INVESTIGATING THE RELEVANCE OF THE GRADUATE ATTRIBUTES TO AUSTRALIAN TERTIARY CHEMISTRY EDUCATION: A STAFF, STUDENT, AND INDUSTRY PERSPECTIVE

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Statement of Original Authorship

The work contained in this thesis has not been previously submitted to meet requirements for an award at this or any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made.

Signature: Rami Ibo

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Abstract

Universities are increasingly seen to have both a research and a vocational training role. They have responded to this expectation by proclaiming the graduate attributes on their public websites. However, disciplines are also expected to develop their own graduate attributes and train students at them. For the discipline of chemistry in Australia, it is unclear how relevant these graduate attributes are to the different stakeholders of tertiary chemistry education: students, staff, and industries. The purpose of this study was to investigate the relevance of the graduate attributes to those three different stakeholders.

Chemistry students and staff at the ANU, as well as industries in Canberra that employed chemists, were surveyed and interviewed and asked to rate the importance of and the student competence at the ANU graduate attributes for science.

Results of this study showed that all stakeholder groups perceived the graduate attributes to be important, except some attributes were perceived more important than others – scientific analysis and problem solving were perceived as more important than communication, teamwork, and professionalism. Results also showed a discrepancy between students' perceived self-rated competence at the attributes, and the perceived competence of staff and industry; with competency ratings declining in the order of student, staff, and industry. Industry perceived students to be deficient at scientific analysis and problem solving, the very two attributes it valued most, and perceived deficiencies in students' wet chemistry and instrumentation skills.

This thesis showed that the graduate attributes are relevant to the three stakeholders of Australian tertiary chemistry education, and that further work involving these stakeholders needs to be done in order to ensure that Australian chemistry students are receiving the best chemistry education possible, and the best future employability outcomes.

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List of Abbreviations

ANU – Australian National University

ALTC – The Australian Learning and Teaching Council

APVMA – Australian Pesticides and Veterinary Medicines Authority

CPAS – Centre for the Public Awareness of Science

CSIRO – Commonwealth Scientific and Industrial Research Organisation

DI (DIIRTE) – Department of Industry

Go8 – Group of Eight Universities

GPA – Grade Point Average

IP – Department of Intellectual Property

RSC – Royal Society of Chemistry

RSC ANU – Research School of Chemistry ANU

TEQSA - The Tertiary Education Quality and Standards Agency

TGA – Therapeutic Goods Administration

USYD – University of Sydney

UWA – University of Western Australia

Chapter 1: Introduction

1.1 Background

Employers expect that university graduates not only demonstrate a mastery of discipline-specific skills and knowledge, but also other generic skills more commonly known as 'soft' or 'transferable' skills. Universities attempt to impart these skills through helping students achieve what are known as the 'graduate attributes'. It remains unclear however, where Australian chemistry graduates lie on the skills spectrum.

1.2 Purpose

It was hypothesized through observation and personal experience that chemistry education could be more holistic and integrated with the broader graduate attributes that numerous industries desire within the workplace. The aim of this project was to find out chemistry students', chemistry staff's, and industry employers' perspectives of the relevance of the graduate attributes to tertiary chemistry education in Australia. This was done by exploring the perceptions of the stakeholder groups in two ways:

1.2.1 Relevance of the graduate attributes within the student stakeholder group

Chemistry students from first year to post-doctoral level were asked to rate the importance of the graduate attributes in chemistry as well as their own competence at those attributes. In addition, they were asked several short-answer type questions to add more context to their provided answers. The purpose of this was to explore chemistry students' perceptions across the years, and see whether any they differed from year to year.

1.2.2 Relevance of the graduate attributes across the student, staff, and industry stakeholder groups

In addition to researching chemistry students' perceptions of the relevance of the graduate attributes to Australian tertiary chemistry education, chemistry staff and industries that employed chemistry graduates were included in the research. The two latter stakeholder groups were interviewed, and they rated the importance of the graduate attributes that students should possess in chemistry, as well as student competence at those attributes. In addition, they were asked several short-answer type questions to add more context to their

provided answers. The purpose of this was to explore the three stakeholders' perceptions, and see whether they differed in terms of their perceptions.

The results from this study will attempt to offer recommendations as to how any gaps in the different expectations can be bridged; to maximise the appropriateness of chemistry education in Australia, and better prepare chemistry students for increasingly global, and ever-changing workforce.

1.3 Definitions

For the purposes of this study, I have defined and explained the following terms:

Chemistry alumnus: someone who has completed a major in chemistry. Chemistry alumni may also include staff of the RSC ANU.

Chemical industry: mainly Government departments that would employ science and/or chemistry graduates.

Chemistry students: ANU chemistry students including first, second, third, fourth year Honours, Master, Doctoral, and post-doctoral level. While a post-doctoral fellow may be employed as a staff member at the ANU, they would not necessarily be involved in faculty activities, such as lecturing, as a more senior staff member of the University. Post-doctoral fellows are typically employed to carry out research for the research unit or university. They are seen as staff members in training and under probation; and hence, still learning.

Chemistry staff: ANU chemistry staff that range from early career researchers to seniors in the RSC. Also included are laboratory technicians and assistants who serve teaching roles within the RSC as well.

The following terms have been defined in the literature:

Soft/Transferrable/Graduate employability skills: Skills obtained during study that can cross many different industries. Examples include oral and written communication skills, ability to critically analyse and synthesise information, problem solving, teamwork, and the ability to work independently and be an active learner. (Andrews & Higson, 2008, p. 417; Graduate Opportunties, n.d.)

1.4 Thesis Outline

Chapter 2 of this thesis reviews the literature pertaining to the purpose and relevance of the graduate attributes, generally and scientifically/chemically, both nationally and internationally. Chapter 3 discusses and justifies the methods used to answer the research questions for this project. The results of this study are then provided in Chapter 4, followed by their analysis and discussion in Chapter 5. Chapter 5 also concludes the thesis by summarising the answers to the posed research questions, discussing the limitations of the project, and offering future recommendations.

Chapter 2: Literature Review

2.0 Introduction

This chapter will outline and describe the literature pertaining to the perceived relevance of the graduate attributes to students, industries, and universities; from general and scientific/chemical points of view; nationally and internationally.

It will discuss the purpose of universities, what the graduate attributes are and their purpose, and how universities internationally and nationally address them based on discipline. The chapter will then discuss how the graduate attributes are perceived according to stakeholder group, and then discuss the attributes within the context of ANU: what they are, how they are perceived, and their status within chemistry.

The chapter will conclude by synthesizing the material presented, and by formulating the research questions.

2.1 Purpose of universities

In 2011, Boulton and Lucas released a paper titled *What are Universities for?* in which they voice what academics believe to be the purpose of universities, and refute along the way the upheld government perception of university function. Governments view universities as fundamental sources of innovation, skill, and talent; and hence, seek to regulate them so that they provide defined outcomes to policy problems within a short time-frame (Boulton & Lucas, 2011). The assumption that universities are like 'levers' that when pulled, gush wealth and economic prosperity into a society, has also led Governments to treat universities as 'supermarkets', placing higher premiums on disciplines, such as the sciences, that are perceived to hold more potential at solving governments' policy agendas, compared to the humanities and the social sciences. (Boulton & Lucas, 2011).

While the authors, on behalf of academics in general, agree with governments that universities should serve societies and help pave their paths towards betterment, they disagree with their misconceived attitudes, and state that universities' strengths lie in their freedom to think, to teach, and to research; that it is "the totality of the university enterprise" (Boulton & Lucas, 2011, p. 2506) and its ability to engage with ideas in the long-term that are important (Boulton & Lucas, 2011).

"In research, universities create new possibilities; in teaching, they shape new people" (Boulton & Lucas, 2011, p. 2506). One of the fundamental pillars of university function is to teach people. Universities train students in both disciplinary and non-disciplinary knowledge, so that they exit the university environment and are equipped with the necessary tools to tackle the world's contemporary problems (Boulton & Lucas, 2011). The following paragraph encapsulates what universities offer students:

"Generation by generation universities serve to make students think. They do so by feeding and training their instinct to understand and seek meaning. It is a process whereby young people, and those of more mature years who increasingly join them as students, are taught to question interpretations that are given to them, to reduce the chaos of information to the order of an analytical argument. They are taught to seek out what is relevant to the resolution of a problem; they learn progressively to identify problems for themselves and to resolve them by rational argument supported by evidence; and they learn not to be dismayed by complexity but to be capable and daring in unravelling it. They learn to seek the true meaning of things: to distinguish between the true and the merely seemingly true, to verify for themselves what is stable in that very unstable compound that often passes for knowledge. These are deeply personal, private goods, but they are also public goods. They are the qualities which every society needs in its citizens." (Boulton & Lucas, 2011, p. 2511)

The quote above reveals particular skills that universities impart upon their graduates: "universities serve to make students think" and "[students] are taught to question interpretations", equate to analytical thinking skills. "[students] taught to seek out what is relevant to the resolution of a problem" represents problem solving skills. "They [skills] are the qualities which every society needs in its citizens" equates to social responsibility, and perhaps even teamwork as a skill required for societies to function effectively.

These skills: analytical thinking, problem solving, teamwork, ethics and social responsibility, and communication are what are called generic or transferrable skills – the skills that can be applied in any context. Within the university environment, they are generally known as the graduate attributes.

2.2 The graduate attributes: Description and purpose

The term 'graduate attributes' does not have a single, universal definition (S. C. Barrie, 2007; S. Barrie, Hughes, & Smith, 2009). Despite this however, many researchers

view the graduate attributes to be the university-recognised core values and skills that students should have upon graduation, in order be productive moral citizens (Bowden et al. 2000 as cited by Barrie et al., 2009). They are also the skills that employers look for in today's labourers (Watts, 2006 as cited by Barrie et al., 2009).

Barrie (2004, p. 270) used a phenomenographic research-based approach to help develop a set of graduate attributes. Phenomenography is a qualitative research method that uses an 'experience of a phenomenon' as the subject of study, and "seeks to describe the qualitatively different ways in which people understand a phenomenon" (S. C. Barrie, 2007, p. 442). With the phenomenon in this case being the graduate attributes, Barrie articulated these attributes by researching the activities of academics responsible for developing the graduate attributes as part of the university curricula. He identifies five clusters of personal, cognitive, and applied skills that form the graduate attributes:

- "Research and inquiry: Graduates of the university will be able to create new knowledge and understanding through the process of research and inquiry.
- Information literacy: Graduates of the university will be able to use information effectively in a range of contexts.
- Personal and intellectual autonomy: Graduates of the university will be able to work independently and sustainably, in a way that is informed by openness, curiosity and a desire to meet new challenges.
- Ethical, social and professional understanding: Graduates of the university will hold personal values and beliefs consistent with their role as responsible members of local, national, international and professional communities.
- Communication: Graduates of the university will recognize and value communication as a tool for negotiating and creating new understanding, interacting with others, and furthering their own learning."

Barrie (2004) explains that these five clusters help support graduates in being engaged global citizens who value scholarship and life-long learning, and should ultimately inform graduate attribute policy formulation and implementation in universities. This is particularly important, seeing that a research-based approach towards structuring the graduate attributes has been absent in Australian universities' policy-statement formulation (Barrie, 2004). Instead, universities have structured their graduate attributes based on what their stakeholders

deem to be popular or important, without a thorough underlying understanding of the nature of the outcomes of these attributes (Barrie, 2004).

2.3 How universities address the graduate attributes

2.3.1 A general overview

Universities around the world are increasingly concerned that their students graduate with the skills and qualities that will enable them to be the best citizens they can be in their respective societies (S. C. Barrie, 2007). In Australia, Great Britain, and the USA, the increasingly vocational role of universities has led governments and businesses to place pressures on them in order to ensure that their graduates are both employable and professional (Green, Hammer, & Star, 2009).

Universities have reacted in a number of ways to address their vocational training role. In the UK, universities offer skill development to their students either by embedding these skills within existing course curricula or by offering standalone, parallel courses (Higher Education Funding Council for England, 2003). In Australia, for example, universities proclaim that they provide students with the graduate attributes via their public websites (Donleavy, 2012), and it is "assumed that most courses have graduate attributes embedded into disciplinary knowledge and learning" (Green et al. 2009 as cited by Herok, Chuck, & Millar, 2013, p. 47). However, whether Australian students are actually graduating with these attributes remains vague (S. Barrie, 2005).

2.3.2 An international science and chemistry overview

According to Green et al. (2009, p. 26), "it is logical that each discipline be responsible for conceptualising, mapping, designing, implementing and assessing graduate attributes".

In the discipline of chemistry, a growing body of evidence reveals that today's chemistry graduates are not equipped with the necessary skills to work effectively in the "real world". Runquist and Kerr (2005, p. 231) found "that college faculty members either were unaware of or insensitive to the expectations and challenges of the 21st century technological workplace". As part of their study, Runquist and Kerr invited companies from industry such as 3M (a science-based technology company), to discuss with them the importance of the graduate attributes. The authors discovered that industry employers in general value scientists who were all-rounded in their communication, teamwork, and analysis skills; as well as

having business and cultural acumen. Being interdisciplinary was something also sought after, with a desire for graduates to be able to move effortlessly beyond their fields of specialisation. Having excellent grades or a good GPA seemed to be of less interest (Runquist & Kerr, 2005). Furthermore, it became apparent that the study's authors' university, Hamline University, taught science curricula that only prepared students for a career in academia and not one in industry or a non-academic setting.

These sentiments are further echoed by Francisco (2008) who urged that in order for chemistry graduates to be globally competitive, preparation needs to begin from the K-12 phase, stating that teachers should have the opportunities to go abroad, through teacher exchanges, to see how others teach and bring back that knowledge; that new technologies such as teleconferences can be exploited to amalgamate student classroom experiences amongst the US, Europe, or Asia (Francisco, 2008). At the undergraduate level, Francisco encourages that universities and businesses foster dialogue between each other, in order to shape future chemistry curricula with an industry context. And at the graduate research level, an increase in collaborations and exchange programs between the US and other countries is believed to give chemistry students a competitive edge in a global workforce (Francisco, 2008).

