emerged, as shown in Table 5-25 below:

Table 5-25 Points of inflection that appear to have shifted supervisors' conception of purpose under 'Person' and 'Person & Product' from stewardship towards the knowledge worker paradigm

Main theme	Number of Persons	Coding rule
Awareness of Post-PhD Job Reality	5	Supervisor's awareness of post-PhD job realities appeared to account for their conception of purpose being positioned towards the knowledge worker paradigm.

Being Reflective	4	Supervisor's heightened reflection appeared to account for their conception of purpose being positioned towards the knowledge worker paradigm.
Exposure through Leadership	3	Supervisor's exposure to new experiences through leadership positions appeared to account for their conception of purpose being positioned towards the knowledge worker paradigm.
Destabilising Experiences	2	Supervisor encountering a destabilising or challenging experience appeared to account for their conception of purpose being positioned towards the knowledge worker paradigm.

These themes will be explored in detail in the following sections.

5.6.1 Awareness of Post-PhD Job Reality

One of the points of inflection that appeared to shift a supervisor's conception of doctoral purpose from the traditional underpinning of stewardship to that of the knowledge worker paradigm is an awareness of the job realities facing graduates after completing their degrees. This trigger point took more than one form. For example, for Go8F1, it appears that exposure to the Australian Academy of Science's Early- and Mid-Career Researchers forum (or the EMCR forum) afforded her the opportunity to broaden her perspective of the different careers available to PhD graduates:

> I'm involved with the EMCR Forum which is for early to mid-career graduates, so I think a lot about training opportunities. It's obviously something that we as the forum can't extend to PhD students, but we are thinking about encouraging universities to do more of, which is identifying what the possible careers are. Because I think the biggest challenge for a PhD student is that they think that research is the career that they should be aiming for, and yet there are so many exciting and different careers for them. (Go8F1)

When asked about the sorts of careers to which a PhD in chemistry could lead, Go8F1 replies with the following, demonstrating a breadth of understanding of post-PhD careers for chemistry graduates:

> So there are many really exciting careers in science communication, so whether they're writing for a science magazine, or science journalism, or working for an organisation Questacon, doing outreach. There are opportunities to be involved in science research, so for example running clinical trials, so we have quite a few chemistry graduates from here who go and work for clinical trials. Working for health organisations from an admin perspective. Obviously a lot of our graduates go and work for the finance sector

> and that's something that's being really pushed at the moment by the finance sector, to be looking to employing STEM graduates. Quite often our graduates end up in patent law. (Go8F1)

Furthermore, Go8F1's research of her university's alumni appears to be another point of inflection in shaping her conceptions of doctoral purpose:

> I do know this because I [researched] all of the alumni from our university recently so that I can talk to students about, not only my students, but other PhD students about what career opportunities there are. So they are the kind of areas the most of our graduates end up in. (Go8F1)

Finally, in Go8F1's concluding comments, her interactions with the EMCR forum also appear to have heightened her attention to and awareness of the issue of Academic Career Privileging discussed earlier:

> I guess not. I am very aware, particularly through the EMCR Forum, of the lack of considering other scientific careers and the value of PhD graduates going into many different areas and the challenge of people feeling like they've failed if they don't stay in academia. So often PhD graduates will say to me, "Oh well, even though I haven't stayed in academia, I'm still doing okay". You know there's always this… It's funny right? Because my interpretation is kind of like 'Well they're lucky they kind of escaped from this crazy world that is academia!' I don't really have anything to say about it but I think it's a helpful thing to keep in mind. When you talk to people, I think there is still this feeling amongst many academics that they're training their students to be researchers, and if they don't make it, then they've fallen off the path. I don't I think that's true, and I think the younger generation of supervisors are certainly not seeing that, but I don't know how we fix it is as a perception. (Go8F1)

In the case of the Go8F5, she talks about how her conception of the purpose of the chemistry PhD has changed over the years:

> Oh! (Laughs). It's probably changed over the years. In the past I always thought the student should work on a research project, focus on a specific area, learn as much as they want. Nowadays I feel that a research project is there for a student to tackle a problem – any kind of problem, try to find information, learn to talk to others of their problems, and deal with frustration… [to] grow as a person… and I think after the three

> years you come out as a person who knows 'I can actually overcome obstacles'. If somebody would have asked me 15 years ago what a PhD is for, I would have said 'interest and research, and it's fun doing it'. (Go8F5)

When asked why she thought her perception had changed, her response focused on her awareness of the kind of workforce her graduates were entering:

> I think simply because most students in Australia do not end up doing research. It's different in Germany where I graduated, very often you sort of locked yourself in your PhD to do polymer chemistry, chances are you're going to work in the chemical industry on a polymer problem. Here in Australia it's different. Not a lot of my PhD students actually end up doing research, they do consulting, they run analytical labs, all sorts of things. And I think the purpose therefore is really to prepare the students in some ways a little bit differently, or maybe basically highlight to the students what you can expect from the PhD. (Go8F5) (Upon further probing, Go8F5 later defines research as "any kind of research and development").

Even her self-evaluation of success as a supervisor had been destabilised as a result of this new shift in her conception of doctoral purpose in chemistry:

> Oh, I still don't know if I've succeeded. (Laughs). In the past it was always very simple because, (recording inaudible) I've succeeded if the student goes out and published some papers. Now I sort of start thinking maybe I need to offer the students a few more things during the PhD? And I do actually talk to our university about them because I feel we need to prepare students much better for the workforce. It's not about them doing a research project, yes that's maybe most of the time, but going along we should acquire skills as well, for example, managing teams, maybe how to read the patent literature, maybe get some basic business understanding, you know all these little things where I think... We have to be realistic where our students go and I don't think we really prepare them for that. (Go8F5)

Go8F5's final comment on skills and the lack of student preparation in that regard resonates well with the data from this study that show less than one quarter of responses on skills ensured were related to non-academic skills (see Table 5-11).

In addition, Go8F5 provides further deep reflection over the kind of work environments she expects her students to face:

> When they leave they're usually sort of 25 to 30, so they will probably spend 40 years in an environment that is not the University. So they will spend it in an environment where they have to deal with customers, they have to be able to talk to people, they have to be able to understand business principles, and they have to be able to understand laws, so all these things. And I don't think we prepare them for that. (Go8F5)

Further insights from her interview suggest that her experience of work outside of the university sector was a contributing factor to the changed conceptions of doctoral purpose she now holds:

> The other thing that I tell them [her students], 'Look, just get a job, see the real life, stack some shelves at Coles or something, see what real life is like, what real people are like'... I've done it as a student, working in a factory, and I found it quite eye-opening working with people who have to work in a factory for a living. So I think it doesn't hurt for some of my students to really see the real life. (Go8F5)

If exposure to real life is something that Go8F5 wanted for her students, then IRUF2 happened to share the same sentiment, demonstrating an awareness of the incongruence between university training and post-PhD careers in chemistry:

> I did my PhD with industry, but I didn't go into industry afterwards... So one thing I would change, I would say exposing students more to the real world, so whether it's industry or could be others as well... I tend to expose my students quite a bit to industry, we have two students working on PhDs funded by industry, so everyone in the group is actually aware, a little bit more aware of industry, but I think as a whole if you're only relying on the university training, it's still very academic, and not oriented towards other careers, which would probably be industry mostly for chemists, but could be other careers as well. And possibly some skills for, probably just exposure actually, exposure to the corporate world, and see how it works. Well my students I actually expose more or less, but to a lot of students around, they've never seen how it works in industry. So they're in for a surprise if they want to go to industry after their PhD. (IRUF2)

IRUF2's final statement relates well with the findings from this study that show that work experience in academic teaching and related activities is predominantly more encouraged compared to work experience in industry or government (see Table 5-16).

5.6.2 Being Reflective

This section of the findings draws attention to the reflection of supervisors and how it appears to have accounted for shifts in their conceptions of purpose. These comments varied, and were best coded under the general theme of 'Being Reflective'.

For example, ATNF2 reported that she encouraged her students to reflect upon contemporary issues relating to chemistry by having her students read and engage with scientific news in the media. But it is in her explanation as to why she found this practice to be important that showed reflection regarding her role as a scientist and her place in society:

> Because I think it's very important. We as scientists have the ability to understand where we fit in, and our roles are actually far bigger than just knowing a tiny little specialised piece of knowledge that nobody else understands in the real world. I think we have a real power. When I say that PhDs not how to think, I think that comes into our ability to think critically and analyse… that's where scientists progress more and offer their wider job opportunities by understanding where and how we all fit in and have that social responsibility. When your family ask something, you actually have that knowledge of how your fundamental knowledge reflects in actual life. (ATNF2)

The breadth of her role becomes apparent from her comments above – that she sees her knowledge and critical thinking skills serving society and the workforce broadly – a point quite resonant with the knowledge worker paradigm.

Similarly, Go8F4's reflection on her role as a chemist and the public accountability she has towards the Australian taxpayer appear to explain the shifts she has made in her conceptions of doctoral purpose:

> And then how do we think about, I mean, why are we here in the first place? Why are we doing chemistry in the first place? We are funded by taxpayers, we have to deliver. Can't just be about what I'm interested in researching (Laughs). (Go8F4)

5.6.3 Exposure through Leadership

The third point of inflection that appears to have moved supervisory conceptions of doctoral purpose along the lines of developing doctoral candidates as knowledge workers is being in a leadership position and the exposure that comes with it.

When asked whether being Head of School might have influenced her views of the discipline of chemistry, Go8F4 provides a critique of the way the discipline communicates internally and externally with the public:

> I think that chemistry as a discipline could do with functioning better [,] talking to each other more, but also with the outside world. I think chemistry is kind of the child in the corner that we don't talk about, we talk about astronomy and people get excited about it, we talk about biology and people get excited about it, but we don't talk about chemistry in the same way, in the general public. In the general public chemicals are bad, right? So it's a kind of, how do we actually make people register or realise that chemistry is actually good for them?... (Go8F4)

This leads her to reflect upon how being Head of School in chemistry had exposed her to the opportunity to work with the Academy of Science, and how that in turn helped further cement the issues relating to postgraduate employment, despite them not being new issues at the time of her involvement:

> So that's [being Head of School] definitely had an influence on thinking that way [in terms of the issues above], particularly because I was involved [with] the Australian Academy of Science launched last year, and so because I was Head of School, I was involved in actually looking at putting that together. So being involved in that was actually a really interesting experience and got me thinking a lot more about what the interaction is between chemistry and the wider world, what the interaction is between chemistry and academia, and chemistry and industry, and part of that was recognising that yeah we've got lots of PhD students but what happens to them at the end of the day? I mean they can't all be academics and that's been the case for 20 years, it's 20 years this year since I got my PhD, and at that point people were all going 'Oh, what are we going to do when we graduate?', so it's not a new problem, it's gotten worse, because groups have gotten bigger and there is more academics than there were, but

> having the realisation that they got to go somewhere else and do something else… (Go8F4)

Go8M13, also Head of School, provides extensive reflection on the relationship between the leadership positions he anticipates chemistry PhD graduates will occupy in society and how doctoral studies prepare students for these leadership positions:

> When I say to the PhD students, 'You're going to be the professional people, the leaders of this nation, over 10, 20 years' time, as a group'… many of those people are going to be highly successful alumni of the [participant's university], and they will be doing a huge spectrum of things, and a lot of that will be leadership, management-type roles. And whatever you do, and that could be doing research, but it could also be working for some large multinational corporation, running your own business, et cetera et cetera. That's all leadership, or management, these sorts of skills. And the thing about the PhD is that it teaches you pretty well to do all of those things, because you've got to be well planned, you've got to execute your plan, think where you're going, be progressive in your thoughts, you've got to be logical in your thoughts, and those sorts of skills are generic skills that are really applicable across the spectrum.

This applicability that Go8M13 mentions resonates with the reflective practices of supervisors undertaken by over half who encouraged thinking beyond the research conclusions to applications and societal implications and the few supervisors who were specifically reflective over issues relating to science and the public (see Table 5-13).

Similarly, Go8M1, being a senior academic and the leader of an important scientific body in Australia, reflects in hindsight on the need for PhD candidates to be able to work in areas outside of their original field of training:

> I can talk about the whole spectrum of both experimental sciences through to social sciences through to the arts and humanities. People these days will probably be more likely to be working in an area outside of their original research training, which may have nothing to do with the basic research that they have done. So the skills have to be built into the research training in a very thorough way… So this is something that I think academics hadn't thought about at all at the time I started my research career. They thought people will be trained to be like them. (Go8M1)

He then acknowledges how reflection helped change the career expectations he had for his students:

> I mean I would have at the start been quite disappointed if someone hadn't gone into a research job after doing a PhD with me. But now, many years later after reflection and understanding, I'm very relaxed about that, it's very good to see PhD students, good to see scientists in the social sciences, you know, it's a very good mix to have that crossover.

Based on his previous comment, "so this is something that I think academics hadn't thought about at all at the time I started my research career. They thought people will be trained to be like them" (G08M1), it is argued that his disappointment would have been in relation to his students not becoming stewards of the discipline. However, this changed as his research experience broadened and his exposure to the social sciences and humanities occurred:

> … [in the] late 1980s, early 1990s… my research experience had been very much broadened by collaborative science and activities. I didn't ever collaborate with a social scientist scientifically but became more and more aware of the importance of the aspects of the social sciences and the humanities could bring to critical thinking in the sciences, and also for preparation for a job… [I became] more and more aware of it since I've been [leader of peak scientific body in Australia]. (G08M1)

5.6.4 Destabilising Experiences

Besides the previous inflection points of being aware of the post-PhD employment market and exposure through leadership positions, encountering a destabilising experience at some point during their own doctoral education or academic career appeared to challenge the traditional notions and conceptions of doctoral purpose towards participants' current 'knowledge worker' conception of doctoral purpose. In the case of G08F1, the destabilising experience was academic disillusionment, with her deeply questioning the nature of academic work, including her own:

> The other thing that I would say is, my concern would be, in my group, that I'm actually turning people off an academic career because they see me working so ridiculously hard and being so stressed. I wouldn't look at my career and want to have it. It's great, and I have an amazing opportunity, but seriously who would sign up for 13-hour days forever? (G08F1)

Similarly, Go8F3 recounts a number of destabilising experiences that appear to account for the position she has taken in terms of her conceptions of the purpose of the doctorate in chemistry:

> A number of my colleagues, and I'm not sure I understand why, the discussion about what comes after a PhD seems to be shrouded in secrecy, and I'm not sure I really understand why. And even for myself as a PhD student I was always a bit worried about talking about that with my PhD supervisor because I think he had a very set vision about where he thought I should go. (Go8F3)
>
> Was he expecting you to be an academic? (Interviewer)
>
> I think he was and I didn't want to be. He said, "Here's the person you should go to." And for me, I've taken a bit longer, but I figured my own roots and ended up I guess in the end here! (Laughs). (Go8F3)
>
> But you figured it out for yourself. (Interviewer)
>
> To me, I had to do that for myself. (Go8F3)

In the conversation above, it is clear that Go8F1 feels concerned that her colleagues are not as transparent and open as she would like them to be regarding post-PhD life and the other experiences she reported above.

Go8F3 then emphasises her openness with her students about post-PhD life, but then moves to another destabilising experience and that is her disillusionment with academic norms and rules surrounding publications and research outputs, and the impact this has on her students:

> So I guess I'm saying that I'm pretty open with my students about the discussion at the end of the second year of a PhD about look a bit ahead now. I know this sounds incredibly black-and-white, and I don't mean it to sound this way, but getting a really strong publication record is something all my students have come out with, really strong records, I don't really do things in any other way other than if they mean something. So to me, the literature is a discussion and we have internationally and I've always seen it that way but that's just my perspective, so the whole bean counting thing that happens around Australia and that I get so frustrated by, ERA ratings, just the whole stuff, the publications, the message is just so wrong to young people. I'm very concerned about the messages coming down to young people. I just think the meaning

> is being lost. Why are we actually here? To train the next generation, to find solutions for problems, the world's problems.

Of course, things like being aware of postgraduate employment figures are not guaranteed to trigger altering a supervisor's conception of doctoral purpose into the knowledge worker paradigm. For example, Go8M8 was aware of the small percentage of graduates becoming academics: "And realistically, what, 5% of graduates end up becoming academics?", but still saw the purpose of the chemistry PhD as being focused on doing research and making an original contribution to knowledge.

In fact, for a number supervisors, knowing that their graduates were employed seemed to close off the process of reflection. As seen in the previous findings, a number of these supervisors indicated that if their graduate got a job then that meant a measure of success for them as supervisors, as summarised in Table 5-26 below.

Table 5-26 Supervisors stopping at graduate attainment of a job as a measure of success

Main theme	Number of Persons	Coding rule
Graduate Got Job as Indicator for Supervisory Success	17	Evidence of supervisor using and stopping at graduate attaining a job as a measure of supervisory success.

However, these supervisors were stopping at the point of job attainment, as represented by this quote: "They've all got jobs I suppose" (Go8M3). This needs to be problematised as the event of a graduate attaining a job, in and of itself, is not enough to form a nuanced understanding of supervisory success. Other observations need to be made in conjunction with this: How difficult was it to attain the job? What aspects of the doctoral experience have helped prepare (or hinder) job performance? How fit was the doctoral experience for that purpose? Here, awareness of graduate employment was not fully triggering the conceptions of doctoral purpose into the knowledge worker paradigm, and perhaps it is awareness of larger trends in graduate employment that could do so.

Furthermore, the points of inflection discussed here do not constitute an exhaustive list. For example, one particular supervisor expressed some level of frustration with being less able to measure her success beyond measures familiar to her such as student producing publications or attaining a post-doctoral position, as seen in the conversation below:

> How do you know you've succeeded as a supervisor with your students? (Interviewer)

(Laughs) That's a difficult question! It's more easy to ask on the side of the research. So I would say… (Go8F6)

In what sense? (Interviewer)

Well, you know, if they've got recognised publications, if they've gone on to other laboratories, you know they've found positions elsewhere. So my first PhD student finished and went on to a postdoc in a quite high-profile overseas lab, so I took that as quite a positive in terms of research training that they'd obviously had the skills that meant they were contributing to high-impact work elsewhere. So I guess that's probably one main consideration is where they end up. (Go8F6)

And you were saying at the side of research, you're saying it's easier. Is there another side? (Interviewer)

So I mean in terms of those more general skills, I guess it hasn't necessarily applied to me because I haven't had that many students finish, but for those students who don't necessarily stay on the academic path, it doesn't necessarily mean that you haven't trained them well, it just means, it's harder to judge, 'Was their training was good? Was their training insufficient to get them to where they wanted to go?', it's a bit harder to judge. But if they stay on an academic track, and end up with a nice postdoctoral position and that kind of thing, then I will count that as evidence of good training. (Go8F6)

The supervisor in this case is aware of the more diverse career pathways doctoral graduates can take, but upon reflection, is unsure and rather frustrated about how her educational practices facilitate or constrain student employability beyond the standard and familiar postdoctoral position.