If according to Francisco (2008), that skills preparation must begin in school, then the commonly known decline of science enrolments needs to be addressed at that point as well. Lyons & Quinn (2010) attempt to understand the declines in senior high school science enrolments in Australia and explain that the decline is most likely due to the following reasons:

- The inability for students to see themselves as scientists - students seem to find science interesting but do not necessarily want to pursue it as a career.
- The relative cost versus relative utility - students feel that they can do other subjects that are less demanding but more rewarding, and can be in-line with their personal image and aspiration.
- School science is disengaging - teachers have commented that the curriculum needs to be more interesting and relevant while students wanted more practical experiences.

Similarly, Read (2010) described a UK approach to counter declining enrolment in university chemistry. The decline was combatted in two ways:

- By making chemistry outreach programs that give a sense of what chemistry is like in the real world
- By altering current chemistry curricula so that they meet the changing needs of today's students

In more detail, the approach involved showing school students how real science instruments work like spectrometers, analysing school-to-university transitions through higher education curriculum development, working with school teachers to understand how school graduates think, and opening university labs for school students. The outreach programs which included bringing university science instruments to class and opening laboratories to students and their teachers, were found to enhance the perception that inviting young students to university laboratories raises the profile of chemistry to those students. Bringing school teachers in contact with university staff was revelatory for both parties – university staff became more aware of the teaching environment in the classroom, why students are unable to do what was straight forward to first-year undergraduates in the past, and the different mindset of today's undergraduate cohort. Meanwhile, the higher education curriculum developments fostered a new sense of collaboration among chemistry departments across the UK, where academics began discussing the concept of 'best practice' in the context of chemistry education, and were sharing their ideas on teaching techniques and resources in chemistry – a phenomenon that is not commonly seen in the tertiary sector in the UK, as most universities regard one another as rivals rather than collaborators (Read, 2010)

Forbes & Davis (2008) stressed the importance of first year chemistry students participating in research projects, as the experience led to a greatly enhanced skill set for the first years as well as an increased research output for the faculty members who participated. Similarly, Karukstis (2008) shared the sentiment of Forbes & Davis (2008) and argued for more undergraduate research activities in order to diversify students' skills.

Ashraf, Marzouk, Shehadi, & Murphy (2011) describe how chemistry graduates in the UAE University were lacking the transferrable skills that were essential to function successfully in the workforce. They decided to develop a new and flexible course with seven

units focusing on teaching students communication skills, critical thinking skills, data acquisition, manipulation, and analytical skills, as well as chemical information retrieval and use of chemistry-specific software packages. The feedback from the students was generally positive regarding this course, with students commenting that they felt that course would help them in their future chemistry courses. Faculty members who took on research students noticed a marked improvement in the quality of those students, specifically in their ability to effectively use Microsoft Excel, carry out data manipulations, and make effective poster and oral presentations (Ashraf et al., 2011).

The recent article by Mc Goldrick, Marzec, Scully, & Draper (2013) reveals that chemistry students at the University of Dublin were only giving presentations in their final year of study. The school introduced a second year compulsory program that helped students develop skills in communication, data mining, and cooperative work. The postgraduate body was used to aid in the delivery, in order to bridge the disconnect between the undergraduate and postgraduate bodies in the School of Chemistry at the University of Dublin (Mc Goldrick et al., 2013). Results of the second year chemistry student survey revealed that most students found that that course was more beneficial at developing their teamwork, information sourcing, and decision making skills compared to the traditional undergraduate learning environments. In addition, the students appreciated the meetings with their mentors and postgraduate coordinators (Mc Goldrick et al., 2013).

Not only can collaboration occur between the undergraduate and postgraduate bodies, but also within a student body itself. Megehee, Hyslop, & Rosso (2005) explain how chemistry students collaborated with each other by using one another's compounds in different chemical studies. This allowed the students to work not only with others in their chemistry branch, but with other students from other chemistry branches, namely, the organic, physical, and inorganic chemistry branches. According to the authors, the idea behind this approach was "to mimic what is found in an industrial or research setting" (Megehee et al., 2005, p. 1345). For example, researchers working for the same organisation may be working on compounds that are structurally similar; and hence, may have common shared knowledge of each other's field of work. Furthermore, synthetic chemists may not completely characterize or study the compounds, and would send their compounds to other chemists who are specialised in analytical chemistry, which is concerned with identifying and characterising chemical compounds. By simulating this form of work amongst the chemistry

students, the results and compounds were shared in class and with students in another course for further study and experimentation. Overall, students and staff found this experience to be positive, confirming that this model of interdisciplinary work promotes communication skills, teamwork, and an understanding and appreciation of other people's work – the skills which happen to be the ones that employers seek in today's graduates (Megehee et al., 2005).

Recognising that chemists upon graduation may not only work in academia, but also in the workforce with an array of audiences such as those in government and industry, Sivey & Lee (2008) designed a course that allowed chemistry students to use popular magazine articles and assess them against reliable science sources to learn the art of writing for non-technical students. The major assignment had students select a scientific magazine article, summarise it, evaluate its integrity and how well it was communicated against the peer reviewed literature, and then write an editorial response suggesting strengths and recommended revisions to it. By encouraging students to act as editors, the assignment allowed them to develop the techniques of writing to non-technical audiences (Sivey & Lee, 2008).

Not only do deficiencies in students' soft skills seem to exist, but also in discipline-specific skills as well. Walker, Sampson, & Zimmerman (2011) state that a lot of science graduates are leaving university and entering the US workforce without really understanding how science works and how to do science. To address this issue, a new learning model was introduced for the undergraduate chemistry students known as the Argument-Driven Inquiry (ADI) (Sampson, Grooms, & Walker, 2011). The ADI model affords students the chance to think like scientists when conducting an experiment, allowing them to design the methods of the experiment and evaluate the results of their work using higher-order thinking skills. The model also allows students to engage with their peers in discussions about their results, questioning assumptions made and even peer reviewing their reports at the end of the experiments. By learning through this process, students develop their reasoning and argumentation skills, in addition to their communication skills as a result of writing the peer reviews (Walker et al., 2011).

2.3.3 An Australian science and chemistry overview

In 2011, The Australian Learning and Teaching Council (ATLC) published the report for the Learning and Teaching Academic Standards project, in which standards statements for science were set, as summarised in Table 1. The threshold learning outcomes for science describe skills Bachelor of Science graduates should possess upon completing their program (ALTC, 2011, p. 11):

Table 1: Threshold learning outcomes for science (ALTC, 2011, p. 11)

	Upon completion of a bachelor degree in science, graduates will:
Understanding science	1. Demonstrate a coherent understanding of science by: 1.1 articulating the methods of science and explaining why current scientific knowledge is both contestable and testable by further inquiry 1.2 explaining the role and relevance of science in society.
Scientific knowledge	2. Exhibit depth and breadth of scientific knowledge by: 2.1 demonstrating well-developed knowledge in at least one disciplinary area 2.2 demonstrating knowledge in at least one other disciplinary area.
Inquiry and problem solving	3. Critically analyse and solve scientific problems by: 3.1 gathering, synthesising and critically evaluating information from a range of source 3.2 designing and planning an investigation 3.3 selecting and applying practical and/or theoretical techniques or tools in order to conduct an investigation 3.4 collecting, accurately recording, interpreting and drawing conclusions from scientific data.
Communication	4. Be effective communicators of science by: 4.1 communicating scientific results, information, or arguments, to a range of audiences, for a range of purposes, and using a variety of modes.
Personal and professional responsibility	5. Be accountable for their own learning and scientific work by: 5.1 being independent and self-directed learners 5.2 working effectively, responsibly and safely in an individual or team context 5.3 demonstrating knowledge of the regulatory frameworks relevant to their disciplinary area and personally practising ethical conduct.

However, a study conducted on a faculty of science in an Australian university showed that approximately 70% of teaching, development, and assessment focussed on imparting students with disciplinary knowledge; with only most of the remaining time spent on training in professional skills (Herok et al., 2013). The same study found that "oral presentations, portfolios, extended writing, and field trips comprised approximately 15% of assessment" (Herok et al., 2013). And as mentioned previously, whether Australian students are actually graduating with the graduate attributes remains vague (S. Barrie, 2005).

The same 2011 report published by the ALTC sets threshold learning outcome statements for chemistry as well (ALTC, 2011, p. 23), shown in Table 2:

Table 2: Threshold learning outcomes for chemistry (ALTC, 2011, p. 23)

	Upon completion of a bachelor degree with a major in chemistry, graduates will be able to:
Understanding the culture of chemistry	Understand ways of scientific thinking by: • demonstrating a knowledge of, and applying the principles and concepts of chemistry • recognising that chemistry is a broad discipline that impacts on, and is influenced by, other scientific fields • recognising that chemistry plays an essential role in society and underpins many industrial, technological and medical advances • recognising the creative endeavour involved in acquiring knowledge, and the testable and contestable nature of the principles of chemistry.
Inquiry, problem solving and critical thinking	Investigate and solve qualitative and quantitative problems in the chemical sciences, both individually and in teams, by: • formulating hypotheses, proposals and predictions and designing and undertaking experiments in a safe and responsible manner • applying recognised methods and appropriate practical techniques and tools, and being able to adapt these techniques when necessary • collecting, recording and interpreting data and incorporating qualitative and quantitative evidence into scientifically defensible arguments • synthesising and evaluating information from a range of sources, including traditional and emerging information technologies and methods.
Communication	Communicate chemical knowledge by: • appropriately documenting the essential details of procedures undertaken, key observations, results and conclusions • presenting information, articulating arguments and conclusions, in a variety of modes, to diverse audiences, and for a range of purposes.
Personal and social responsibility	Take personal, professional and social responsibility by: • recognising the relevant and required ethical conduct and behaviour within which chemistry is practised • demonstrating a capacity for self-directed learning • demonstrating a capacity for working responsibly and safely • understanding and being able to articulate aspects of the place and importance of chemistry in the local and global community.

It proved difficult; however, to find data in the scholarly literature regarding chemistry and its relationship with the graduate attributes sought after by employers in Australia. The Group of Eight Universities' websites were searched and it was found that only the University of Western Australia ran a third year chemistry course titled 'CHEM3001

– Essential Chemical Skills' (University of Western Australia, 2014), aimed at providing students an understanding of principles and concepts related to:

- Legislative requirements for management of hazardous substances;
- Principles of OHS in the chemical laboratory;
- Intellectual property pertaining to chemistry and chemical inventions;
- The diverse literature of chemistry and chemicals.

According to the course description, CHEM3001 helps students further their skills development in scientific writing, problem solving, critical analysis and teamwork, as well as more advanced research skills specific to chemistry as a discipline. All of this would be achieved through a combination of practical class experiments, written assignments, preparation and presentation of a poster on a topic in modern chemistry, chemical data mining from a variety of sources, and a group project. Where possible, industry site visits would be incorporated (University of Western Australia, 2014). While this course does not explicitly state that it trains chemistry students in the graduate attributes, the training may still be achieved indirectly through the various activities undertaken.

It is worth noting that these findings do not necessarily imply that other universities do not offer these skills or classes – it may be a matter that these soft skills and activities are simply embedded within existing curricula, but it is only known to the students and staff of those courses, at those universities; an issue that is of interest to this research.

2.4 Perceptions of the graduate attributes

2.4.1 Industry perception

As per described so far, different stakeholder groups within the higher education sector perceive and value student skills differently. Reports in the media sphere show, for instance, that employers want graduates who can think both critically and creatively, and who are adept at expressing themselves in both oral and written communication; with far less interest in graduates having narrow training (Berett, 2013). In the scholarly literature, the findings of the study by Runquist and Kerr (2005) showed that industry employers of science graduates in the US valued scientists who were all-rounded in their communication, teamwork, and analysis skills; and possessed business and cultural acumen. Being interdisciplinary was something also sought after, with a desire for graduates to be able to move effortlessly from

science, to business, to humanities (Runquist & Kerr, 2005). The study also showed that those industries were not very interested in students' GPAs.

While it proved difficult to find published scholarly work on the relevance of the graduate attributes to Australian tertiary chemistry education and its stakeholders, further investigation of the literature did reveal a conference paper titled (Ashman, Scrutton, Stringer, Mullinger, & Willison, 2008) which explored chemical engineering education in the context of the graduate attributes. The paper described chemical engineering students', graduates', and industry's ratings of the level of competence at and importance of chemical engineering graduate attributes. In more detail, the study identified four relevant stakeholder groups: recent graduates (< 5 years) of the School of Chemical Engineering at the University of Adelaide, the line managers of recent graduates, Human Relations (HR) personnel at companies that employed recent graduates, and undergraduate students. These stakeholder groups were asked to rate the importance of 14 graduate attributes important to chemical engineering as part of a survey instrument. All stakeholder groups identified those attributes relating to communication and teamwork as being the most important of the 14 graduate attributes specified in that study. While managers and recent graduates agreed that graduates displayed a high level of competence in teamwork, they disagreed in their assessment of graduates' competence in communication. Graduates rated themselves much higher than the managers did; and in fact, managers rated communication as being one of the most deficient attributes in the graduates' skill-set. Interestingly, undergraduates self-identified communication as a key weakness, while graduates did not perceive any deficiencies in their self-assessed skill-set. Hence, the study indicated that surveying recent graduates alone may not truly reveal areas for improvement within chemical engineering curricula (Ashman et al., 2008). This informed this study by showing that in order to best reveal the perceptions of the relevance of the graduate attributes to chemistry in Australia, multiple relevant stakeholder groups would need to be identified, in order for the information gathered to be as holistic and robust as possible.

Another publication by the Royal Society of Chemistry in the UK, further echoed the findings of Ashman et al. (2008). Titled *The Chemical Skills Pipeline* (RSC, 2009) (Full report: (Purcell, Atfield, & Ball, 2008)), the study monitored students from the time they entered the field of chemistry at universities, up until seven years after their graduation. They were asked what motivated them to study chemistry and what influenced their subsequent

career decisions. In addition, employers from 60 organisations that recruit chemical science graduates took part in the study. Through face-to-face and over-the-phone interviews, they were questioned about their recruitment experiences, the ease or difficulty of appointing suitable candidates, the types of jobs chemical science graduates did within their organization, as well as their perceptions of the strengths and weaknesses of chemical science graduates.