This section of the findings chapter drew attention to the points of inflection or trigger points that appear to have caused a shift in supervisors' conceptions of doctoral purpose away from the historical roots of the stewardship paradigm, and towards preparing doctoral candidates for the knowledge work environment. A number of points of inflection were found, which were categorised into four themes: awareness of post-PhD job reality; exposure through leadership positions; destabilising experiences; and being reflective. Supervisors' awareness of the job realities facing PhD graduates, afforded through interactions with industry and career forums, seemed to trigger their thoughts into considering the diverse career pathways following a

chemistry PhD and the necessary skills training needed for them. Leadership positions such as being Heads of School placed these supervisors squarely in an environment that required them to be contemplative about the roles that chemistry and chemists play, including chemistry PhD graduates, in nation building. Going though destabilising experiences such as academic disillusionment drew forth critically reflective stances related to the doctoral education of chemists. Finally, a sense of deep reflective practice appeared to underpin the thinking of supervisors who were able to conceive not just the purpose of the chemistry PhD, but also their roles as scientists within the broader frame of society and its needs. Awareness of postgraduate employment figures are not guaranteed to trigger altering a supervisor's conception of doctoral purpose into the knowledge worker paradigm. Furthermore, the points of inflection discussed here do not constitute an exhaustive list. However, these findings presented themselves as the most convincing points of inflection to account for the aforementioned shifts in doctoral purpose conceptions.

5.7 Summary

Stage Two of this Findings chapter took a more inductive approach by analysing the emergent theme of 'Academic Career Privileging' and exploring the 'Points of Inflection' for a number of supervisors that could explain the shifts that had occurred in their conceptions of doctoral purpose from the traditional doctoral paradigm to that focused on the person and developing candidate knowledge, skills, and attitudes. Under the theme of 'Academic Career Privileging', sub-themes relating to supervisors assuming doctoral study was followed by academic employment, the shepherding of 'bright' students into academia, and accompanying student guilt and supervisory disappointment were explored. In addition, the analysis shed light on 'trigger points' that have changed supervisory conceptions of doctoral purpose, such as awareness of trends in post-PhD employment, having a sense of reflection, exposure through leadership positions and the experiences acquired by extension, as well undergoing destabilising experiences such as academic disillusionment. These findings, along with the ones from Stage One of the analysis, will be synthetically discussed in the following chapter.

CHAPTER 6 – DISCUSSION

In the previous chapter on Findings, the data analysis was separated into two stages: Stage One which focused on the semi-structured interview analysis and Stage Two which focused on both the inductive and semi-structured interview analysis. Stage One organised the findings around the three main themes of supervisory conceptions of doctoral purpose, reported supervisory educational practices, and reported methods of supervisory evaluation. Stage Two of the analysis followed an initial inductive approach where the emergent theme revolving around 'Academic Career Privileging' was further explored, alongside supervisors and their 'Points of Inflection' that appear to have triggered and caused shifts in their conceptions of doctoral purpose.

This chapter offers a synthetic interpretation to these findings and their meaning, given the literature reviewed for this study, as well as new literature deemed relevant in the discussion. First, it brings into focus the disconnects and alignments between supervisors' conceptions of doctoral purpose and their reported educational practices. However, in order to better appreciate this observation, the shorthand concepts of 'Person' and 'Product' are related back to the paradigms of 'Knowledge Worker' and 'Stewards of the Discipline' respectively. In so doing, this allows supervisors' conceptions of doctoral purpose to be viewed on a spectrum ranging from purpose being focused on preparing knowledge workers to purpose as preparing stewards of the discipline. Similarly, supervisors' reported educational practices can be conceptualised on a spectrum of educational practices focused on preparing knowledge workers to focused on preparing stewards of the discipline. To help visualise this, a managerial grid is drawn up in order to 'chart' supervisors and their 'zones' in terms of their conceptions of doctoral purpose and reported practices. Next, the emergent theme of Academic Career Privileging is reviewed and substantiated, given the relevant literature, and the implications of the findings from Stages One and Two of the analysis are discussed. A Supervisory Framework has been developed to help address these implications.

6.1 Alignments and Disconnects between Supervisors' Conceptions of Purpose, Reported Practices, and Reported Measures of Evaluation

The Findings chapter concluded with a final observation about the disconnects and alignments between supervisors' conceptions of purpose, reported practices, and reported measures of evaluation. For example, even though supervisors in the 'Person' category had thought of the purpose of the chemistry PhD as developing the candidate's knowledge, skills, and attitudes (both for indefinite purposes and for jobs), their reported practices did not align with this, and

they were largely preparing students for academic work. This constitutes a disconnect between conceived purpose and reported educational practices. On the other hand, supervisors in the 'Product' category thought the purpose of the chemistry PhD was about executing research and producing knowledge, and their reported practices very much aligned with this. This constitutes alignment. Finally, supervisors in the 'Person & Product' category provided conceptions of doctoral purpose in chemistry that spanned both of the previously mentioned conceptions, except that despite this, their reported practices also tended towards ensuring their students were equipped for academic work. This constitutes a disconnect. These disconnects also manifested across supervisors' evaluation practices where, despite participants reporting seeing their graduates employed as a chief marker of success, their reports of not following up with graduates to gauge what aspects of the program had both facilitated and constrained these employment outcomes stood at odds with these claims.

In the following sections, the discussion will focus on the relationship between supervisors' conceptions of doctoral purpose in chemistry and their reported educational practices. Their reported measures of evaluation will be revisited to provide further context to the discussion. The conceived purposes and reported practices of supervisors in the sample can be seen across two dimensions: one dimension relating to conceived purpose, the other, reported practices. However, to understand these dimensions better, a number of definitions will need to be expanded and nuanced first.

6.2 'Person' relates to the Knowledge Worker doctoral paradigm as 'Product' relates to Stewards of the Discipline doctoral paradigm

For the purposes of this discussion, the shorthand words of 'Person' and 'Product' that have been used in the Findings chapter and up until this point need to be related back to the doctoral paradigms of Knowledge Work and Stewards of the Discipline. This needs to happen in order to be able to proceed with a nuanced discussion in this chapter. A reminder that the literature review for this study synthetically established that when the scholarly debates talked about doctoral purpose as developing the person, this correlated with meanings such as developing the candidate, training the candidate, developing their knowledge, skills, attitudes, making sure they are employable, making sure they have generic/soft/employability skills, and that this is associated under the doctoral paradigm of preparing knowledge workers for the knowledge economy. When the debates talked about doctoral purpose as about the product, this correlates with meanings such as producing a thesis, a focus on the research, a focus on developing knowledge, expanding the boundaries of the discipline, a focus on the artefacts of

research, and that this is associated with the paradigm of preparing stewards of the discipline, which has been the historically dominant paradigm that has underpinned doctoral education. The latter has happened through the process of socialisation in which the doctoral candidate, during the period of candidature, acquires and internalises the values, norms, and ways that would make them accepted and part of that discipline, and consequently, ensuring the sustenance, maintenance, and reproduction of the discipline. A reminder that in this thesis, I have argued that despite the doctoral paradigm of 'stewards' of the discipline appearing to be concerned with the person or the student, at the heart of it, however, it is actually focused on the knowledge produced – the product – that keeps disciplines alive and relevant. Therefore, when discussing stewards of the discipline in this thesis, the term should not be conflated nor confused with the doctoral paradigm concerned with 'Person' or the student. These important concepts of socialisation, stewardship, and knowledge work in doctoral education are revisited below.

6.3 Recapping Stewardship, Knowledge Work, Socialisation

6.3.1 Socialisation

Socialisation is the process through which an individual gains the knowledge, skills, attitudes, characteristics, and the habits of mind necessary to function and be part of a social group, community, culture, or organisation (Bragg, 1976; Merton & Reader, 1957). In terms of doctoral student socialisation, the duration of candidature is a period of socialisation for students in which they learn the rules, norms, and values of what it means to carry out research and be an academic within their chosen disciplines (Austin, 2009).

Weidman, Twale, and Stein (2001) put forth that students pass through several stages as they are socialised from novice entering the program, to the final stages in which the student fuses and internalises the rules, norms, and values that are specific to the culture of that discipline (Gardner, 2008).

In the literature review, it was argued that supervisors, through their socialisation and apprenticing practices, are an important 'cultural reservoir' of the discipline, and perhaps arguably the "most powerful socialization agents of doctoral students" (Fogarty & Jonas, 2010, p. 304).

6.3.2 The Doctoral Paradigms of Stewardship and Knowledge Workers

Based on the literature review, debates on the purpose of doctoral education could be distilled into the question 'Is the doctorate about the product, that is, the research, the thesis, the knowledge contribution… or is it about the person, that is, the student, the development of the student, and so on?' The literature review highlighted this tension in great detail, particularly in section 2.2.2 of the review in the discussion on arguably the two most prominent paradigms for doctoral purpose that have featured strongly in both associated debates and doctoral program design: Stewards of the Discipline and Knowledge Workers.

Under the stewardship model, the answer to the question "What is the purpose of doctoral education today?" is to produce "stewards of the discipline" (Golde & Walker, 2006, p. 5). Stewards of the discipline act as 'guardians' of the discipline and its knowledge. They conserve, replenish, and help reproduce their discipline through the socialisation processes. They are stewards, *of the discipline*.

Under the knowledge worker paradigm, doctoral purpose shifts from its traditional role in producing stewards of the discipline to producing knowledge workers who must grapple with an economic reality where knowledge becomes a commodity that needs be effectively managed and locked into systems and processes that enhance innovation and development. This move treats a doctoral graduate's knowledge, skills, and attitudes as valuable assets in the workforce. Unsurprisingly, these assets are placed squarely in the focus of employability agendas. Under this paradigm, doctoral graduates will need to demonstrate flexibility, creativity, and collaboration with both academic and non-academic sites of knowledge production, extending beyond the boundaries of their own disciplines (interdisciplinarity).

Boud and Lee (2009) argue that while the PhD had traditionally been the training ground for 'stewards of the discipline', the knowledge economy environment detaches the focus of the PhD from producing stewards, to producing knowledge workers who are flexible researchers possessing both specific and 'generic' knowledge and skills.