Two different classes of employers were defined - those who require that applicants have a relevant chemical science degree (referred to as specialist employers), and those who recruit graduates for roles which do not require a specific degree subject, but would be suitable for chemical science graduates (referred to as general graduate employers).

Table 3 summarises general employers' and specialist employers' desired skills, strengths, and weaknesses in graduates in decreasing order of importance (Purcell et al., 2008):

Table 3: Comparisons of general employers' (GE) and specialist employers' (SE) desired skills, strengths, and weaknesses in graduates (Purcell et al., 2008)

GE Desired Skills	SE Desired Skills	GE Graduate Strengths	SE Graduate Strengths	GE Graduate Weaknesses	SE Graduate Weaknesses
- Teamwork - Spoken communication - Written communication - Problem-solving - Numeracy - Presentation - Analytical skills - Leadership skills - Research skills	- Teamwork - Communication - Technical - Self management & organisation - Problem solving - Motivation - Flexibility - Management - Research - Business focus	- Analytical skills & dealing with data - Numeracy - Research skills - Logic - Attention to detail & accuracy - Problem solving - Written communication, particularly certain types of report writing - Organisation - Intelligence	- Analytical thinking - Technical - Numeracy - Problem solving - Interpersonal skills - Flexibility - Motivation and self-discipline - Attention to detail - Love & enthusiasm of subject	- Spoken communication - Written communication - Teamwork - Social skills/being personable - Leadership - Ability to deal with clients/customers - Business awareness & commerciality - Presentation skills	- Communication - Technical skills - Report writing - Business & commercial awareness - Breadth of knowledge - Lack of self-motivation

It is important to note that specialist employers felt that a number of specific chemical science skills were in short supply, such as physical organic chemistry and analytical science (Purcell et al., 2008). They were concerned that students were dropping out from courses that were perceived to be difficult or boring like physical chemistry or mathematics, which employers consider to be vital. Furthermore, interviews with general graduate employers revealed that they were unlikely to favour a graduate with a Master Degree in chemistry over of Bachelor of Science graduate, stressing that they were more interested in the transferable skills that graduates could demonstrate, regardless of the duration of their degree. In contrast, specialist employers did distinguish between graduates on three or four year courses, with higher degrees in particular being sought after for research or academic positions (RSC, 2009). The study advised that the soft skills mentioned above cannot be developed using one-off courses and must be nurtured throughout the whole of the degrees without jeopardizing course content. However, as argued by Ashraf et al. (2011), one-off courses did help improve chemistry students' soft-skills, such as the course employed at the UAE University. Irrespective, one can assume that having these soft skills embedded in courses across the years with continual assessment would be more beneficial for student attainment of the graduate attributes.

Exploring *The Chemical Skills Pipeline* report further showed that employers felt that employability skills could be integrated into chemical science degree courses and departments should take advantage of all opportunities to make their graduates employable, particularly that only a very small percentage of undergraduates in the report undertook an industrial placement as part of their course (RSC, 2009). Placements provide an excellent opportunity for students to develop employability skills, and final year undergraduates in the report expressed a concern that not having relevant work experience would hinder them in finding the job they wanted (RSC, 2009). While it was found that most chemistry students pursue the field out of interest and enjoyment, the majority of them appeared to be unaware of their career prospects (RSC, 2009). The report recommends that university careers offices raise their profile better with undergraduates, and ascertain the importance of students seeking paid or unpaid work experience venues during their degrees (RSC, 2009).

Similarly in Australia, the report for the Learning and Teaching Academic Standards project published by the ALTC in 2011 reported that industry groups that employed science graduates valued "a core set of scientific knowledge and skills, personal motivation, ethical

conduct, verbal and communication skills, and personal skills in teamwork, with potential for leading teams", and valued science graduates who possessed interdisciplinary skills (ALTC, 2011, p. 10).

The findings of Herok et al. (2013) also paint a similar picture; where a survey of the selection criteria perceived to be most important for graduate recruiters showed that communication skills were to be most important for all employers, followed by industry knowledge and critical thinking skills in second and third place, on average, respectively (Herok et al., 2013, p. 43); showing that specialist knowledge is not perceived to be centrally important to these industry employers. The results of that survey are summarised in Table 4:

Table 4: Most important selection criteria when recruiting graduates, by industry, 2011. (Herok et al., 2013, p. 43)

Selection criteria	G/D/H	C/M/E	A/F	L/PS	M	C/T/U	All
Interpersonal and communication skills	1	1	1	1	1	1	1
Passion/knowledge of industry (etc)	3	2	6	2	1	2	2
Critical reasoning and analytical skills (etc)	2	5	3	3	3	3	3
Calibre of academic results	5	4	2	6	3	4	4
Work experience	6	3	4	4	3	5	5
Cultural alignment/values fit	7	5	5	4	6	8	6
Teamwork skills	4	7	7	7	6	7	7
Emotional intelligence	8	8	8	7	8	6	8
Leadership skills	9	9	9	10	8	10	9
Activities	10	10	10	9	10	9	10

Note: G/D/H = Government/Defence/Health, C/M/E = Construction/Mining/Engineering, A/F = Accounting/Finance, L/PS = Legal/Professional Services, M = Manufacturing, C/T/U = Communication/Technology/Utilities.)

Observing these findings in total shows that, unless a specialist employer, most generalist employers are looking for graduates who possess a range of generic skills and attributes, with a particular desire for graduates to be adept at communication, teamwork, critical thinking, and problem-solving skills. In the context of Australian tertiary chemistry education; however, no scholarly data exists on chemical industries' perceptions of the importance of such skills.

2.4.2 University perception

Universities in general have traditionally focussed primarily on imparting students with discipline-specific skills (Bridgestock, 2009 as cited by Herok et al., 2013). Science teaching and learning at the undergraduate level still appear to focus largely on transferring knowledge to students, with minimal attention given to the skills needed to apply knowledge (Weiman, 2007; Wood, 2009 as cited by Varsavsky, Matthews, & Hodgson, 2014). As shown in the work of Runquist and Kerr (2005), discussions with industry employers of science graduates revealed that the authors' university's science curriculum was largely paving graduates' paths towards a career in academia, and not one in industry (Runquist & Kerr, 2005). This agrees with the study by Herok et al. (2013) that showed that approximately 70% of teaching, development, and assessment focussed on imparting students with disciplinary knowledge; with only most of the remaining time spent on training in professional skills; in an Australian university faculty of science (Herok et al., 2013). The same study found that "oral presentations, portfolios, extended writing, and field trips comprised approximately 15% of assessment" (Herok et al., 2013). And as mentioned previously, whether Australian students are actually graduating with the graduate attributes remains vague (S. Barrie, 2005).

In the context of Australian tertiary chemistry education, no scholarly work has been done that sheds light on the university-perceived importance of the graduate attributes. As discussed earlier, of all the Go8 universities, only the University of Western Australia offered a third year chemistry course titled 'CHEM3001 – Essential Chemical Skills' (University of Western Australia, 2014), aimed at providing students some professional-skills training, in chemistry-related activities.

While chemistry Schools in the Go8 universities may indeed be training their chemistry students at the graduate attributes; at surface-level however, it seems that these

universities may not perceive them to be highly important (as indicated by their course websites), and are focussing instead on the more traditional approach to teaching; that is, discipline-specific training.

2.4.3 Student perception

According to Tomlinson (2008), despite having university degrees, students are increasingly placing value in the soft skills in order to distinguish themselves and stand out from other graduates when applying for jobs; to fit better with the demands and selection criteria of employers.

In terms of higher education performance measurement, universities collect information on the skills they offer at the undergraduate level through student surveys mainly (Varsavsky et al., 2014). The literature is scarce; however, with studies where the student perceptions of skills have been "sought to inform curriculum development" (Varsavsky et al., 2014, p. 931). In Australia, the instrument used to collect student perceptions of skills is the Course Experience Questionnaire, offered to students after they graduate from their universities; however no reference is made to the specific disciplines studied (Varsavsky et al., 2014).

In the reviewed literature for this project, most studies have focussed on how different stakeholders in education, particularly industry and business stakeholders, rate student competence at the graduate attributes. This does not appear to be an unusual finding, considering that the graduate attributes and employability skills are seen as skills that universities are trying to offer due to their increasingly vocational role, and the subsequent pressures governments and businesses place on them in order to ensure that their graduates are both employable and professional (Green et al., 2009).

In the context science, and specifically bioscience, a study done in the UK found that graduates tended to self-rate their skills more highly than employers, especially if they did not receive industry training or experience during their course of study (Varsavsky et al., 2014). This finding agrees with those of Ashman et al. (2008) that showed discrepancies between industry ratings of graduate competence and graduates' self-rated competence at communication skills; with graduates rating themselves highly at those skills and industry rating them lowly. The media also highlights similar occurrences: A survey by Chegg (an academic student support company in the US) and Harris Interactive (a US research firm) showed that around 80 percent of current US

college students said they were either "very" or "completely" proficient, while only 54 percent of hiring employers agreed (Big Think, 2013; Chegg, 2013)

Varsavsky et al. (2014) conducted a study in which 400 responses were collected from undergraduate science students about to graduate from two Australian research-intensive institutions. Students in the study were asked to rate six science graduate skills on a four-point Likert Scale. The six skills were: scientific content knowledge, scientific communication, scientific writing, teamwork, quantitative skills, and ethical thinking skills. Students perceived all six skills to be important, although "ethical thinking, quantitative skills, and teamwork were perceived to be less important than scientific content knowledge, oral communication, and scientific writing" (Varsavsky et al., 2014, p. 945).

In the discipline of chemistry, the findings of Ashraf et al. (2011), Mc Goldrick et al. (2013), and Megehee et al. (2005) show that offering chemistry students training at the graduate attributes, whether as a stand-alone course that focuses on teaching students soft skills in a chemistry context (Ashraf et al., 2011), or a program that helps chemistry students develop skills in communication, information-mining, and teamwork (Mc Goldrick et al., 2013), or embedding the training in existing chemistry courses and helping chemistry students leave their 'silos' and collaborate with one another (Megehee et al., 2005), would generate positive student feedback in general. This may imply that chemistry students perceive these skills as important to their learning and training.

2.5 The Australian National University context

2.5.1 The ANU graduate attributes for science

ANU, like all other universities (Donleavy, 2012), has developed graduate attribute statements available on its website (ANU, 2013a). The following is the list of science graduate attributes as stated by the ANU:

- develop, apply, integrate and generate scientific knowledge in educational and professional contexts;
- use a range of skills and methods to identify, analyse and respond to problems and issues;
- convey and relate professional and disciplinary information and ideas to diverse audiences in effective and appropriate ways;

- work in both independent and collaborative ways with others to encompass diverse abilities and perspectives; and
- exercise personal, professional and social responsibility as a global citizen.

The website also states the following:

"To guide the formation of specific and measurable learning outcomes, we have also developed some generic indicators that might guide how disciplinary areas frame:

- firstly their learning outcomes for majors and minors; and
- secondly the course level learning outcomes they specify as capability expectations of students.

Click on each of the above attributes to look at expanded ideas of how they might to your disciplinary context or course" (ANU, 2013a).

Clicking on the attributes; however, does not open any links that show how to perhaps embed them within ANU science courses.

2.5.2 Chemistry education structure

The Research School of Chemistry at the ANU states that "[it] is responsible for offering undergraduate courses in chemistry at ANU. The School boasts state of the art facilities and instruments, as well as globally recognised Lecturers. Studying chemistry at ANU will prepare you for any field-related career development" (RSC ANU, 2012).

The RSC ANU course website (RSC ANU, 2012) describes the range of courses on offer at the university, from first year to fourth year Honours. Course subjects range from general chemistry in first year, to specialised programs in second year which expose students to the different branches of chemistry such as organic, inorganic, physical, organometallic, and biological chemistry. Courses offer students both theoretical and practical exposure to the world of chemistry. The RSC also offers Master and Doctoral research programs in chemistry.

Visiting the ANU course description websites for the undergraduate chemistry courses on offer revealed that most of these courses had learning outcomes that largely focussed on chemistry-specific knowledge and skills, with no apparent incorporation of the proposed learning outcomes for ANU science students. Several of these courses describe safe handling of chemicals and proper report writing as learning outcomes; which could relate to professionalism and written communication respectively. However,

there is no evidence of diverse communication or exposure to teamwork, whether in the learning outcomes or in the indicative assessments. (ANU, 2014)

2.5.3 Status of graduate attribute perception

Course feedback at the ANU is collected through the Student Experience of Learning and Teaching (SELT) online survey forms. Students are asked to complete these surveys at the end of the sessions and semesters. Results of these surveys are only available for ANU staff and students, and hence, cannot be disclosed in this document. However, the SELT websites explain that the surveys collect student feedback for course evaluations and teaching evaluation (ANU, 2013b, 2013c). It is not stated that the SELT forms collect data on student perceptions of the graduate attributes of ANU.

Considering this, and the fact that the learning outcomes for chemistry courses at the ANU are hardly centred on the science graduate attributes, it can be assumed that the perceived relevance of the graduate attributes for chemistry at the ANU is largely unknown.

2.6 Synthesis and research question formulation

This chapter outlined and described the literature pertaining to the perceived relevance of the graduate attributes to students, industries, and universities; from general and scientific/chemical points of view; nationally and internationally. These different findings can be synthesised as follows:

Universities are increasingly expected to have a vocational training role (Green et al., 2009). They have responded to this expectation by proclaiming graduate attributes statements on their websites (Donleavy, 2012). Different disciplines; however, are responsible for developing their own contextualised graduate attributes (Green et al., 2009). In the discipline of chemistry, universities that attempt to train students at the graduate attributes, do so in two general approaches: they either offer stand-alone parallel courses for this purpose or embed the training within existing chemistry courses (Ashraf et al., 2011; Higher Education Funding Council for England, 2003; Mc Goldrick et al., 2013; Megehee et al., 2005). However, whether students exit university with an ability to apply these skills remains vague (S. Barrie, 2005), as there can be a disconnect between proclaimed graduate attributes and actual in-class training (Donleavy, 2012; Herok et al.,

2013). By gathering industry's perceived competence of students at those skills, evaluating university rhetoric versus actual implementation becomes an easier task. Most industry employers find chemistry graduates to be strong at analytical thinking and numeracy skills, but weak at communication skills – the very skills that employers perceive to be of utmost importance (Herok et al., 2013; Purcell et al., 2008). The same pattern also emerges within the discipline of chemical engineering: communication skills are perceived to be very important for industry employers. However, chemical engineering graduates are perceived to be very deficient at those skills; despite the graduates rating themselves as highly proficient at them (Ashman et al., 2008). This means that there exists a discrepancy between perceived student self-rated competence and the perceived student competence by industry at the graduate attributes (Varsavsky et al., 2014). At the ANU, it appears that the learning outcomes for chemistry courses do not correlate with the ANU science graduate attributes. All of this considered, and the paucity of scholarly studies on the relevance of the graduate attributes to Australian tertiary chemistry education, leads to the following research questions:

1. How important are the graduate attributes perceived to be by the stakeholders of Australian tertiary chemistry education: students, staff, and industries?
2. How competent are students perceived to be at the graduate attributes by themselves, and by the remaining stakeholders of Australian tertiary chemistry education: staff and industries?

These research questions will be addressed according to the research methods described in the following chapter.

Chapter 3: Research Design

3.0 Introduction

This chapter discusses the research methods used to address the research questions that were formulated at the end of Chapter 2. It will describe the instruments used, the designing of the online survey and interview, the participants for the project, ethical considerations, and provide an analysis plan of the results.

3.1 Instruments

3.1.1 Choice of data collection methods, explanation, and justification

The previous chapter outlined and described the literature pertaining to the perceived relevance of the graduate attributes to students, industries, and universities; from general and scientific/chemical points of view; nationally and internationally.

Based on that review, two research questions emerged:

1. How important are the graduate attributes perceived to be by the stakeholders of Australian tertiary chemistry education: students, staff, and industries?
2. How competent are students perceived to be at the graduate attributes by themselves, and by the remaining stakeholders of Australian tertiary chemistry education: staff and industries?

In order to determine the most appropriate data collection instruments to answer the research questions above, the different research methods used in the social sciences, mainly qualitative and quantitative methods, needed to be explored and understood.

Yilmaz (2013, p. 314), summarises the differences between qualitative and quantitative modes of inquiry (Table 5):

Table 5: Comparisons between quantitative and qualitative modes of inquiry (Yilmaz, 2013, p. 314)

Quantitative Mode	Qualitative mode
Assumptions	*Assumptions*
• Reality is single, tangible, and fragmentable. Social facts have an objective reality.	• Realities are multiple, constructed, and holistic. Reality is socially constructed.
• Knower and known are independent, a dualism.	• Knower and known are interactive, inseparable.
• Primacy of method	• Primacy of subject matter
• Variables can be identified and relationships measured	• Variables are complex, interwoven, and difficult to measure.
• Inquiry is objective, value-free.	• Inquiry is subjective, value-bound.
Purposes	*Purposes*
• Generalisability (Time and context free generalisations through nomothetic or generalised statements)	• Contextualisation (Only time and context bound working hypotheses through idiographic statements)
• Prediction	• Interpretation
• Causal explanations	• Understanding actors' perspectives
Approach	*Approach*
• Begins with hypotheses and theories	• Ends with hypotheses or grounded theory
• Manipulation and control	• Emergence and portrayal
• Uses formal, structured instruments	• Researcher as the instrument
• Experimentation and intervention	• Naturalistic or nonintervention
• Deductive	• Inductive
• Component analysis	• Searches for patterns
• Seeks consensus, the norm	• Seeks pluralism, complexity
• Reduces data to numerical indices	• Makes minor use of numerical indices
• Abstract language in write-up	• Descriptive write-up
Researcher Role	*Researcher Role*
• Detachment and impartiality	• Personal involvement and partiality
• Objective portrayal	• Empathic understanding
• Etic (outsider's point of view)	• Emic (insider's point of view)

Source: Adapted from Glesne & Peshkin (1992); Lincoln & Guba (1985).

According to Bazeley (2004, p. 2) "qualitative and quantitative approaches have been distinguished (and thereby defined) on the basis of the type of data used (textual or numeric; structured or unstructured), the logic employed (inductive or deductive), the type of investigation (exploratory or confirmatory), the method of analysis (interpretive or statistical), the approach to explanation (variance theory or process theory), and for some, on the basis of the presumed underlying paradigm (positivist or interpretive/critical; rationalistic or naturalistic".

Johnson & Anthony (2004) state that there exists a dispute between advocates of qualitative research and advocates of quantitative research. They summarise that quantitative purists believe that social research should be conducted in the same way scientists study physical phenomena in their field; that the investigator should separate oneself from the entities being studied, and empirically justify one's proposed hypotheses, free of time and context (Nagel, 1986 as cited by Johnson & Anthony, 2004). At the other polar extreme, they also explain that qualitative purists reject their counterparts' beliefs, stating that time- and context-free generalisations cannot be made, that research is value-bound, and that the investigator cannot be separated from the entities in study since the "subjective knower is the only source of reality" (Gubba, 1990 as cited by Johnson & Anthony, 2004, p. 14). The authors further explain how qualitative purists dislike the emotionally detached and passive writing style of quantitative purists, and prefer richer, active, and more detailed written descriptions (Johnson & Anthony, 2004). This dispute between the qualitative and quantitative researchers has led them to advocating what is known as the 'incompatibility thesis' (Howe, 1988 as cited by Johnson & Anthony, 2004), in which the purists argue that the two research approaches cannot be and should not be mixed. Despite this; however, Bazeley (2004), explains that the separating lines between these two research approaches is blurred – "If one uses numbers, interpretation is still involved. If one's data are texts, counting may still be appropriate. Variables do not necessarily have cut meanings; processes can be revealed through numeric analysis as well as through narrative, and so on. This inability to definitively distinguish one approach from another has implications for the acceptability of mixing methods in that "lines of conflict" cannot be clearly drawn" (Bazeley, 2004, p. 2). Johnson and Anthony further argue that both approaches are important, and that researchers should use them in tandem in order to capitalise on their strengths and minimise their weaknesses in one or across studies (Johnson & Anthony, 2004).

One cannot ignore the familiar relationship that exists between the concept of 'perception' and that of 'belief'. In fact, Smith (2001, p. 283), argues that "the relation between perception and belief is more than merely contingent". Within the education literature, the terms 'perception' and 'belief' appear to be used synonymously. In her study on the influences on the science teaching self-efficacy beliefs of Australian primary school teachers, McKinnon (2010) uses the two terms both in conjunction and interchangeably, so do several of the authors cited in her review (Appleton and Kindt, 2002; Friedrichsen & Dana, 2003; Holstermann, Grube, & Bögeholz, 2010; Schwarz & Gwekwerere, 2006; Stevens and Wenner, 1996 as cited by McKinnon, 2010). Therefore, it can be assumed that the terms 'perception' and 'belief' are synonymous.

Considering that the concepts of perception and belief appear to be synonymous, it can be assumed that the study of perception is as complex as the study of beliefs. The study of beliefs is difficult to conduct empirically (Pajares, 1992), due to the vast range of beliefs of, and influences on, individuals (McKinnon, 2010). In response to this complexity, using a mixed qualitative-quantitative research approach would "capture a broad range of issues, maximise the depth of understanding and 'cross check' any identified trends" (McKinnon, 2010, p. 81). Furthermore, utilising more than one research method permits a less biased interpretation of the results overall compared to a single method (Denzin, 1989 as cited by McKinnon, 2010). Therefore, this study uses a mixed research approach in order to maximise the benefits and richness of the findings as described by Johnson and Anthony (2004) and McKinnon (2010).

The qualitative and quantitative approaches used in this study are largely contextual in nature – it is research that is concerned with finding what exists, and to what extent, in the social world (Ritchie & Lewis, 2003) of Australian tertiary chemistry education and its perceived relevance of the graduate attributes. According to McKinnon (2010), research in the past has identified the need for interviews to be used with surveys in tandem in order to verify the findings of these instruments, as well as to add an additional dimension of deep contextual data (Lewthwaite, 2005; Palmer, 2006a; Singh & Shifflette, 1996 as cited by McKinnon, 2010).

Based on this study's research questions, chemistry staff, chemistry students, and industries that employ chemistry graduates were the target participants for this research.

Primarily, since the number of students surpassed those of industry and staff, online surveys were the instrument of choice for collecting data from this cohort; while semi-structured interviews were the instrument of choice for the staff and industry groups; due to the small number of potential participants available.

According to Evans & Mathur (2005), online surveys are best suited for collecting data from the students due to a number of reasons. Given the simplicity with which surveys can be made and emailed to participants, they are ideal data collection instruments when a large sample is desired. Online surveys work best when a company has a list of valid e-mail addresses of its employees as was the case when sending the central email to participants through the RSC ANU administration. Online surveys afford the researcher strong methodological control, with the ability to command the number of questions, the type of questions (yes/no, short-answer, multiple choice), and their order. When researcher interaction with respondents is not necessary and/or desirable, particularly with larger sample sizes, online surveys are seen as a more suitable data collection instruments compared to interviews. Indeed, online surveys are regarded as less intrusive and personal than face-to-face and telephone interviews (Evans & Mathur, 2005). Finally, when time is vital, online surveys offer a quick way of yielding data; as was the case in this project where by virtue of starting the research project mid-year, it was crucial to collect the data as early as possible before the students entered their examination study period, and consequently left the university for their vacation.

As with any data collection instrument, Evans & Mathur (2005) explain the potential weaknesses of online surveys and how they can be reduced.
For instance, participants may treat the online survey as spam. This problem is reduced if online surveys are opt-in rather than sent in an unsolicited manner. In the case of this research project, having the survey link sent through the course convenors and the RSC ANU administration itself as well as a reminder from the director of the RSC ANU could have helped reduce this problem. Participants may misinterpret survey instructions as well; however, this problem can be mitigated by conducting pilot studies where any ambiguities, errors, and/or issues may be uncovered in the early stages of the research (Evans & Mathur, 2005). In the early stages of this study, the online survey responses were monitored for such errors and ambiguities and were addressed appropriately. Evans and Mathur further explain the limitations of online surveys, stating that low response

rates are a significant weakness not only of online surveys, but any survey for that matter. In the hopes of boosting survey responses, in the addition to online survey invitations, participants (who were present at lecture theatres, tutorials, and laboratories) were contacted face-to-face personally and told of the benefits of the research to their own discipline and prospective chemistry/science careers. Personalising the research project to the students and explaining to them how completing its online survey would potentially benefit them in the future, was based on the idea of enhancing some of the motives for participation such as altruism (for example, the survey promotes some purpose important to the respondent or the respondent is fulfilling a social obligation) and survey-related reasons (for example, the respondent is interested in the survey topic) (Singer & Bossarte, 2006).

Interviews on the other hand, are qualitative means of data collection that generate information-rich data, and for this study, semi-structured interviews were conducted. Semi-structured interviews consist of numerous key questions, but also allow the interviewer or interviewee to diverge in order to explain an idea or response in more detail (Gill, Stewart, Treasure, & Chadwick, 2008).

According to Birmingham City University (2006), interviews are useful for obtaining detailed information about personal feelings, perceptions and opinions. In an interview, a researcher is able to tease out more data from the session by observing a respondent's body language, gestures, facial expressions, and tone of voice (provided the interview is face-to-face) (Ritchie & Lewis, 2003). Participants' responses can be recorded and revisited multiple times, and ambiguities can be clarified and incomplete answers followed up through phone call or emails for instance (Birmingham City University, 2006; Ritchie & Lewis, 2003). Furthermore, when sample sizes are small, interviews can compensate for this by providing information-rich data (McKinnon, 2010).

This does not mean; however, that interviews are not without their flaws. A large drawback of interviews is that they can be very time-consuming: setting up the interviews, interviewing the participants, transcribing the recordings, and analysing them demands time and effort (Ritchie & Lewis, 2003), as was the nature of this study. Recordings may be muffled and subject to external noise, words may be pronounced unclearly by either party, and all this can lead to difficulties in transcribing and analysing the data. Finally, interviewer bias may skew the interpretation of the results; in which

case, applying reflexivity continuously would be important, in order to identify one's backgrounds and beliefs, and strive for objectivity and neutrality (Ritchie & Lewis, 2003).

Compared to online surveys and interviews, focus groups result in data that is generated by interaction between the group participants (Ritchie & Lewis, 2003). Participants voice their own views and experiences, but may also be influenced by what they hear from the remaining participants, and in light of what is said, they may reflect consider their own point of view further (Ritchie & Lewis, 2003). Focus groups are hence used to gather information on collective views, and the possible meanings behind those views (Gill et al., 2008).

Data collection through focus group sessions was not adopted in this study primarily because the aim was to collect individual responses for the posed research questions, and not collective group data; as per the research methods of Ashman et al. (2008) and Purcell et al. (2008). While it is acknowledged that focus groups would have generated an additional dimension of thick, information-rich data, a main concern would have been the potential for reticent participants to emerge, who might have had viewpoints or experiences that differed from the main; and hence, may have been uncomfortable in voicing their inner-most beliefs (Ritchie & Lewis, 2003), particularly within and across the staff and industry stakeholder groups. Furthermore, setting up the interviews with the individual participants proved to be uneasy task; interviewing them as groups would have potentially been even more difficult, considering these participants' time constraints and competing demands.

A final point to note is that despite it not being an Australian study, *The Chemical Skills Pipeline Report* (Purcell et al., 2008) was the most appropriate study on chemistry students and their employment in industry, and in the absence of an Australian-led study for chemistry graduates post university graduation, that report, along with the work of Ashman et al. (2008) on Australian chemical engineering graduates in industry, formed the two main authoritative resources from which the methods of this study were drawn.

3.2 Online survey and interview question design

3.2.1 Online survey questions

The online survey questions are provided in the Appendices. The survey was designed using the SurveyMonkey account provided by CPAS. The methods of Purcell et al. (2008) and Ashman et al. (2008) were used as a reference for the methods of this study. Each question in the survey had to provide an answer to the posed research questions. For the student stakeholder group, the questions were:

1. How important are the graduate attributes perceived to be by ANU chemistry students?
2. How competent at the graduate attributes do ANU chemistry students perceive themselves to be?