6.4 Charting the Positions of Supervisors

Having cast socialisation theory and the paradigms of stewardship and knowledge worker onto the findings, it is important to attempt to visualise this interpretation. It is evident that the paradigms of doctoral stewardship and knowledge workers can be seen in two dimensions: in one dimension (the X-Axis), a conceived purpose continuum spanning from Knowledge

Worker Purpose to Stewardship Purpose, and in the second dimension (the Y-Axis), a reported practices spectrum ranging from Reported Knowledge Worker Practices to Reported Stewardship Practices. Using the *Managerial Grid* developed by Blake and Mouton (Blake & Mouton, 1964 as cited by Gatfield, 2005 and Kane, 2014), the X-Axis can represent the dimension of [intended] conceived purpose while the Y-Axis can represent the dimension of reported practice. Supervisors can then be charted based on the overall categorisations of 'Person', 'Product', and 'Person and Product' to give an overall qualitative tool for comparison:

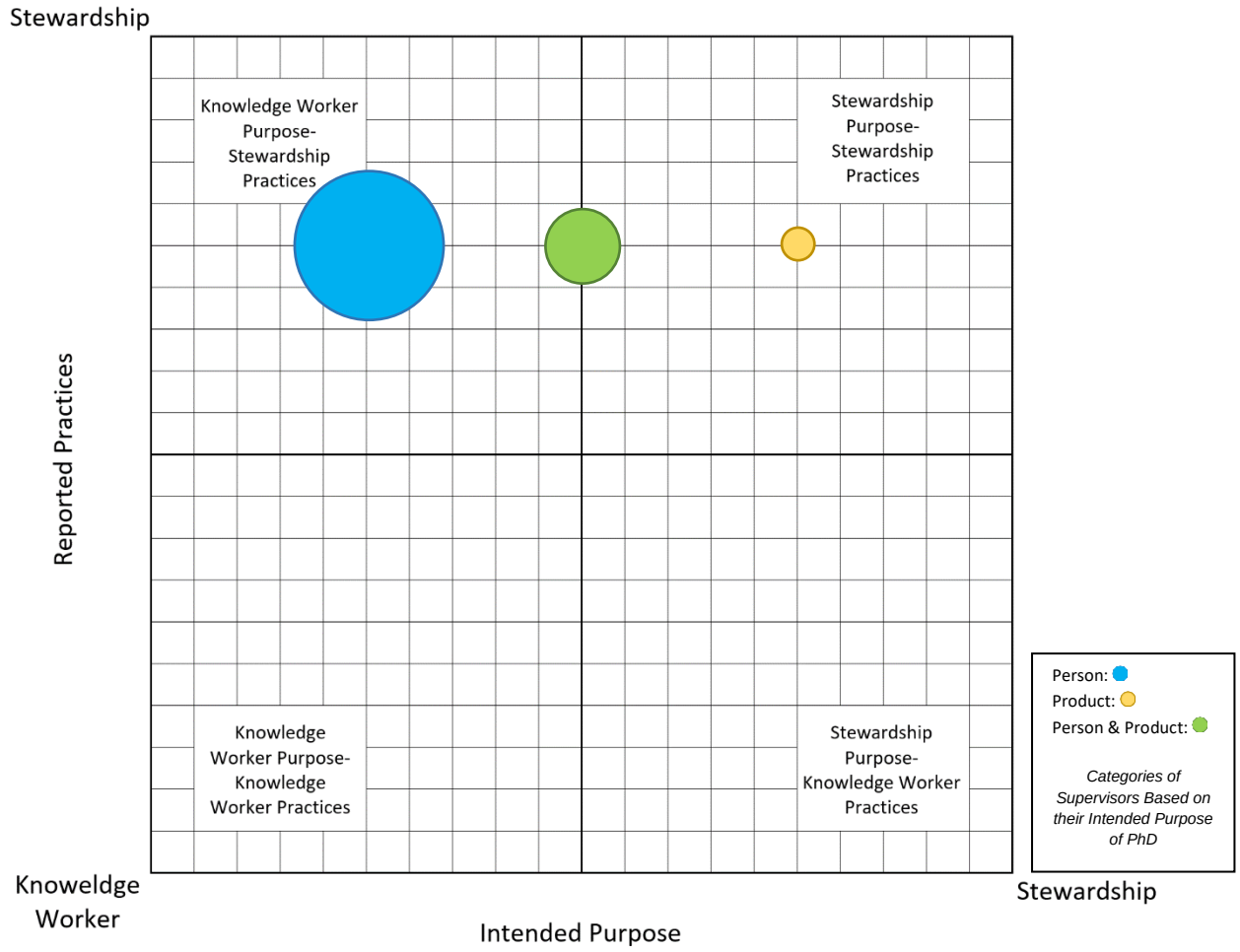

Figure 6-1 Charting the Positions of Chemistry PhD Supervisors Based on Conceptions of Purpose and Reported Practices

The circles represent the different groups of supervisors based on their conceived doctoral purpose in chemistry. The blue circle represents the cluster of 18 supervisors who conceived the purpose of the chemistry PhD as developing the candidate in terms of their knowledge, skills, and attitudes (both in a general sense and for the purposes of acquiring work). The yellow circle represents the group of four supervisors who conceived the purpose of the chemistry doctorate as being focused on conducting research and associated activities relevant

to it such as the creation of knowledge. The green circle represents the cluster of nine supervisors whose conceptions of doctoral purpose covered both of the conceptions above. The different colours were intended to help represent the differences in conceptions of doctoral purpose: Blue for the 18 supervisors under 'Person', yellow for the four supervisors under 'Product', and green for the supervisors under 'Person and Product' to try to visually capture the mix of conceptions for this group.

Further, the size of circles relative to each other was considered. The number of supervisors in the clusters of 'Person', 'Product', and 'Person & Product' can be represented as a ratio of 18:4:9. By dividing each of these values by nine and simplifying the ratio to 2:0.4:1, this allowed the circles to be drawn with those respective diameters in centimetres, aiding in the visual representation of the number of supervisors in the sample.

The position of the circles is determined based on the supervisors' intended conceptions of doctoral purpose of chemistry and their reported practices. The 18 supervisors who intended a conception of doctoral purpose relating to developing candidate knowledge, skills, and attitudes (the shorthand 'Person' category) were in alignment with the knowledge worker paradigm, and were located on the left side of the X-Axis. However, their reported practices were disconnected from their intended purpose, and strongly tended towards the development of stewards of the discipline, and were thus plotted on the top half of the Y-Axis in blue. On the other hand, the group of four supervisors who conceived the purpose of the PhD in chemistry as being about the execution of research and the creation of knowledge, aligned with the stewardship paradigm on the right-hand side of the X-Axis in terms of intended purpose (the 'Product' label). Their reported practices coincidentally align with their intended conceptions of purpose and are plotted on the top half of the Y-Axis in yellow. Finally, the nine supervisors whose conceptions of doctoral purpose covered both of the previous conceptions were plotted in the middle of the X-Axis in an attempt to represent that mix. Though, once again, their reported practices did not largely align with their intended conceptions of purpose, which is why they too are plotted on the top half of the Y-Axis, representing reported stewardship practices, in green (the original shorthand label of 'Person and Product').

It is necessary to openly clarify that the above chart is simply an aid to help visualise the findings more easily. As with all models, it comes with inherent limitations. Positioning the clusters on the X-Axis posed some challenge. For example, for supervisors whose conceptions of purpose fell in line with the knowledge worker doctoral paradigm, these were located on the

left-hand side of the X-Axis. But how left is left? Similarly, supervisors whose conceptions of purpose fell into the doctoral paradigm of stewardship were plotted on the right-hand side of the X-Axis. Again, how far right should they be plotted? At an individual level, some supervisors appeared to be more strongly anchored in their views than others. It is difficult to graphically represent this, and is not the point of this exercise. Instead, the circles need to be seen as 'zones' in which these supervisors reside and resonate. The same applies to positioning supervisors in terms of their reported practices. At the individual level, some supervisors, for example, did encourage their students to work in industry. This could be plotted on the lower half of the Y-Axis towards knowledge worker practices. But their reported practices, when considered as a whole, do not position them there and need be located as per this graph.

This leads to the final, and perhaps more important point which is that regardless of their conceived purposes, the reported practices of supervisors in this sample tend strongly towards stewardship. There is something more deeply ingrained steering the reported practices of supervisors than what is being expressed. Socialisation theory within the discipline could offer an explanation, suggesting that these supervisors' reported educational practices have been ingrained within them as they were, throughout the time and processes of doctoral candidature, enculturated and moulded to fit into the norms, rules, and values of the discipline of chemistry. Maybe they intend and wish to supervise their students as per their reported conceptions, but have fallen into the modes of supervision and educational practices learnt from their supervisors, cultivated and fine-tuned over many years by their discipline. From the perspective of socialisation theory, this is indicative of supervisors acting as the 'cultural reservoirs' of the discipline – ensuring the next generation of candidates have the knowledge that enables them to become the gatekeepers of the discipline – without necessarily being aware of this. There is also always the possibility that a supervisor provided self-censored views in terms of their conceptions of doctoral purpose, but reported a contradictory account of their practices and potentially exposed their inner-most views of what they think a PhD in chemistry should be about.

The graphical illustration here is a visual aid as part of the wider ensuing discussion on positioning supervisors in relation to the contemporary debates on doctoral education, and the possible implications of this for the discipline of chemistry.

6.5 Academic Career Privileging

In Stage 2 of the Findings chapter, the emergent theme, which I term Academic Career Privileging, was explored. The emergence of this theme followed preliminary data analysis of the first 13 interviews in this research, where it was observed that some supervisors held preferential views towards academic careers and considered them superior to other career pathways. Based on the inductive and subsequent interview data analysis, three main themes were formed: Default Expectations for Academic Careers; Shepherding 'Bright' Students into Academia; Student Guilt and Supervisory Disappointment.

Default Expectations for Academic Careers referred to a behaviour whereby a supervisor assumed and expected that their students would become academics by default. Some supervisors in the study reported, often in a critical manner, other supervisors behaving this way with their own students. In other instances, this behaviour was observed in the reported practices of some supervisors in this study. Shepherding 'Bright' Students into Academia captured the situation in which some supervisors reported steering students who they deemed as 'bright' into academic careers. Finally, Student Guilt and Supervisory Disappointment captured the reported instances of student guilt for not becoming academics, and the associated disappointment of the supervisor.

Following this analysis, it was necessary to examine and further substantiate these emergent findings against any existing literature.

6.5.1 Examining the Literature on Doctoral Shame and Failure

It was previously argued in this thesis that the doctorate has been in a 'tug of war' over its purpose. The traditional purpose of the doctorate was to "license scholars to profess a discipline" (Boud & Lee, 2009, p. 2), including ensuring replenishing and maintaining the reserves of scholars to continue the production of disciplinary knowledge. The doctoral paradigm of stewardship ensured that supervisors and program convenors were "reproducing the ways in which they themselves were inducted into their discipline" (Boud & Lee, 2009, p. 11). Under this paradigm, the central goal of the doctorate is in the "reproduction, maintenance and transformation of disciplines" (Boud & Lee, 2009, p. 2). However, the economic and political shifts that have repositioned the doctorate are in tension with the aforementioned older doctoral practices of disciplinary enculturation and knowledge making. In fact, the knowledge economy environment has detached the focus of the PhD from producing stewards

of the discipline to producing knowledge workers armed with skills and knowledge for this workforce (Boud & Lee, 2009).

Nevertheless, the preparation of stewards of the discipline has arguably underpinned much of doctoral education thinking and practice. From the perspective of socialisation theory, the paradigm of doctoral stewardship has been historically and culturally embedded in the practices of supervisors and doctoral program coordinators. Examining the literature on doctoral shame and failure, which is largely located in the US, against this backdrop provides an additional layer of depth to the discussion.

In 2015, Nerad (2015) published her work in which she searched for taboos in doctoral education both in the US and Japan, where she found taboos in three domains of doctoral education: taboos between supervisors and doctoral students; taboos among doctoral students; and taboos among doctoral supervisors. For the purposes of this discussion, the focus will be on taboos between supervisors and doctoral students.

Nerad (2015, p. 20) explains that one theme that frequently emerged in her interviews with doctoral candidates, both in the US and Japan was that "they would not tell their advisors that they did not want to become professors". Several reasons accounted for this. Specifically, Nerad (2015, p. 20) found that:

- Did not want to be seen as 'not smart enough' to become professors.
- Feared being seen as 'less worthy', and therefore, receiving not financial support or nominations for a fellowship, or research assistantship, or teaching assistantship position in their department.
- Avoided situations in which they might be treated as 'second class citizens'. This was a reaction they feared would happen if their advising professor discovered their decision not to become a professor.
- In Japan, students stated that they did not want to be seen as failures and possible academic dropouts, if they explained that they did not want to become a professor.

These reasons particularly raise concerns given that the appeal of academic careers decreases significantly over the duration of the doctoral program, despite supervisors strongly encouraging academic careers over non-academic ones (Roach & Sauermann, 2017; Sauermann & Roach, 2012).

In Sauermann and Roach (2012), a survey of over 4,000 graduate students across the life sciences, physics, and chemistry at 39 tier-one US institutions found that students stated that the faculty research career was by far the most often 'strongly encouraged' career while other careers were less encouraged, with a few students even feeling certain that other careers were explicitly discouraged, mostly careers in teaching and industry. Furthermore, "even in chemistry, where industry careers are very common and where students express a strong interest in industry careers, students feel that research careers in academia are much more strongly encouraged" (Sauermann & Roach, 2012, p. 4). The authors commented that strong encouragement of academic careers may be dysfunctional if it worsens already existing workforce imbalances or causes students anxiety if their "career aspirations do not live up to the expectations of their advisors" (Sauermann & Roach, 2012, p. 5). They raised concern that this could stall student career exploration, raising the need to allow students the time to discover different career pathways, as well as creating an open environment that accepts and values non-academic career paths (Roach & Sauermann, 2017).

This theme of academic career privileging in the literature is further explored by Brownell and Tanner (2012) where they discuss barriers to faculty pedagogical change in the sciences. Here, academic career privileging is compared in relation to teaching identities. The authors note that scientists are trained in an environment "that defines their professional identities primarily as research identities to the exclusion of teaching identities" (Brownell & Tanner, 2012, p. 341). Furthermore, "not only is teaching not a formal or recommended component of postdoctoral training, some faculty advisors even view teaching as completely ancillary to, and a distraction from, the training that postdoctoral scholars need, ostensibly to become professors" (Brownell & Tanner, 2012, p. 342). The authors point out that some doctoral students have advisors who do not allow them to participate in activities outside of the laboratory, with some advisors being of the mindset that students must never leave the work bench (Wulff, Austin, Nyquist, & Sprague, 2004 as cited by Brownell & Tanner, 2012).

These practices can result in a student's internal conflict with the fear that their desire to embark on a teaching career could risk their status within the scientific community and that they may not be considered 'real' scientists. Correlating this with socialisation theory, "these actions might even be subconscious, a natural result of years of being surrounded by other faculty who view research as superior to teaching and hearing the age-old adage "'those who can, do; those who can't, teach'" (Brownell & Tanner, 2012, p. 343).

Academic career privileging, especially over teaching careers, is further highlighted by Connolly (2010) in which interviews with doctoral students who self-identified as college teachers found that they felt that confessing an interest in teaching would put their careers at risk, regardless of their research proficiency. This led to some of them "overemphasizing their genuine interest in research to pass themselves off as the kind of laser-focused doctoral students that advisors tend to favour" (Connolly, 2010, p. 3). Furthermore, those who divulged an interest in teaching with their advisors were confronted with a range of reactions. Despite some advisors being enthusiastic, it was more common for them to have mixed feelings about this, demanding that teaching-related activities were allowed so long as they did not clash with the student's research productivity. Some advisors felt that an interest in teaching to be a "tacit repudiation of the advisor's research agenda" (Connolly, 2010, p. 3), while others disowned their students who accepted jobs at teaching-focused institutions. These findings connect well with those of Nerad (2015), and almost present themselves as outcomes of some of the student concerns and worries presented in her research.

Feelings of failure are also described by Whelan (2016), in which she tackles and explains the different kinds of failure she had experienced in her PhD:

> If you do not get an academic job, you are often made to feel like a failure. In a sense, there are two types of "failures" here: the first is the feeling of failure for those actively trying to get an academic job, but who are having to temporarily work elsewhere to pay the bills; second is the feeling of failure for those who actively reject the academic career path as they are seen to have failed to follow the conventionally expected route… Undertaking a PhD does not automatically mean that you will be a professor or researcher, nor that you want to be. That traditional train of thought needs to be broken.

She adds that universities need to manage the expectations surrounding post-PhD careers by promoting and supporting the variety of career pathways PhD graduates embark upon, whether by circumstance or by choice.

This section of the discussion chapter has discussed the emergent theme of Academic Career Privileging in light of the literature on doctoral failure and shame. The reviewed literature points to the default expectations and the taken-for-granted assumptions in academia that a PhD should lead to an academic job and that students should be encouraged to do so, as well as the stress and anxiety experienced by students who do not wish to follow this path. Student experiences of failure and rejection in relation to this were also evident. Overall, the reviewed

literature supports and substantiates the emergent theme of Academic Career Privileging in this study. The following section will discuss the implications of these findings in relation to the sub-research questions that have guided the research project.

6.6 Implications

This research project aimed to understand a) the conceptions of doctoral purpose held by chemistry doctoral supervisors in Australia and b) how supervisors' reported educational practices relate (or not) to their conceptions of doctoral purpose. Supervisors interviewed in this study provided conceptions of doctoral purpose that aligned with the development of graduates as knowledge workers equipped with the knowledge and skills for broad career pathways. But their reported practices show a strong tendency to socialise students into becoming stewards of the discipline. What are then the implications of this, given that cotemporary debates on doctoral purpose and practice have shifted towards developing knowledge workers as described previously? What could this mean for heads of chemistry departments or HDR convenors keen on ensuring the best doctoral education experience for their chemistry students going into the future?

In addition, the sub-research question: 'What knowledge and skills do they ensure their students have upon graduation?' guided the research into the more specific aspects of supervisors' reported educational practices. Based on the reported findings as outlined in Chapter 5, supervisors appear to be primarily developing the disciplinary knowledge of their students (or Mode 1 knowledge). This means that students are more likely to exit their degrees with the requisite content knowledge to carry out further research within their field of specialisation, such as an advanced understanding of chemistry reaction mechanisms or molecular orbital theory. However, the work environment in which graduates are likely to find themselves requires a breadth of knowledge not usually covered by the specialised research practices traditionally covered under the paradigm of doctoral stewardship. This could give other graduates with wider knowledge bases a competitive edge in the employment market in terms of both the capacity to gain jobs as well as job performance. Chemistry departments will need to consider the implications of this as they try to market their programs to prospective students in terms of employability.

Similarly, supervisors tend to largely focus on developing student skills closely related to academic work, based on their reported comments. This means that a chemistry PhD graduate will probably demonstrate proficiency in disciplinary skills such as experimental research,

bench work, mathematical, and computational skills. Mastery of such disciplinary skills will be crucial for academic research to continue in these sub-disciplinary areas, provided the graduate remains working in academic and disciplinary research. For graduates leaving academia and entering the wider workforce, broader skill sets will be valued. Some of those broader or 'generic' skills would have been developed through the course of the doctoral program and even before that during undergraduate study. Nevertheless, the literature review on skills and skills transferability signalled the need to be aware of the contextual nature of skills development. A PhD graduate in chemistry would have developed a high level of written and oral communication skills as a result of writing their thesis and presenting at different seminars and conferences, presumably. Then again, the thesis is an academic piece of writing, with accepted norms and rules of writing, for a chemistry audience, with accepted disciplinary norms and conventions of language. And to be socialised and accepted into becoming a licensed chemistry researcher means adhering to these norms and conventions. This does not mean that these skills cannot be transferred to new environments. It just means that transferability might not necessarily be immediate, and the skills will need to be reworked and honed depending on that new environment.