A five-point Likert scale was used to rate the student-perceived importance of and the student-perceived self-rated competence at the ANU science graduate attributes; with one being the least important/competent and five being the most important/competent. Each of the five graduate attributes were given a descriptive heading in bold for clarity purposes. In addition, short-answer type questions were posed, to add rich and contextual data to the ratings within the online survey: demographic data (chemistry year/level of experience), purpose of university chemistry education, motivations for doing chemistry, nature of experience in chemistry, skills and changes desired in chemistry, and additional comments were questions asked to tease out more information and identify potential themes from students' responses.

3.2.2 Interview survey questions

The interview questions are provided in the Appendices. Similar to the online survey questions, the semi-structured interview questions for staff and industry were designed in reference to the methods of Purcell et al. (2008) and Ashman et al. (2008). Again, each question in the interview had to provide an answer to the posed research questions. For the staff and industry stakeholder groups, the questions were:

1. How important are the graduate attributes perceived to be by ANU chemistry staff and employers of chemistry graduates?
2. How competent at the graduate attributes do ANU staff and employers of chemistry graduates perceive chemistry students and graduates to be respectively?

RSC ANU staff were asked to rate the ANU graduate attributes on a five-point Likert scale, with one being the least important skill that chemistry students should possess and five being the most important skill that chemistry students should possess. They were also asked to rate the ANU graduate attributes a second time, with one being the skill that chemistry students were least competent at and five being the skill that chemistry students were most competent at. Similarly, industry employers of chemistry graduates were asked to do the same exercise, but for chemistry graduates instead of RSC ANU students. The graduate attributes were the same ones described in the student online survey. In addition, short-answer type questions were posed to both stakeholder groups, to add rich and contextual data to the ratings:

For staff: purpose of university chemistry education, thoughts on university chemistry curricula at ANU and in general, other perceived strengths and weaknesses of chemistry students, skills they wanted their students to have, and additional comments;

For industry: nature of the relationship with chemistry graduates, other perceived strengths and weaknesses of chemistry graduates, expectations of chemistry graduates they would employ, and additional comments were the questions asked to enrich the findings. Additionally, the nature of the semi-structured interviews allowed for additional ideas to be explored, further adding richness to the findings.

3.3 Participants

3.3.1 Choice of participants

As identified through this study's research questions, chemistry staff, chemistry students, and industries that employ chemistry graduates were the target participants for this research.

Chemistry students were chosen to participate in the online survey. Due to the geographic location of the research (Canberra) and its ethical parameters, chemistry students at the RSC ANU were chosen: First, Second, Third, Fourth Year Honours, Master students, Doctoral scholars, postdoctoral fellows, and ANU chemistry alumni formed the chemistry student participant group. This allowed to capture varied responses from course-work and research students. The purpose of this was not only to try to detect emerging themes and trends for the student stakeholder group as a whole, but also within the group and its sub-groups.

Chemistry staff were chosen to participate in the interviews. Due to the same geographic and ethical limitations, staff from the RSC ANU were chosen to participate in this study. The staff members ranged from teaching, to research, to technical staff in order to maximise the variety of responses and data collected.

Industries that employ chemistry graduates were chosen to complete the interview as well. Based on the 2011 *Graduate Destination Report by the ANU Joint College of Science* (ANU, 2011), chemistry graduates from the ANU were found to be in a range of positions, some of which included public servant roles in the Australian Government. As the seat of the Australian Government, Canberra is the site of numerous government departments and agencies. It is for these reasons, and the geographic and ethical contexts of this study, that the following departments were chosen as potential employers of chemistry (and even science) graduates: IP, DIISRTE, TGA, CSIRO, and the APVMA.

3.3.2 Sample size

According to the RSC ANU administration, the total number of people in the RSC ANU, including students and staff, 650-700 at the time of data collection. Ideally, to have been able to report the results with confidence, the margin of accepted error should equal ±5%, which would have meant that the number of respondents needed would be between 248 and 255 respondents (SurveyMonkey, n.d.).

3.3.3 Identification of participants

Participants in this study were identified in a number of ways: chemistry students up to third year were not identified, but self-selected. They were visited in their lecture theatres and told about the research project and asked if they would like to complete the online survey. The online survey links were also posted on the respective Wattle course pages with the permission of the course convenors.

Fourth year Honours students and onwards were identified and contacted via the RSC ANU administrator who sent a central email to all RSC ANU professional staff (including administrative, workshop, technical), academic staff (including Group Leaders, Post-doctoral Fellows, Research Officers, Research Fellows), Masters, Doctoral, and Honours students. The participants were also reminded to complete the survey one week from the initial invitation through the RSC ANU administration once again. Furthermore, the Director of the RSC ANU assisted by sending an email to all participants to participate in the research. In addition, the survey invitation and link were posted on the

RSC ANU public website, and yellow paper slips with the survey link were handed out to students in their lecture theatres, tutorials, laboratories, and drop-in centres. Student consent to participate was indicated by the submission of the online survey.

RSC ANU staff were identified through the RSC ANU website and were contacted via email where they were provided with information sheets detailing the nature of the research project (please see Appendices).

Chemical industry employers were identified through the Graduate Destination Surveys. They were contacted via email and phone where they were provided with information sheets detailing the nature of the research project (please see Appendices).

Staff and industry provided consent in writing and orally. A copy of the consent form is provided in the Appendices.

3.4 Ethical considerations

The ethical aspects of this research were approved by the ANU Human Research Ethics Committee. Please see Appendices for the information sheets and consent forms offered to the participants.

3.5 Approach to analysis of results

The approach to analysing the results was done so that it answered the posed research questions in the most appropriate way. To reiterate, the research questions for this study were:

1. How important are the graduate attributes perceived to be by the stakeholders of Australian tertiary chemistry education: students, staff, and industries?
2. How competent are students perceived to be at the graduate attributes by themselves, and by the remaining stakeholders of Australian tertiary chemistry education: staff and industries?

Following this, the findings of this study were analysed:

1. Per stakeholder group, to see what the perception of the relevance of the graduate attributes to Australian tertiary chemistry education is according to each one.

2. Across the three main stakeholders groups, to compare and see if and how they differ regarding their perception of the relevance of the graduate attributes to Australian tertiary chemistry education.

For the ratings given in the online surveys and the interviews, numeric findings were analysed by identifying trends and patterns in the data, similar to the analysis approach by Ashman et al. (2008). This numeric data was then placed in context by examining the responses to the short-answer type questions for the online survey and extracting general themes based on recurring keywords, using SurveyMonkey's search and filtering options. For the responses to the short-answer type questions in the interviews, notes were taken for recurring keywords in addition to emerging themes. This data was then organised by stakeholder group, based on the questions they were asked, and substantiated with the respective quotes by the participants (as per Purcell et al. (2008)).

Chapter 4: Results

4.0 Introduction

The previous chapter described the methodological approach used for this project. This chapter will provide and compare the results of this study.

It will describe the data demographics, and then provide the results and their comparisons by stakeholder group.

4.1 Demographics

4.1.1 Student stakeholder group

The total number of students who completed the online survey was 105 (n=105) students. Because both students and staff members of the RSC ANU were invited to complete the online survey, this meant that the total student population was between 650 to 700 participants. This means that 15%-16% of the total population at the RSC ANU completed the survey.
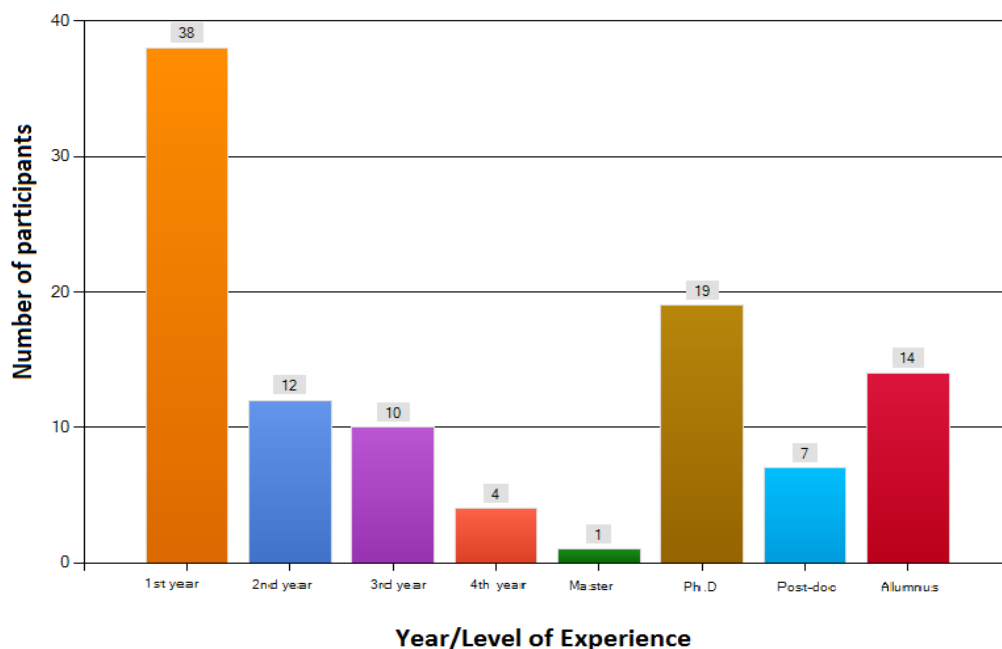
Figure 1: Breakdown of student respondents by year/level of experience

Figure 1 shows the breakdown of student respondents by year/level of experience. Of the 105 students who completed the survey, 38 were first years, 12 were second years,

10 were third years, four were fourth years, one was a Master student, 19 were doctoral scholars, seven were post-doctoral fellows, and 14 were alumni.

4.1.2 Staff stakeholder group

The RSC ANU staff stakeholder group was comprised of 10 participants, who ranged from teaching, to research, and to technical staff.

4.1.3 Industry stakeholder group

The industry stakeholder group was comprised of 7 participants from IP, DIISRTE, TGA, CSIRO, and the APVMA.

4.2 Results from the student stakeholder group

4.2.1 Quantitative results

Observations and trends were drawn from the student ratings of importance of and self-rated competence at the graduate attributes.

The Master student's rating for all analyses was combined with the doctoral ratings, since it was statistically not significant, and would have skewed the results.

The student ratings of the perceived importance of graduate attributes, across first year level to alumni, are summarised in Table 6 and graphed in Figure 2:

Table 6: Ratings of students' perceived importance of the ANU science graduate attributes, by year

	1st Year	2nd Year	3rd Year	4th Year	Ph.D	Post Doc	Alumni
Scientific Analysis	4.45	4.25	4.7	4.5	4.75	4	4.43
Problem Solving	4.32	4.33	4.7	4.75	4.7	4.29	4.36
Communication	3.97	3.75	4.3	4	3.5	4	4.21
Teamwork	3.53	3.42	4	4	3.25	3.71	3.64
Professionalism	3.53	3.17	3.8	3.75	3.5	3.57	3.93
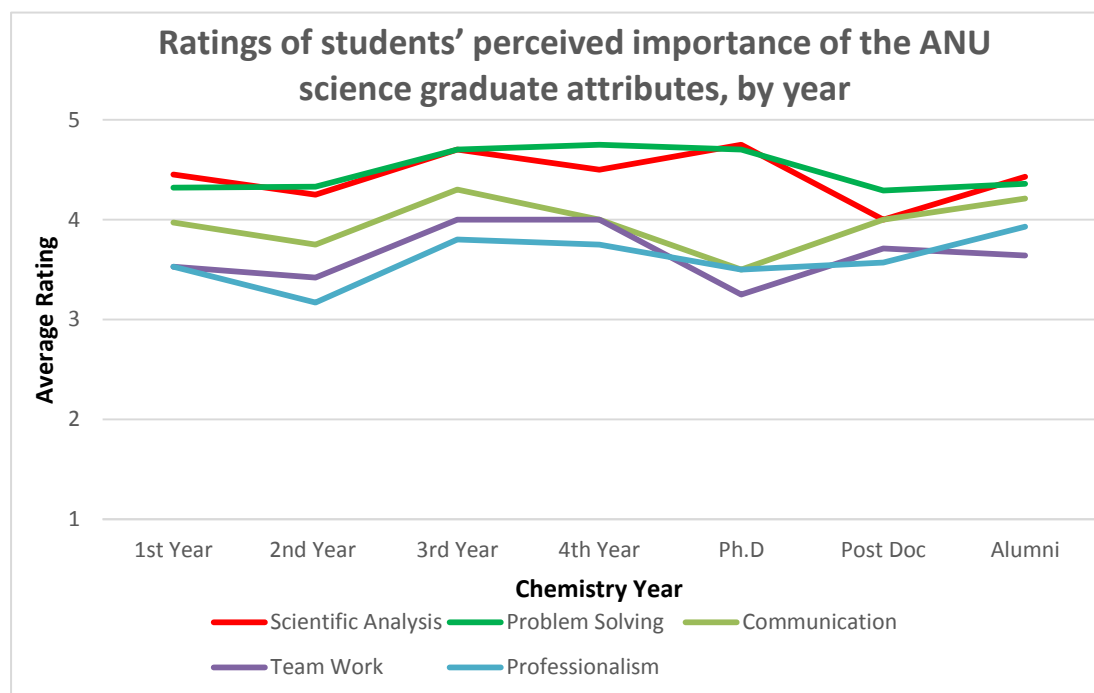
Figure 2: Ratings of students' perceived importance of the ANU science graduate attributes, by year

The first trend that appears here is that from first year to alumni level, the scientific analysis and problem solving attributes are consistently rated more highly than communication, teamwork, and professionalism. The highest ratings for scientific analysis and problem solving are 4.75 (Ph.D) and 4.75 (Honours) respectively. The lowest ratings for these two attributes are 4.0 (Post-doc) and 4.29 (Post-doc) respectively.

In comparison, communication's highest rating is 4.3 (third year), teamwork's highest rating is 4.0 (third and fourth year), and professionalism's highest is 3.93 (alumni); which are equal to or less than the lowest ratings given for scientific analysis and problem solving.

The second observable trend is the decline in the perceived importance of the attributes from first year to second year level, and then their recurring increase in third year level. However, at the Honours level, the perceived importance of scientific analysis declines and that of problem solving increases to its highest peak at 4.75.

The third observation that can be made is the rather high ratings for scientific analysis and problem solving and the low ratings for the remaining attributes for the doctoral scholars. However, the ratings for the former two attributes then decline again, with scientific analysis being perceived to be as equally important as communication (ratings of 4.0 and 4.0 respectively), and the ratings for all attributes appearing to cluster together for the post-doctoral fellows.

Table 7: Ratings of students' perceived self-rated competence at the ANU science graduate attributes, by year

	1st Year	2nd Year	3rd Year	4th Year	Ph.D	Post Doc	Alumni
Scientific Analysis	3.47	3.92	3.4	3.25	3.5	3.43	4.14
Problem Solving	3.55	3.83	3.5	3.5	3.65	4	4.43
Communication	3.58	3.25	3.7	3	3.4	3	4.21
Teamwork	3.42	3.75	3.7	3.5	3.15	3.43	3.93
Professionalism	3.45	3.42	3.6	3	3.2	3.71	3.86
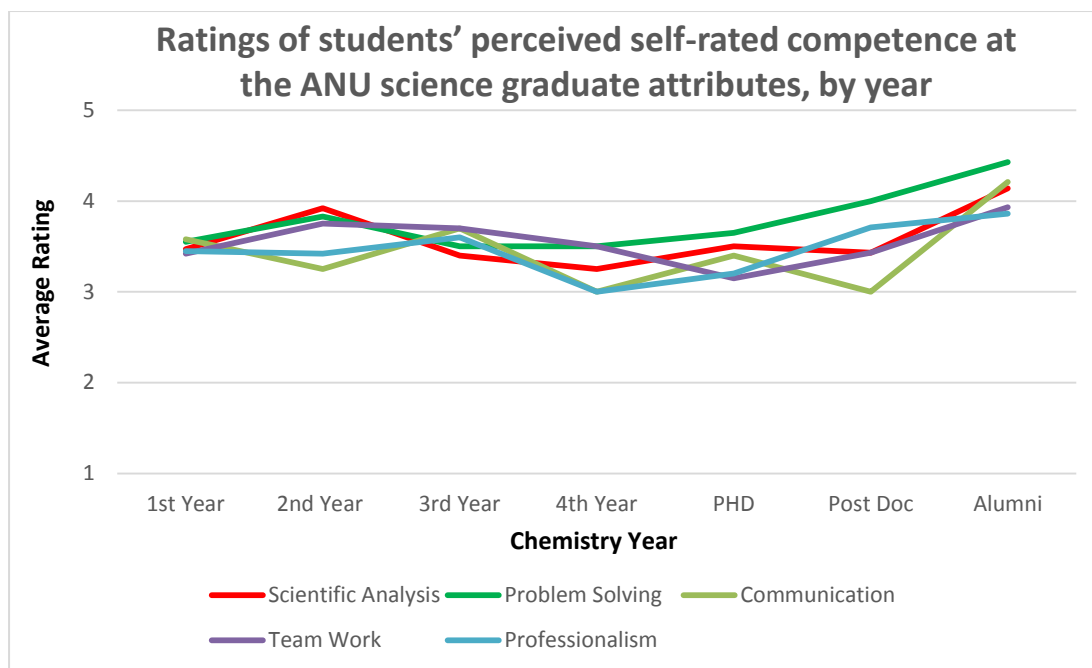
Figure 3: Ratings of students' perceived self-rated competence at the ANU science graduate attributes, by year

Table 7 shows that in terms of their perceived self-rated competence at the graduate attributes, the first point to note is that most students self-rate themselves towards competence: all ratings are above three on the Likert scale of five.

By graphing and comparing the ratings in Figure 3, the second trend that can be seen is that the ratings of the second years are higher than those of the doctoral scholars in all of the graduate attributes, with the exception of communication skills.

The third observation is the lower ratings for Honours students at scientific analysis, communication, and professionalism.

Post-doctoral fellows appear to rate themselves highly in problem solving, but relatively lowly in communication.

Finally, the alumni appear to rate themselves as the most competent group across all years.

4.2.2 Qualitative results

Observations and trends were drawn from the student responses to the short-answer type questions. From these answers, general themes have been drawn, substantiated with indicative quotes, and the number of responses containing keywords representative of these themes.

1. **What is the purpose of university chemistry education?**

    Students perceive the purpose of chemistry education to teach chemistry in order to provide knowledge about the world and other sciences. It is also perceived to prepare one for a career in academia or industry, and should provide skills such as communication, critical thinking and problem solving.

    Number of responses containing representative keywords: teach = 17; knowledge = 25; world = 15; science = 17; career = 12; industry = 13; research = 33; skill = 17.

    "To develop skills and knowledge that can be applied to not only to acaedmic chemistry research but also to (but not limited to) private industry and the public sector." – Chemistry alumnus

    "I imagine it is different for every student. Some students will study chemistry to support their biology/psychology/physics/medicine studies, some students will take chemistry for interest, some people may want to go on in industry and some may want to go onto chemistry research." – Third year student

    "To equip students with a sufficiently high understanding of chemical concepts such as reactions, reactivities and properties of compounds and technical skills for good laboratory competence so that they may be well-prepared to work at a high level in industry or academia." – Ph.D scholar

2. **Why are you doing chemistry? (for alumni, why have you done chemistry?)**

    Students study chemistry out of interest or to pursue a chemistry or science-related career in order to better the world. Some students commented that they study chemistry since it is a compulsory subject, but most of those respondents said that they enjoyed it.

    Number of responses containing representative keywords: interest = 44; career = 8; better AND world = 2; compulsory = 4.

    "Because it is interesting and you can't study science if you don't have a background/ understand chemistry." – First year student

"I found it both interesting and challenging." – Chemistry alumnus

"to build a solid foundation in a range of science subjects" – First year student

3. **What do you like most about your chemistry experience so far? (for alumni, what did you like most about your chemistry experience?)**

    Several students enjoy the problem-solving aspect of chemistry as well as the laboratory work, and find the support of the RSC ANU staff to be of high standard.

    Number of responses containing representative keywords: problem OR solve = 7; lab = 16; support OR lectures = 17.

    "Great lecturers, very well organised course material and supportive academic staff. Makes all the difference when it comes to stirring interesting in students" – First year student

    "The labs - hands on." – Ph.D scholar

    "being given the tools to solve complex problems." – First year student

4. **What do you dislike most about your chemistry experience so far? (for alumni, what did you dislike most about your chemistry experience?)**

    Some students dislike the rote-learning aspect of the courses and the large workload of exams and excessive laboratory reports.

    Number of responses containing representative keywords: rote OR memorisation = 2; workload OR work OR report OR exam = 15.

    "The workload! Ugh." – First year student

    "So much rote learning" – Ph.D scholar

5. **What skills do you hope you'll get at the end of this chemistry experience? (for alumni, what skills did you get at the end of your chemistry experience?)**

Students appear to expect a variety of skills at the end of their chemistry experience. These skills appear to be mostly laboratory- and research-related, and also generic in nature.

Number of responses containing representative keywords: lab OR research = 29; communication OR teamwork OR problem OR solving = 20; scientific OR analysis OR critical OR thinking OR = 15

"I gained the skill to think critically from a chemistry perspective and an increased understanding of nomenclature and basic concepts in chemistry." – Chemistry alumnus
"critical thinking, lab-related abilities and skills, research design, and passion" – First year student
"Specific laboratory skills - critical thinking, researching, creativity in problem solving - written and oral communication skills" – Third year student

6. **Are there any changes that can be made to improve your experience in chemistry? If so, what are they? (for alumni, what changes would you have recommended or liked to have seen?)**

Some students appear to want a curriculum that involves more training at skills such as communication, and a greater degree of mathematics integration.

Number of responses containing representative keywords: curriculum = 3; math OR mathematics = 6; skill OR communication = 12.

"a curriculum that focussed more on skills appropriate to industry." – Chemistry alumnus
"Chemistry and ANU should be structured to provide skills that are desired in the work force. A structured curriculum would allow us to target work place skills and produce graduates of high importance to the work force." – Ph.D scholar
"More emphasis on research skills in undergrad, such including reading literature." – Ph.D scholar

Tables 8 and 9 represent student ratings, as a whole group, of the importance of the attributes and self-rated competence at the attributes. These tables largely show the same trends as per described above: Table 8 shows that students appear to perceive scientific analysis and problem solving (ratings of 4.48 and 4.45 respectively) as more important than communication, teamwork, and professionalism (ratings of 3.92, 3.55, and 3.57 respectively). Table 9 shows that students appear to rate themselves towards competence, with no rating below three on the Likert scale of five. The highest rating goes to problem solving at 3.74 and the lowest is for professionalism at 3.47.

Table 8: Average ratings of students' perceived importance of the ANU science graduate attributes, where 1 is not at all important and 5 is extremely important

	1	2	3	4	5	Rating Average	Rating Count
Scientific Analysis	2.9% (3)	1.0% (1)	4.8% (5)	28.6% (30)	62.9% (66)	4.48	105
Problem Solving	1.9% (2)	1.9% (2)	4.8% (5)	32.4% (34)	59.0% (62)	4.45	105
Communication	2.9% (3)	6.7% (7)	17.1% (18)	41.9% (44)	31.4% (33)	3.92	105
Teamwork	8.6% (9)	7.6% (8)	31.4% (33)	24.8% (26)	27.6% (29)	3.55	105
Professionalism	4.8% (5)	10.5% (11)	30.5% (32)	31.4% (33)	22.9% (24)	3.57	105

Table 9: Average ratings of students' perceived self-rated competence at the ANU science graduate attributes, where 1 is not at all competent and 5 is extremely competent

	1	2	3	4	5	Rating Average	Rating Count
Scientific Analysis	4.8% (5)	6.7% (7)	29.5% (31)	41.9% (44)	17.1% (18)	3.60	105
Problem Solving	1.0% (1)	9.5% (10)	27.6% (29)	38.1% (40)	23.8% (25)	3.74	105
Communication	3.8% (4)	13.3% (14)	27.6% (29)	35.2% (37)	20.0% (21)	3.54	105
Teamwork	3.8% (4)	10.5% (11)	32.4% (34)	38.1% (40)	15.2% (16)	3.50	105
Professionalism	6.7% (7)	12.4% (13)	29.5% (31)	30.5% (32)	21.0% (22)	3.47	105

4.3 Results from the staff stakeholder group

4.3.1 Quantitative results

Observations and trends were drawn from the staff ratings of the importance and the competence of RSC ANU students at the graduate attributes. The ratings have been summarised in Tables 10 and 11:

Table 10: Ratings of staff's perceived importance of the ANU science graduate attributes that chemistry students should posses

	1	2	3	4	5	Rating Average
Scientific Analysis	0	0	1	3	6	4.50
Problem Solving	0	0	1	5	4	4.30
Communication	1	3	2	1	3	3.20
Teamwork	4	3	1	1	1	2.20
Professionalism	2	3	3	0	2	2.70

Table 11: Ratings of staff's perceived competence of chemistry students at the ANU science graduate attributes

	1	2	3	4	5	Rating Average
Scientific Analysis	1	3	0	2	3	3.33
Problem Solving	1	1	2	1	4	3.67
Communication	4	3	0	1	1	2.11
Teamwork	1	0	5	2	1	3.22
Professionalism	2	2	3	2	0	2.56

The trend observed from the data in Table 10 is that staff perceive scientific analysis (4.50 rating) and problem solving (4.3 rating) to be more important attributes for

chemistry students to possess than communication (3.2 rating), professionalism (2.7 rating), and teamwork (2.2 rating).

From Table 11, it can be seen that staff appear to perceive RSC ANU students to be more competent at problem solving (3.67 rating) and scientific analysis (3.33 rating) than teamwork (3.22 rating), professionalism (2.56 rating), and communication (2.11 rating).

4.3.2 Qualitative results

Observations and trends were drawn from the staff responses to the short-answer type questions. From these answers, general themes have been drawn, substantiated with indicative quotes. Quotes were not attributed, in order to preserve anonymity, because of the small sample size of this cohort.

1. What is the purpose of university chemistry education?

Staff perceive the purpose of chemistry education to education people in the chemistry skills needed to obtain a professional degree in order to work in academic research and in industry. It is also perceived to teach people how to learn, and to provide soft skills like communication, critical thinking, and analysis; as well as make people aware of chemistry more broadly.

"Probably two-fold: One, to provide people with some chemistry content knowledge, so they can be critical of chemistry that's in the newspaper or the media, so they can make intelligent decisions and participate in intelligent discussions. Probably also some skills, graduate skills, the ability to write, the ability to debate, interpret, analyse, evaluate material, as well. And probably third, motor skills, very important as well, lab skills".

2. What do you think of the current chemistry curriculum at university (in general & ANU)?

Staff perceive ANU chemistry education to be quite good, with it being largely consistent across the major Australian universities. However, it is perceived that more work needs to be done, particularly in the areas of instrumentation, wet chemistry skills, and physical/theoretical chemistry where [for physical/theoretical chemistry] content is

weak because of mathematics being a non-compulsory subject for science students at ANU.

It also seems the case that for research universities, the laboratory skills gained are academic in nature, and are rather different to the hands-on practical skills that industry focuses on. However, universities like UTS and RMIT generate graduates that are better equipped to work in industry, due to the more technical nature of those universities. In terms of the graduate attributes, ANU could improve at teaching those skills, particularly in the areas of oral and written communication. One staff member commented that chemistry students should be encouraged to do first year science communication, while three other staff members echoed a need for students to be more adept at mathematics, in order to be able to engage with subjects like physical chemistry. A few staff members remarked that the undergraduate chemistry curriculum is already packed with information for a three-year degree, making it difficult to dedicate the necessary time and resources to train students not only in the graduate attributes, but also in other important research skills in chemistry such as data-mining, literature navigation, and referencing; in addition to using chemical structure drawing software packages like ChemBioDraw. Some of those staff members believe that these time and resource constraints account for why some of that training is left for the Honours year; with one staff member mentioning the benefits of having a program such the UK Oxbridge program in Australia – where students are part of a college system that provides them with an academic social hub, in addition to more personalised teaching offered by their supervisors; a program that resembles the Bachelor of Philosophy program at the ANU.