The research study also aimed to understand if supervisors encouraged their students to reflect upon contemporary issues pertaining to the discipline of chemistry. As outlined in the Findings chapter, several supervisors in the study reported that they did not specifically engage their students in reflecting upon the ethical, social, political, and economic issues pertaining to the discipline. When reflective practice reportedly did take place, supervisors seemed to mainly engage their students in reflecting upon the potential applications of their research. In the context of student development, this is a more favourable practice than no reflection at all. However, it does raise the question of the student's, or rather, graduate's capacity for reflection on issues unrelated to chemistry research or research altogether. Complex problems in the workplace will be multi-varied and are likely to intersect multiple disciplines. In designing chemistry doctoral programs, these issues need to be considered.

It was also important to understand whether supervisors encouraged their students to experience work during their degrees. Based on their responses, supervisors appear to strongly encourage their students to work as laboratory demonstrators and tutors. Positive outcomes from this could be enhanced oral communication skills, bearing in mind the issues raised on skills transferability earlier. But the sites of work experience are limited. Predominantly encouraging academic work experience during the course of the doctorate can constrain the

range of experiences and exposure to different work environments such as industry, government, and other workplaces.

Further complicating these issues is the reported lack of local adequate, systematic graduate follow-up and feedback mechanisms on career outcomes that can help with supervisory reflective practice, as guided by the sub-research question: 'How do chemistry PhD supervisors evaluate their success in terms of follow-up on graduate career outcomes?' A number of supervisors claimed that they wanted to see their students employed, yet they were not following up to see how and what they were doing as supervisors was contributing or hindering this from happening. Unless there is some systematic and formal way of reflecting and learning from chemistry alumni of the strengths and weaknesses of the doctoral experience in relation to career preparation, as discussed in Section 2.6.3 of Chapter 2, then supervisors and departments will be hugely constrained in terms of evaluating and improving their practices.

In addition to all of this, the default expectation and encouragement of some supervisors of pursing academic careers, while making students who do not want to become research academics feel guilty and having 'failed' as shown in the emergent theme of Academic Career Privileging and substantiated by the reviewed literature, arguably pushes supervisory practices even further towards preparing stewards of the discipline. This is concerning, given the resounding argument that the knowledge economy environment has shifted the focus of the doctorate from producing stewards to knowledge workers armed with the depth and breadth of knowledge and skills required to tackle today's complex problems.

Finally, in providing the answers to the guiding sub-questions, this section addresses the gaps in the literature outlined earlier in the thesis, and delivers a newfound understanding regarding the conceptions of doctoral purpose held by chemistry PhD supervisors in Australia and their reported educational practices.

6.7 Development Framework

One the key recommendations that came out of the ACOLA review focused on the professionalisation of research supervision in Australia through a number of mechanisms, including the provision of quality supervisory training to support the needs of supervisors, their students, and industry (McGagh et al., 2016). Following that review, several developments in that space were reported.

In 2017, Guerin et al. (2017) reported work done on mapping supervisor development programs in Australia. The results of their study found great diversity in the training programs and offerings provided to support research supervision. The study specifically found:

> … three broad kinds of supervisor development programs: those aimed at inducting staff who are new to the university and/or to supervision; sessions designed for current supervisors seeking a 'refresher' and/or to maintain eligibility to supervise; and more extended professional development with an educational focus (Guerin et al., 2017, p. A-92).

In 2018, Kiley (2021) undertook a small-scale survey of supervisory development programs of the Australian universities listed on the *Universities Australia* website (Universities Australia, n.d.). Results showed that over 90% of respondents had a supervisory register listing academic staff qualified to supervise and provided induction programs for staff new to supervision. For over 85% of respondents, completion of development programs by experienced supervisors were required to remain on the Register, with the requirements varying from once every year to every three to four years.

In response to the ACOLA review, The Australian Council of Graduate Research, which promotes excellence in research training and scholarship in Australia, released the ACGR Guidelines for Quality Graduate Research Supervision (The Australian Council of Graduate Research, 2018). These guidelines cover key areas of relating to supervisors, including the need for university-level polices and governance to ensure supervisory best practice; evaluating supervisory performance through different institutionally based mechanisms; the establishment of a system of supervisor registration and accreditation; the provision of quality continuing professional development opportunities for supervisors; and the recognition and rewarding of supervisory best practice (The Australian Council of Graduate Research, 2018).

In the previous section, the discussion of the implications of the findings raised concerns regarding the strong tendency to towards training students into becoming stewards of the discipline despite the realities imposed by the knowledge work economy. In order to address this, this study provides, in Table 6-1, a Supervisory Development Framework informed by the work done by Guerin et al. (2017), Kiley (2021), and in line with the ACGR guidelines:

Table 6-1 Table Supervisory Development Framework

Overarching theme	Examples of Content Covered
Doctoral Purpose	Coverage of conceptions of doctoral purpose such as 'Stewards of the Discipline' and 'Knowledge Work'.
Contemporary Doctoral Educational Practices	Coverage of kinds of knowledge and skills required for post-PhD employment. Examples internships and interdisciplinary discussion spaces can be drawn from APR Internships and *ANU's Conversations Across the Creek.*
Post-PhD Employment Trends	Coverage of post-PhD employment trends and figure. Examples can be drawn from latest research from QILT and Office of the Chief Scientist.
Academic Career Privileging	Coverage of Default Academic Career Expectations; Shepherding of Bright Students; Doctoral Shame, Guilt, and Supervisory Disappointment.
Examples of Doctoral Success Beyond Academia	Participation in events such as *'PhD to Present: a day dedicated to the career pathways of those who have gone before* you'; conferences such as *'Beyond Academia Conference'*; and exploring UK's Vitae various resources on the different careers of researchers.

The idea of the Supervisory Development Framework would be to extend and evaluate existing frameworks to include 'top-level' overarching themes or topics that would stimulate and encourage supervisors to think about their role and their work in novel and unprecedented ways, providing 'points of inflection' to positively challenge preconceived and taken-for-granted notions about the research doctorate and research supervision. These could be delivered online or face-to-face, for new or current supervisors, and could include overarching themes on Doctoral Purpose; Contemporary Doctoral Educational Practices; Post-PhD Employment Trends; Academic Career Privileging; and Examples of Doctoral Success Beyond Academia.

Under the theme of **Doctoral Purpose**, paradigms that have underpinned conceptions of doctoral purpose such as 'Stewards of the Discipline' and 'Knowledge Work' can be introduced to supervisors.

The theme of **Contemporary Doctoral Educational Practices** could include coverage of the different types of knowledge and skills expected of PhD graduates entering today's workforce. These can be drawn from the multitude of scholarly resources available online.

Examples of internships such as APR Internships can be included. APR.Intern provides hands-on experience for PhD students in an industry setting for three to five months where students can apply their theoretical knowledge and disciplinary skills while learning to navigate the

non-academic workplace and its associated challenges, bridging the gap between industry and academia (Australian Mathematical Sciences Institute, 2020). These internships could be incorporated into doctoral programs, including chemistry doctoral programs, enriching the student learning experience while also providing academics with collaborative opportunities with industry.

Examples of interdisciplinary discussion spaces could be included, such as ANU's Conversations Across the Creek:

> Conversations Across the Creek is an initiative by the Humanities Research Centre (HRC) and the Research School of Chemistry (RSC) to provide a space for continuing dialogue among scientists, social scientists, and humanities scholars. The aim of the meetings is to stimulate and unearth research and teaching collaborations across the university (The Australian National University, n.d.).

Presenting at such events could give a chemistry student the chance to rethink their communication skills in light of an interdisciplinary audience. A student could be directed to the various communication training opportunities available at their university, such as through Science Communication at The Australian National Centre for the Public Awareness of Science (CPAS) or the ANU Researcher Development Team.

Under the theme of **Post-PhD Employment Trends**, coverage of post-PhD employment realities, trends, and figures can help simulate some the points of inflection identified in this study. These can be drawn from the Quality Indicators of Learning and Teaching (https://www.qilt.edu.au/) and the Office of the Chief Scientist (https://www.chiefscientist.gov.au/).

The theme of **Academic Career Privileging** can help raise awareness about assumptions that some supervisors might hold about what comes after a PhD; the shepherding of bright students into academia; and topics such as doctoral shame, guilt, failure, and supervisory disappointment.

Finally, **Examples of Doctoral Success Beyond Academia** provides three examples of events from Australia, the US, and the UK in three different formats (face-to-face, online virtual, and Twitter chat) that can help supervisors develop better awareness and recognition of the multi-faceted career pathways that exist outside of academia.

'*PhD to Present: a day dedicated to the career pathways of those who have gone before you'* was a face-to-face event organised in 2014 by the ANU Researcher Development Team (Eventbrite, 2014). The aim of the event was to raise the awareness of PhD students regarding the different career pathways that can be forged with a PhD, by inviting talks from doctoral graduates who have entered the public service, consultancy, and politics and parliament such as Dr Adam Bandt, MP and the Hon Dr Andrew Leigh, MP. Despite being aimed at PhD candidates, this could be revived and re-pitched for PhD supervisors. This is an example of one approach that can not only raise awareness of the different career pathways that can follow from a PhD, but also provide the opportunity to discuss and reflect upon how the PhD had best prepared, and could have better prepared, these people for their chosen careers.

Supervisors can also participate in conferences such as the 'Beyond Academia Conference' run by Beyond Academia in order to better support their understanding of post-PhD careers. Beyond Academia is a not-for-profit organisation run by UC Berkley graduate students and postdoctoral fellows that aims to expand the career trajectories of its students and postdoctoral fellows beyond the traditional academic track through conferences, workshops, and tutorials (Beyond Academia, 2021). Specifically, the 'Beyond Academia Conference' is a free and fully virtual event that brings around 100 PhD speakers who made the successful transition into non-academic careers across both HASS and STEM disciplines, to share their experiences and help students recognise how their skills and knowledge translate to non-academic careers (Hopin, 2021).