"I think this place [ANU] is very good at putting forward research grad students that are going to go into the fields of study that the ANU does, but not good at providing students with the hands-on skills in modern analytical chemistry that will stand them in good stead in any chemical industry…"

"…graduate attributes, probably not so well, we probably don't equip our students well enough to be able to participate in those higher level activities like evaluating and analysing information, based on the three-year degree. We probably could do better."

"…the material we get across, generally speaking, is consistent from university to university, at least the major universities, the Group of Eight universities"

"ANU doesn't teach a course which could be viewed as instrumental methods. We don't do it."

"...I suppose Go8 universities don't cater so much for analytical chemistry."

"I think the curriculum is quite good, but missing some things. Theoretical physical content is quite weak because we aren't allowed to require anyone to do maths."

"I had a student who came from RMIT who was fantastic at analytical chemistry".

"... the best for hands on learning for laboratories within Australia I would be looking at the University of Technology…"

"A lot of other universities, run sandwich courses for instances University of Technology Sydney. They run sandwich courses in industry, so you spend 6 months in industry and then 6 months at the uni"

3. Are there any other strengths that chemistry students possess?

Staff perceive chemistry students to possess interdisciplinary strengths, to be contextual in their thinking, inquisitive, inventive, committed, and dedicated.

"Chemistry students seem to be more astute [than other students]"

"Their mind is trained in a very analytical manner which is adaptable to a lot of aspects"

4. Are there any other weaknesses that chemistry students possess?

Staff perceive students to have weaknesses in their mathematical capacities, housekeeping/environmental awareness, critical thinking skills, being grade-number driven as opposed to focusing on understanding the subject matter, self-absorption, and making connections between the other sciences.

"Certainly their scientific inquiry".

"This is more of a weakness in modern undergraduate as a whole as opposed to just chemistry. A lot of them are nowadays just grade number driven".

"Many of our students don't see themselves more broadly than the Australian context. They don't think of themselves as contributors to chemistry around the world".

5. What skills do you want your chemistry students to have at the end of the day?

The skills that staff want their students to have are the ability to work efficiently and professionally as a scientist both theoretically and practically, to have a basic fundamental knowledge of all branches of chemistry, learn how to learn, have passion, and good communication and critical thinking skills.

"I think at the BSc level we certainly want for people to graduate with reasonable confidence with basic areas of chemistry, understanding states of matter, doing calculations, stoichiometry, all those basic things, and lab skills as well…"

"Broad attributes, I want them to be able to communicate well… and also [have] problem solving capabilities".

4.4 Results from the industry stakeholder group

4.4.1 Quantitative results

Observations and trends were drawn from the industry ratings of the importance and the competence of chemistry graduates at the graduate attributes. The ratings have been summarised in Tables 12 and 13:

Table 12: Ratings of industry's perceived importance of the ANU graduate attributes that chemistry graduates should possess, with 1 being not at all important and 5 being extremely important

	1	2	3	4	5	Rating Average
Scientific Analysis	1	0	0	2	4	4.14
Problem Solving	0	0	1	1	5	4.57
Communication	0	1	3	1	2	3.57
Teamwork	1	0	2	2	2	3.57
Professionalism	3	4	0	0	0	1.57

Table 13: Ratings of industry's perceived competence of chemistry graduates at the ANU science graduate attributes, with 1 being not at all competent and 5 being extremely competent

	1	2	3	4	5	Rating Average
Scientific Analysis	1	2	1	1	0	2.40
Problem Solving	2	1	3	0	0	2.60
Communication	2	0	1	1	1	2.80
Teamwork	2	1	1	0	1	2.40
Professionalism	1	1	0	2	1	3.20

The trend observed from the data in Table 12 is that industry perceives problem solving (4.57 rating) and scientific analysis (4.14 rating) to be more important attributes

for chemistry graduates to possess than communication (3.57 rating), teamwork (3.57 rating) and professionalism (1.57 rating).

From Table 13, it can be seen that industry appears to perceive chemistry graduates to be most competent at professionalism (3.20 rating), followed by communication (2.80 rating), problem solving (2.60 rating), scientific analysis (2.40 rating), and teamwork (2.40 rating).

The second point to note is that industry do not perceive chemistry graduates to be very competent: all ratings are below three on the five-point Likert scale, with the exception of professionalism.

4.4.2 Qualitative results

Observations and trends were drawn from the industry responses to the short-answer type questions. From these answers, general themes have been drawn, substantiated with indicative quotes.

1. What is the purpose of university chemistry education?

Industry perceives the purpose of university chemistry education to raise students' awareness of the world of chemistry, hone their critical thinking, problem solving, and writing skills, and enable them to take these skills and knowledge to any type of workforce, whether it be academic, governmental, or industrial. However, they do not think that that training is directed towards industry, with graduates lacking a wider scientific view of matters, lacking the hands-on wet chemistry and instrumentation skills necessary for industry-grade laboratory work, and being unable to think outside of the box.

Several industry members shared the sentiment for more university/industry collaboration. One interviewee said that they desired if universities provided students knowledge on applied chemistry in industry, perhaps in the form of a contemporary industrial chemistry course, offered by ANU, that would make the university and its chemistry graduates more sought after. Another interviewee mentioned that all is required for such a collaboration is to set up one meeting or a workshop, where industry employers could meet staff at the RSC ANU, and start the discourse.

"I expect them to be able to write. They should be able to look at a cabinet submission, analyse it, and be able to say, in one page or less, what the cabinet's submission is talking about. So for someone who has done a science degree, I would assume it is very structured, I would assume they would have to do a lot of analytical thinking and try to distil what the core issues are." – Generalist employer

"At the undergraduate level, I'd say the purpose is to give students a broad grounding in, chemistry concepts, and fundamentals, to then give them the skills to either decide to specialise in an area that is of particular interest to them, or to use these skills in a sort of work-place environment." – Specialist employer

"If ANU asked me to give them a chat about what industry wants, yeah I'll let anybody know." – Specialist employer

2. In your experience, are there any other strengths that chemistry graduates possess?

In terms of strengths, most industry members agreed that chemistry graduates are highly motivated and enthusiastic individuals.

"Communication skills." – Generalist employer

"They seem confident in taking challenges in the work, and they are motivated." – Specialist employer

3. In your experience, are there any other weaknesses that chemistry graduates possess?

Several industry employers commented that a significant amount of on-the-site training is required to raise university chemistry graduates to the industry-level of performance, particularly in the areas of wet chemistry and instrumentation skills. One interviewee in specific had worked with chemists in pharmaceutical labs, and said that 90% of students in a pharmaceutical lab company were ill-prepared and under-skilled for real world pharmaceutical science and basic chemistry skills were non-existent. One

interviewee compared chemists to chemical engineers, noting that chemists do not focus so much on professional standards, science ethics, and reporting in the same way that chemical engineers do.

"I think chemistry graduates would benefit from having as wider scientific view as possible, because so many applications for the chemists these days cross into the areas of biochemistry or biology…" – Specialist employer

"When it comes to a skilled person, say a three-year degree, it would take you at least 5 years for that individual to be able to do the work unsupervised." – Specialist employer

"There's a lot of elements of the public service that are process-focussed and I think you could argue that some of the science people would be less interested in some of the very process-focussed stuff". – General employer

4. As an industry leader, what do you expect of chemistry graduates that you would employ?

Industry employers expect chemistry graduates to be all-rounded, professional, to possess strong work ethics, and an understanding of the organisation's goals and culture. They also expect them to be able to work both in teams and individually, and to have an open-mindedness, willingness, and ability to learn new information. Problem solving, communication, and critical thinking skills also rank highly on industry's list of desired graduate attributes.

"If it was a science person, I'd expect them to be very structured. I expect them to have very strong analytical skills, open-minded, think outside the box, be a little bit innovative, and be confident to put up ideas but not arrogant".

"I think open-mindedness, enthusiasm, willingness to learn, ability to learn, ability to unlearn, and the ability to enjoy yourself".

4.5 Stakeholder group results compared

Ratings for the perceived importance of and student competence at the ANU science graduate attributes have been summarised and compared in Figures 4 and 5 respectively:
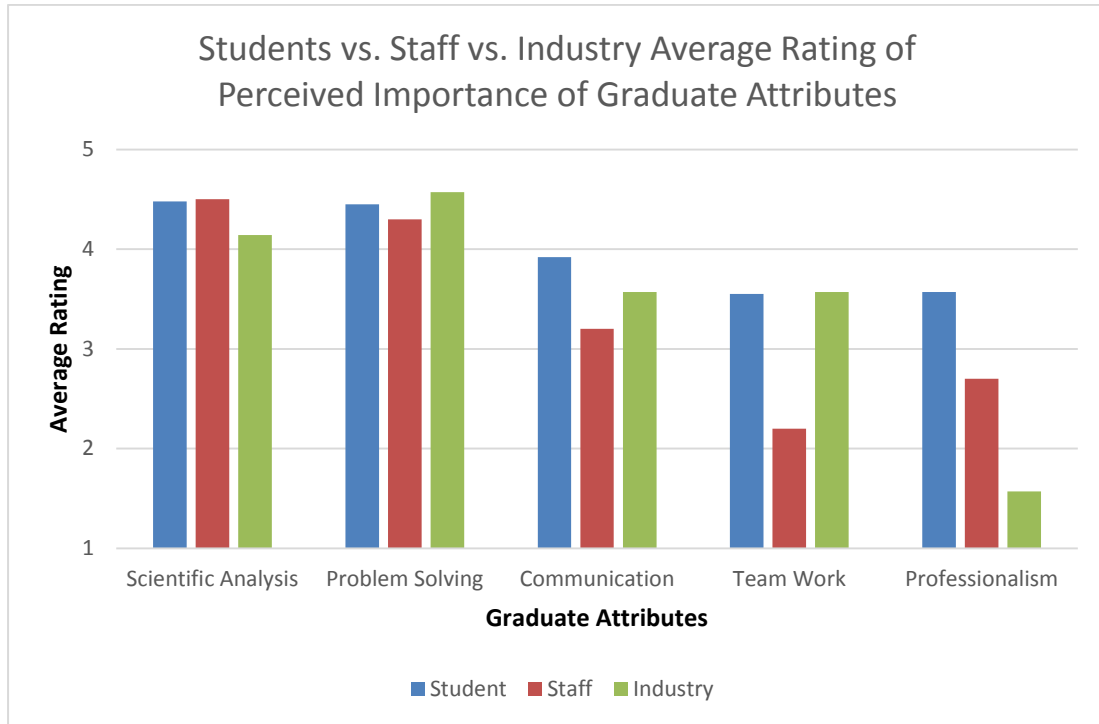

Figure 4: Students vs. Staff vs. Industry Average Rating of Perceived Importance of Graduate Attributes
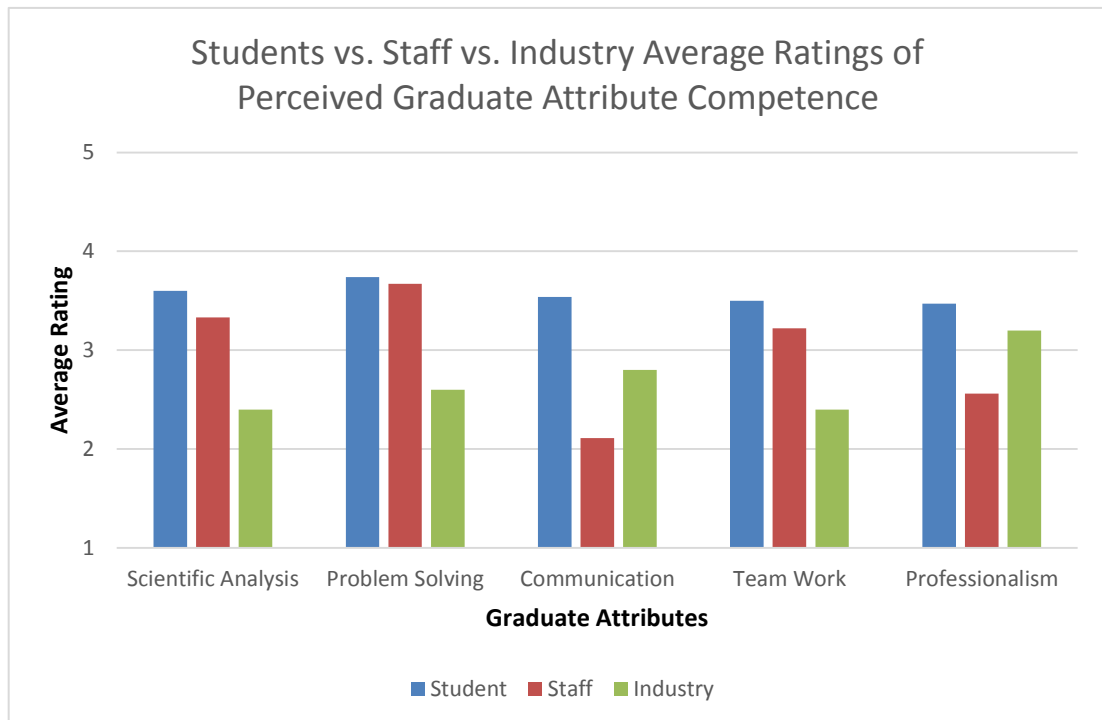

Figure 5: Students vs. Staff vs. Industry Average Ratings of Perceived Graduate Attribute Competence

What is observed upon comparing the ratings of all three stakeholder groups is that in the same way all students perceive scientific analysis and problem solving to be the two most important skills of all the graduate attributes, the same trend is observed across the staff and industry stakeholder groups as well. And of the three remaining graduate attributes, communication is the skill that is consistently rated as the most important skill across all stakeholder groups.

However, in terms of perceived student competence at the graduate attributes, a more interesting trend emerges: there seems to be a steady decline in the perceived student competence at the attributes in the order of students, staff, and industry. Students, as mentioned previously, rate themselves towards competence, while staff on the other hand do not agree with them, and perceive them to be less competent. This decline goes further with industry, which gives students even lower competence ratings than those given by staff, with the exception of communication and professionalism – industry perceive students to perform better in these areas than staff. It is worth noting here that while staff perceive teamwork to be less important than professionalism, and industry perceives teamwork to be more important than professionalism; the inverse is seen in terms of perceived student competence in these areas – staff find students to be better at teamwork than professionalism while industry finds graduates to be weaker at teamwork than professionalism.