Lastly, UK's Vitae offers a number of resources regarding the diversity of post-PhD careers such as infographics on career destinations by discipline, information on careers for researchers outside higher education, and researcher career stories. These resources can be used to help better inform supervisors of the breadth of career options that doctoral students undertake upon graduation (Vitae, 2021).

For all of the above themes, coverage of content could be followed up with self-reflective questions that ask supervisors as to where they might 'chart' themselves in relation to these contemporary doctoral debates and practices. In the case of the discipline of chemistry, frameworks such as the above could be adopted by chemistry Heads of Schools or HDR Convenors in order to ensure best practice in research supervision to enhance and evaluate existing programs.

6.8 Summary

This chapter of the thesis interpreted the meanings of the research findings. The chapter began by focusing on observing the disconnects and alignments between supervisors' conceptions of doctoral purpose in chemistry and their reported educational practices. In order to be able to discuss these findings, the shorthand concepts of 'Person' and 'Product' were related back to the paradigms of Knowledge Work and Stewards of the Discipline respectively. This opened up the possibility of seeing supervisors' conceptions of [intended] doctoral purpose as on a spectrum ranging from purpose as preparing knowledge workers to purpose as preparing stewards of the discipline. Similarly, supervisors' reported educational practices could now be seen spanning reported practices as preparing knowledge workers to preparing stewards of the discipline. Irrespective of their claimed or intended conception of doctoral purpose, the reported practices of supervisors in the study strongly tended towards preparing stewards of the discipline. This suggested a strong mark of socialisation 'steering' the direction of their reported practices. A simple chart was produced to help visualise the different groups of supervisors and their 'zones' in terms of their conceptions of doctoral purpose and reported practices.

The emergent theme of Academic Career Privileging was then reviewed in light of the literature on doctoral guilt and failure. Though still in its infancy, the literature provided reasonable substantiation and support for this emergent theme. The implications of this were then considered, and it was argued that Academic Career Privileging was a more extreme manifestation of the doctoral paradigm of stewardship, and could be seen as shifting doctoral purpose and practice towards that direction.

The implications of all of this were considered in terms of the employability of the doctoral candidate in chemistry and what that might mean for chemistry Heads of School and HDR Convenors wishing to take their doctoral programs into the future. Overall, the discussion of the findings and their implications in light of the reviewed literature provided sketched the profile of a chemistry PhD graduate having developed the elements for continued academic research in the discipline, but rather lacking in the enabling characteristics for work outside of the field dictated by the knowledge economy – a resounding argument in the reviewed literature. A Supervisory Framework was developed to remedy this, bolstered by international examples of best practice. It is proposed that it be used by Heads of Schools and HDR Convenors wanting to provide the best doctoral experience to candidates and to ensure excellence in research supervision, including the discipline of chemistry. This discussion

addressed the gaps in the literature argued earlier in this thesis by providing novel understanding on chemistry doctoral supervisors' conceptions of doctoral purpose and their reported educational practices in Australia.

CHAPTER 7 – CONCLUSION

In this final chapter, the research will be concluded by summarising the major work done in the project, the contribution to knowledge and practice, the limitations of the research and directions for future research, and providing some final thoughts and reflections. Summarising the research project allows the major work and key messages to be distilled and viewed from a bird's eye view. From this point onward, the contribution to knowledge and practice can be articulated, opening up the opportunity to discuss the limitations of the research while paving a path for the future. The final thoughts and reflections offer the final chance for contemplation and bring closure to thesis.

7.1 Summary of the Research

This research project focused on answering the following overarching research question:

> 'What are the Positions of Chemistry PhD Supervisors in Australia in Relation to Contemporary Debates and Practices in Doctoral Education?'

...by answering the following sub-research questions:

1. What are the conceptions of doctoral purpose held by chemistry doctoral supervisors in Australia?

2. How do their educational practices relate (or not) to their conceptions of doctoral purpose?

3. How do chemistry PhD supervisors evaluate their success in terms of follow-up on graduate career outcomes?

After reading and analysing the relevant research literature to define the questions for the interviews and the major themes for analysis, this study undertook semi-structured interviews with 31 chemistry PhD supervisors in Australia. Deductive and inductive analysis of the interview responses was conducted. Based on this analysis, and further consultation of the literature, the following conclusions have been reached:

The majority of chemistry PhD supervisors interviewed believed the purpose of the PhD in chemistry was to develop the candidate's knowledge, skills, and attitudes, with a minority believing that the purpose was to conduct research and pursue the creation of chemical knowledge. With the majority of respondents, their conceptions of doctoral purpose appear to

have shifted, to varying extents, from the traditional purpose of the PhD that sought to socialise and produce 'stewards of the discipline' whose main role was to keep the discipline alive, by ensuring the maintenance and replenishment of its reservoirs of knowledge. Despite this, however, the reported practices of these supervisors show a strong tendency in preparing the aforementioned 'stewards', who are being set up to continue in the knowledge production practices needed for disciplinary longevity. These issues are further complicated by supervisors not adequately following up with their graduates in terms of their career outcomes, despite them indicating that they considered graduate employment as one measure of supervisory success. Besides these disconnects, there is evidence, both from the data and the literature, that non-academic jobs are considered by some to be ancillary to the academic research career. This suggests a strong element of socialisation at play, producing these taken-for-granted assumptions and practices.

If the reported practices of supervisors tend strongly towards preparing students to become stewards of the discipline, what does this mean for doctoral students heading towards an employment reality that focus on knowledge workers whose knowledge and skills are considered economic assets?

7.2 Contribution to Knowledge and Practice

This research sought to chart the positions of chemistry PhD supervisors in Australia in relation to contemporary debates and practices in doctoral education. What appears to be the case from the data is that despite their conceptions of doctoral purpose, supervisors' reported conceptions of doctoral practice tend strongly towards stewardship. The main scholarly contribution this thesis makes is in initiating the much needed debates and discussions about doctoral education within the discipline of chemistry. Specifically, it provides newfound literature on the conceptions of doctoral purpose held by chemistry PhD supervisors in Australia, including the relationship between their conceptions of doctoral purpose and their reported educational practices, in light of their follow-up on graduate career outcomes. In so doing, the thesis provides an understanding of the positions of chemistry PhD supervisors in Australia in relation to contemporary debates and practices in doctoral education. These debates and discussions are also needed in order to not only critically reflect about the role and influence chemistry PhD supervisors have in the education of future chemistry PhD candidates, but also to critically contemplate the purpose and the contribution of the chemistry doctorate in relation to the labour market and broader society. In so doing, the

research also contributes to bolstering and improving the state of science education in Australia, assisting in STEM initiatives such as the *National Innovation and Science Agenda*.

Section 7.1 concluded by posing a question about the implications of current reported supervisory doctoral practices on students heading towards the knowledge work environment. From a practical standpoint, this thesis offers a Supervisory Development Framework aimed at providing the 'trigger points' for novel (re-)thinking about the PhD and doctoral supervision. The framework covers a number of overarching themes with respective examples.

7.3 Limitations and Future Research Directions

It is important to acknowledge the limitations of this study. First, the study is located within the boundaries of the discipline of chemistry. While the findings here may translate well to other disciplines such as physics or biology, they may not translate as well to other disciplines located within the social sciences and humanities where the structure of supervision is different (for example, the 'research group' structure in chemistry with a group leader is usually not a feature within HASS supervision) and with cohorts of students who are generally more mature-aged. This study was anchored within the qualitative research tradition, where smaller sample sizes are acceptable for the production of detailed accounts of cultural phenomena. The sample size was adequately suitable to produce the cultural insights it has produced, and would benefit from a larger sample size in which finer analysis related to issues such as the gendered nature of responses, given the male-dominated structure of chemistry, could be undertaken. The emergent theme in this study, which I termed Academic Career Privileging, would benefit from further critical exploration, within chemistry, STEM, and HASS. Possible partnerships with the RACI, the Academy of Science, and university alumni offices could potentially allow for broader quantitative studies with large sample sizes. Longitudinal studies with supervisors could be done to track changes in their conceptions of doctoral purpose in chemistry over time, including their attitudes towards academic and non-academic careers.

7.4 Final Thoughts and Reflections

I had underestimated the difficulty in writing this section, despite it being perhaps the most personal. Completing a PhD is a difficult task, let alone if you are coming from a background in chemistry and science communication, into a PhD in the social sciences. The learning curves that I had to surpass were immense. Add to that the challenges that life throws at you. This year, 2020, alone has given us the Canberra bushfires, hailstorms, the COVID-19 pandemic,

and a recession. However, these challenges have made me appreciate that I have had the opportunity to study and experience learning across the physical and social sciences. I appreciate the breadth and depth of knowledge and skills I have gained. And with this in mind, I look forward to placing my knowledge and skills into practice and tackling whatever problems I face ahead. In these past five years, I have gone through the most challenging learning experience of my life. I came into this PhD wanting to learn; to learn at the most sophisticated academic level possible. And I can happily say that learnt, I have.

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APPENDIX A – INTERVIEW QUESTIONS

1. What got you into the discipline of chemistry?
2. What branch of chemistry would you describe yours to be?
3. What are the roles that you play here at this university?
4. Would you happen to know the ratio of men to women chemistry academic staff at your university?
5. For how long have you been a group leader?
6. How many PhD students have you supervised to completion? As a primary supervisor? Over the length your career?
7. What do you think is the purpose of a chemistry PhD?
8. How do you know that you have succeeded as a supervisor with your students?
9. What knowledge do you ensure your students have when they graduate?
10. What skills do you ensure your students have when they graduate?
11. Do you encourage your students to reflect about the discipline of chemistry in the broader scheme of things? (e.g. the ethical, social, economic, & political issues pertaining to the discipline of chemistry?)
12. Do you encourage your students to get work experience, paid or unpaid, during their PhD? (e.g. tutoring, university admin, industry, government?)
13. Where are your chemistry PhD graduates employed?
14. Have your PhD graduates ever reported how their PhD, or aspects of it, have best prepared them for the careers they have chosen?
15. Conversely, have your PhD graduates ever reported how their PhD, or aspects of it, could have better prepared them for the careers they have chosen?
16. How have you addressed that?

17. In light of talking about careers, what kind of career expectations did your supervisor have of you?

18. What kind of career expectations do you have of your students?

19. Is there a question I should've asked you?

APPENDIX B – INTERVIEW TRANSCRIPT

The following transcript has been constructed from six different interview transcripts in order to better preserve the confidentiality of the data, while reflecting the overall questions posed.

What do you think is the purpose of a chemistry PhD? (Interviewer)

I think it's a training program, like any PhD in many ways, and that's what it's become across-the-board… This is a really great training regime for being a professional in the broader sense. (Participant)

And do you think the chemistry PhD has a special purpose that sets it apart from other disciplines? (Interviewer)

No. No. And I suggest that in that sense, across Australia and indeed the world, chemistry PhD graduates do not go on to have careers as chemistry researchers. So therefore, if all it was a training (recording inaudible) to chemistry researchers, then we are training way too many of them. But these people get jobs, and it's their critical thinking, problem solving, perseverance skills that are of value to employers. (Participant)

How do you know that you've succeeded as a supervisor with your student? (Interviewer)

Every student I've ever supervised has successfully completed his or her PhD and has gained employment afterwards. Every single one of them. (Participant)

What knowledge do you ensure your students have when they graduate? (Interviewer)

A good understanding of not only their project and how it fits into scientific research, but how scientific research fits into the broader scheme of society. Development of presentation skills, which I think are key. Development of leadership skills, so I make all my students lead different things particularly in the third year of their PhD, leading group meetings, planning things. Ability to talk to different types of people, so I'm very strict on making my students talk to different people at conferences, not just talk to their friends, I make them talk to visiting seminar speakers so they can get an understanding of how to talk to professors or people who may seem more knowledgeable than them. And I also really seek to develop my students as citizens of whatever organisation they're working in. So contributing to the organisation, for

our university, it's contributing to societies, and helping support their fellow peers. Being more outward looking than inward looking. (Participant)

A lot of the things you mentioned are skills. What knowledge would you ensure your graduates have?

They're not going to graduate from a PhD if they haven't demonstrated knowledge in an area. Of course they need to understand their project, and their project is big and broad and they need to know the chemistry of it and they need to know the biology of it, I guess they wouldn't graduate if they didn't have that. (Participant)

Do you encourage your students to reflect about the discipline of chemistry in the broader scheme of things, so with regards to the ethical, social, and economic issues that pertain to the discipline of chemistry? (Interviewer)

Yes. (Participant)

In what sense? (Interviewer)

I try to encourage my students to actually listen to the news and interact with the news constantly. Constantly talking with them about aspects that have occurred, if I see an article in the paper, I forward it to them. (Participant)

Do you encourage your students to get work experience, paid or unpaid, during their PhD. So for example, tutoring, working in the university admin side of things, working in industry, or working in government? (Interviewer)

Yes, pretty much they all typically do sessional work, laboratory demonstrating and workshop facilitation and so forth. But if they wanted to do something else, yeah. There's a rule for the scholarships, where you are not allowed to work on average eight hours a week, in a given week, I talk with them about that. I have had students who have gone part-time, particularly when they've run out of scholarship money, and it worked in a variety of avenues. (Participant)

And that could include government work you say? Or industry work? (Interviewer)

Yep, yep. Yep, yep. People have worked out in all sorts of things. (Participant)

Have your PhD graduates ever reported how their PhD, or aspects of it, had best prepared them for the careers that they have chosen? (Interviewer)

I can't say any of them had ever explicitly said that. (Participant)

Implicitly? (Interviewer)

When they say they've got a job and it was because of the skills that they learnt they assumed that's because of… Actually they say that when they got the job, especially the guy that's now at [a university], he was saying it is all due to the project that we had… (Participant)

So the second question, which is the converse, have they ever reported how their PhD or aspects of it could have better prepared them for the careers that they have chosen? (Interviewer)

Not really. Because they're still in an academic university environment it is all been the same, same. (Participant)

Was there anything else that I should've asked you or anything you felt you wanted to talk about but we didn't cover? (Interviewer)

No, I think I've said everything (laughs). (Participant)

APPENDIX C – PARTICIPANT INFORMATION SHEET

Participant Information Sheet

Researcher:

My name is Rami Ibo and I am a PhD candidate at the Australian National University, Canberra. I study in the Research School of Humanities and the Arts in the College of Arts and Social Sciences.

Project Title: How Chemistry PhD Supervisors in Australia Prepare their Students for Employment.

General Outline of the Project:

This study aims to understand how chemistry PhD supervisors in Australia prepare their students for employment. Chemistry PhD supervisors will be interviewed either face-to-face, through Skype, or over the phone in order to collect the data. Invitations to participate, via the Dean/Head of School and/or myself, will be sent to an approximate total of 330 supervisors across a number of universities in Australia. Based on this, a sample of 30-60 participants will be taken that would be most suited to answer the research question. Results will be disseminated through the thesis, ANU pre-submission presentation, conferences, published journal articles, and other scholarly/academic venues. A copy of the first publication arising from the research will be sent to the participants who request one.

Participant Involvement:

Participation in this project is voluntary. You may, without negative consequences, decline to take part or withdraw from the research without providing an explanation. You may, without any penalty, decline to take part or withdraw from up until and during the interview without providing an explanation, or refuse to answer any question. You have time until the data is prepared for publication to withdraw. If you withdraw, your data will be destroyed and not used.

You will be asked to undertake either a face-to-face, Skype, or telephone interview. The interview, regardless of format, will be audio-recorded. You will only be audio-recorded if you consent to it. Recordings will be transcribed for analysis and both the primary researcher and supervisor will have access to the recordings and transcriptions. You will be asked questions

about chemistry PhD supervision, your students, and your graduates. If you are to have a face-to-face interview, this will take place either in your office or in a public space on your institution's campus. You will be interviewed once, but you may be contacted for follow-up questions or clarifications if needed. Interviews would usually go for 30-45 minutes.

The interview questions do not seek personal or sensitive information. Hence, it is highly unlikely that risks, discomforts, hazards, or side effects will be associated with the research.

At the academic level, it is anticipated that this study develops a theoretical base to build upon and further move debates in chemistry research education. At the policy level, it is hoped that this study helps better inform implementation of the ACOLA review and similar policy initiatives.

Exclusion criteria:

Only the participants mentioned above are allowed to participate in this research project.

Confidentiality:

Only the primary researcher and supervisor will have access to the material provided by the participants. As far as the law allows, the confidentiality of the results will be preserved. Data will be stored on my password-protected PC and on ANU's cloud storage. The data must be stored for a period of at least five years from the date of any publication arising from the research. Following the transcription of the interviews, the names of the participants and any other mentioned names will be replaced by pseudonyms. Once the above five-year period is over, the audio-recordings and transcripts will be permanently deleted.

Queries and Concerns:

Primary Researcher: Rami Ibo – Email: rami.ibo@anu.edu.au

Supervisor: Margaret Kiley – Email: margaret.kiley@anu.edu.au; Phone: +612 61252690

Ethics Committee Clearance:

The ethical aspects of this research have been approved by the ANU Human Research Ethics Committee (Protocol 2015/535). If you have any concerns or complaints about how this research has been conducted, please contact:

Ethics Manager
The ANU Human Research Ethics Committee
The Australian National University
Telephone: +61 2 6125 3427
Email: Human.Ethics.Officer@anu.edu.au

APPENDIX D – ANU ETHICS APPROVAL

THIS IS A SYSTEM-GENERATED E-MAIL. PLEASE DO NOT REPLY. SEE BELOW FOR E-MAIL CONTACT DETAILS.

Dear Mr Rami Ibo,

Protocol: 2015/535
Chemistry PhD Supervisors' Conceptions of Their Roles in the Supervision of Chemistry PhD Candidates in Australia.

I am pleased to advise you that your Human Ethics application received approval by the Chair of the Committee on 18/10/2016.

For your information:

1. Under the NHMRC/AVCC National Statement on Ethical Conduct in Human Research we are required to follow up research that we have approved. Once a year (or sooner for short projects) we shall request a brief report on any ethical issues which may have arisen during your research or whether it proceeded according to the plan outlined in the above protocol.

2. Please notify the committee of any changes to your protocol in the course of your research, and when you complete or cease working on the project.

3. Please notify the Committee immediately if any unforeseen events occur that might affect continued ethical acceptability of the research work.

4. Please advise the HREC if you receive any complaints about the research work.

5. The validity of the current approval is five years' maximum from the date shown approved. For longer projects you are required to seek renewed approval from the Committee.

All the best with your research,

Human Ethics Officer
Research Integrity & Compliance
Research Services Division
Level 2, Birch Building 36
Science Road, ANU
The Australian National University
Acton ACT 2601

T: 6125-3427
E: human.ethics.officer@anu.edu.au
W: https://services.anu.edu.au/research-support/ethics-integrity

APPENDIX E – CONSENT FORM

WRITTEN CONSENT for Participants

How Chemistry PhD Supervisors in Australia Prepare their Students for Employment

I have read and understood the Information Sheet you have given me about the research project, and I have had any questions and concerns about the project (listed here

_____

_____)

addressed to my satisfaction.

I agree to participate in the project. YES ☐ NO ☐

I agree to this interview being audio-recorded YES ☐ NO ☐

I agree that my name and any other mentioned YES ☐ NO ☐

names will be replaced by pseudonyms following

the transcription of the interviews

Name:.....

Signature:.....

Date:.....