Chapter 5: Discussions and Conclusions

5.0 Introduction

Chapter 4 of this thesis provided the results and findings of this project. This chapter will analyse and explain the results, explain the limitations of the study, offer future recommendations, and finally, conclude the thesis.

5.1 Discussion

This section attempts to explain the results of this study in two separate categories in terms of the stakeholders' perceived importance of the graduate attributes, and the stakeholders' perceived student competence at the graduate attributes. However, where appropriate, cross-references from either category were made in order to better weave the themes and trends together.

5.1.1 The perceived importance of the graduate attributes by the stakeholders of Australian tertiary chemistry education: students, staff, and industries

Tomlinson (2008) described that today's students want a variety of skills in order to fit better with the demands and selection criteria of employers. The students in this study were no different, as they too expected to be armed with a range of skills that would prepare them for a variety of careers, by the time they finished their chemistry studies. However, they still did perceive scientific analysis and problem solving to be more important than the remaining attributes, which largely goes in line with the findings of Varsavsky et al. (2014).

It is difficult to give concise explanations for the above findings, however. Students may seem to find scientific analysis and problem solving as the two most important skills due to the nature of the undergraduate chemistry curriculum - as pointed out by some of the interviewed staff, more work could be done at the undergraduate, particularly, pre-Honours years to strengthen skills such as oral and written communication. Hence, in an undergraduate chemistry curriculum that largely focuses on students completing exams and laboratory reports in order to progress academically (the workload was a recurring complaint among students), students may selectively value the skills that would help them the most at completing those tasks. As pointed out by Mc Goldrick et al. (2013),

chemistry students at the University of Dublin were only giving presentations in their final year of study, similar to the chemistry-student experience at the ANU. Perhaps that could account to the rise, specifically, in the perceived importance of communication from first year to third year chemistry, as students are faced with their very first presentation to an academic chemistry audience, within a research context. However, this observation does not go in-line with the doctoral scholars' ratings: Ph.D candidates in chemistry are required to demonstrate strong oral and written communication skills as part of their research, yet the ratings for communication for the doctoral cohort in this study are quite low. Ph.D candidates also perceived teamwork to be their least important skill. This may be due to the perception of chemistry being largely an insular and self-absorbed subject, as one staff member pointed out. This, coupled with the fact that a Ph.D can be a long, personal, and self-absorbed journey, may account for the perceived low importance of teamwork.

Other trends that appeared in the ratings of the student cohort are more difficult to explain. It is unclear why the perceived importance of the graduate attributes overall declines from fist year to second year chemistry, and then rises again in third year. Ratings of the perceived importance of the attributes for post-doctoral fellows appeared to cluster altogether, and they rated their perceived competence at problem solving much higher than their communication skills, but it is unclear why. Analysing first, second, third year, and post-doctoral responses to the experiences they disliked most in chemistry did not seem to reveal general trends or themes that could explain those findings.

Despite students wanting a variety of skills upon graduation, the RSC ANU is largely focussing on the discipline specific skills; a finding that agrees with the reviewed literature for this research (as per Bridgestock, 2009 as cited by Herok et al., 2013; Weiman, 2007; Wood, 2009 as cited by Varsavsky; Matthews, & Hodgson, 2014; Runquist & Kerr, 2005). Like the students, RSC ANU staff perceive scientific analysis and problem solving to be more important than the remaining graduate attributes. Nevertheless, several staff members did comment that the RSC ANU should improve the training of the other attributes such as communication, except that an already-packed curriculum, lack of time, and a lack of resources are some of the hindrances to this.

As with students and staff, industry members in this study perceived scientific analysis and problem solving to be more important than communication, teamwork, and professionalism. This does not come as a surprise, considering that the five out of the

seven employers interviewed were specialist employers, and as determined by *The Chemical Skills Pipeline* report (Purcell et al., 2008), these employers seek graduates with particular disciplinary skills. Though almost all employers is this study wanted chemistry graduates with a variety of skills, as per described in Runquist & Kerr (2005).

5.1.2 The perceived competence of chemistry students at the graduate attributes by the remaining stakeholders of Australian tertiary chemistry education: staff and industries

As previously described, students in this study rated themselves towards competence. Of particular interest is how the second years perceive themselves as more competent than the doctoral scholars at professionalism, teamwork, problem solving, and scientific analysis. One industry employer commented that in her experience, Ph.D graduates demonstrated higher levels of maturity and sophistication compared to the standard baseline science graduate. This could account to the above discrepancy between the second year chemistry students' and doctoral scholars' self-perceived competence ratings.

Of all the students within this stakeholder group, the Honours students perceived themselves to be the weakest at scientific analysis, communication, and professionalism. They were also the students to perceive problem solving as the most important attribute. This could be accounted for by the fact that an Honours year in general, is seen as both a pivotal and transitional year in a student's academic career, where the student shifts from being a passive receiver of knowledge, to an active generator of knowledge. From anecdotal evidence, the Honours year is seen as a highly challenging, intense year, with the stakes for the students being very high – it largely determines a student's future academic research career. This all perhaps explains why the Honours students perceive their own competence to be as such in this study.

A final observation for the student cohort is the rather high perceived self-rated competence of the alumni cohort. It was discovered through the course of the research that several chemistry staff members of the ANU completed the student online survey as alumni; which could account to these high ratings.

The results of this study also showed a discrepancy between the competency ratings of students and those of industry. The findings here agree with those of Ashman et al. (2008) and more generally with the evidence in the media sphere (Big Think, 2013;

Chegg, 2013). This discrepancy could mean that there is a disconnect between the skills offered at university and those needed in industry. Particularly according to the reviewed literature, it was anticipated that students be perceived by industry as weaker at communication, reasonably adept at their analytical and problem solving skills, with perhaps being deficient in industry-specific wet chemistry and instrumentation skills. In *The Chemical Skills Pipeline* (Purcell et al., 2008), industry employers found chemistry graduates' analytical and numeracy skills to be their strengths, their communication skills to be deficient, with some specialist employers perceiving a lack in wet chemistry and instrumentation skills. Ashman et al. (2008) showed that chemical engineering graduates' communication and business skills were perceived to be the most deficient from the point of view of industry. This does not seem to be the case in this study, however. In fact, industry rated students' communication skills as slightly better than their scientific analysis and problem solving skills. Staff on the other hand are in greater agreement with students regarding their perceived competence at scientific analysis and problem solving compared to industry. As pointed out by a few of the interviewed staff members, the university sector provides training in the skills needed for the university sector, but not so much for the industry one; that chemistry students who study at technically oriented universities are more adept at the wet chemistry and instrumentation skills that industry ever so desires. Specialist industry employers interviewed in this study also shared the sentiments of these staff members, mentioning that most chemistry graduates require significant amounts of on-the-site training to reach the industry-standards; urging universities to revive courses such as analytical chemistry that would offer students industry-grade training; or courses on contemporary industrial chemistry, in order to contextualise students' university chemistry knowledge. This could explain the rather low industry ratings of perceived student competence at those skills, and the disconnect between the staff and industry views on this matter.

5.2 Limitations

A limitation for this study is the small number of respondents to the online survey – a smaller number means that the results are less representative of the total population.

This was mitigated by including short-answer type questions within the online survey, providing information-rich qualitative data to the quantitative data.

During the course of the data collection, it was discovered that people were using the terms 'rating' and 'ranking' interchangeably. If someone ranked the importance of graduate attributes instead of rating them, then what we receive is the relative importance of the attributes to one another, rather than their individual importance. A respondent may still highly value all the attributes, but ranking them may make it appear that the respondent's lowest rank has the least rating, and hence, may seem unimportant. The approach used in this project to minimise this issue is by treating the responses as ratings and making an inferred ranking from them – if participants rated as instructed, then the rating will create a ranking order. If participants ranked, then the ranking and inferred ranking will be the same.

RSC ANU staff may have potentially been biased in their evaluations of their own chemistry curriculum that they wrote and their own students whom they teach. This was mitigated by interviewing a number of RSC ANU staff from different areas within the school (teaching staff, research staff, and technical staff), providing a more holistic and less one-sided snapshot of staff's perception of the purpose of chemistry education.

It was discovered that several Alumni respondents for the online survey were chemistry staff members at the ANU, who viewed themselves as past students of the ANU or past students of chemistry, and decided to complete the survey from the Alumni point of view. A possible limitation of this is that these respondents may be basing their observations and evaluations on an outdated chemistry curriculum; which may not correlate with the current standards. Furthermore, their self-rated perceived competence is rather high and may have skewed the competence data.

Another potential limitation is the fact that the industries selected for this project were mainly Government departments, and the industry stakeholder group lacked the large scale chemical or pharmaceutical companies that would employ chemistry graduates. The major reason for this is the location in which the research was taking place: being based in based in Canberra, seeking Government departments that employed chemists was the natural approach. However, these departments were not all generalist in nature – departments such as IP, TGA, APVMA, and CSIRO seek specialised science graduates.

Due to project time constraints, the absence of proper statistical analyses in this study is another limitation. This diminishes the robustness of the results and how representative they are, meaning that this study's findings are only indicative.

5.3 Recommendations

Since universities such as the ANU have adopted the graduate attributes into their teaching and learning structures, one can assume that that burden of responsibility rests on their shoulders. Following this point, several steps need to be taken in order to ensure that our chemistry graduates are prepared for a career in both academia and industry.

Universities in Australia need to develop methods to improve chemistry students' critical thinking, problem solving, and specific analytical chemistry skills.

In order to address the deficiencies in wet chemistry and instrumentation skills, reviving courses such as analytical chemistry should help alleviate those specific problems; particularly if these courses are developed with an awareness of the 21st century chemical industry requirements.

Exposing chemistry students to industry in the form of an internship, for example, may help them take their chemistry knowledge and skills from outside of the lecture theatre and academic laboratory, and apply them in the context of the chemical industry; potentially leading to improvements in students' generic and discipline-specific skills. Developing a contemporary industrial chemistry course could also perhaps be a great way to widen chemistry students' knowledge and increase their awareness of the latest activities in that field of chemistry; which in turn, may lead to smoother university-to-industry transitions and aid students in their scientific analysis and problem solving skills within that environment.

Ashraf et al. (2011) described the development of a soft-skills chemistry course to enable students for life beyond university. Not only did students report higher level of confidence in their soft-skills, but also faculty members who supervised them noticed a marked improvement in their research performance. Perhaps a course as such can be developed for the Australian chemistry student, similar to the chemistry course offered by the UWA, 'CHEM3001 – Essential Chemical Skills'.

Megehee et al. (2005) described a series of intercollaborative laboratory activities that helped university chemistry students mimic the industry environment, by breaking the traditional barriers created by the different silos of chemistry: organic, inorganic, and physical chemistry namely. The ANU, for instance, is renowned for combining the best students and staff from around the world into one setting. The ANU is in a prime position to not only borrow the approach used in Megehee et al. (2005) for its chemistry students, but also take it further and help chemistry students collaborate with students in biology, physics, and perhaps even medicine.

In the case of ANU, the university is also advantaged by virtue of the science communication courses that it offers. From analysing the impact of fiction on the dissemination of science, to dealing with the confronting issues that arise in science, risk, and ethics, ANU offers science communication courses to students from any academic background that encourage long-term learning, and potentially afford students skills that would help them both in their disciplines and later on in their careers. *Science in the Media*; in particular, can expose chemistry students to largely the same activities in diverse-audience writing as described in Sivey & Lee (2008); which ultimately helped chemistry students appreciate the difficulties of conveying scientific simply but without compromising content, to non-scientific audiences.

5.4 Conclusions

The aim of this study was to investigate the relevance of the graduate attributes to Australian tertiary chemistry education, from the point of view of chemistry staff, chemistry students, and industries that employ chemistry graduates.

According to this study, it appears that these stakeholder groups do find the graduate attributes to be relevant, except that some attributes are perceived to be more relevant than others. Students, staff, and industry place a higher premium on scientific analysis and problem solving skills, than on communication, teamwork and professionalism. Ironically, industry appears discontent with the performance of graduates in those two very attributes, particularly in the area of analytical chemistry. This does not mean; however, that the other three remaining attributes are unimportant – they are still desired by all the stakeholder groups.

Seeing that students expect that their university chemistry education to provide them with all of the necessary skills to function adeptly both in an academic and non-academic environment, it appears that only half of their desires are fulfilled. Students may be prepared for a career in academic research after extensive years of university chemistry training, but will most likely struggle if applying for industry positions that require industry-grade chemical knowledge, wet chemistry, and instrumentation skills.

If universities truly want their chemistry students to exit their walls as all-rounded graduates, then more work needs to be done to help them. Dialogue needs to start amongst and within the Australian tertiary chemistry education stakeholder groups. Internationally, this discourse was woven years ago, and this same discourse be can also be woven in Australia. Perhaps at that point, we will finally see a tertiary chemistry curriculum, that is centred on the graduate attributes, and that offers the best chemistry education possible, to our Australian students.

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Appendix A

ANU Science Graduate Attributes

- **Scientific Analysis and Inquiry** - develop, apply, integrate and generate scientific knowledge in educational and professional contexts;

- **Problem Solving Skills** - use a range of skills and methods to identify, analyse and respond to problems and issues;

- **Communication Skills** - convey and relate professional and disciplinary information and ideas to diverse audiences in effective and appropriate ways;

- **Teamwork** - work in both independent and collaborative ways with others to encompass diverse abilities and perspectives; and

- **Professionalism and Social Responsibility** - exercise personal, professional and social responsibility as a global citizen.

Appendix B

Online Survey

Investigating the Purpose of Chemistry Education:

An Academic Staff, Student, and Industry Perspective

Research Project

1. Please answer the following questions:

Please select 1 of the following:

I am a:

a. 1st year chemistry student

b. 2nd year chemistry student

c. 3rd year chemistry student

d. 4th year Honours chemistry student

e. Master student

f. Ph.D scholar

g. Post-doctoral fellow

h. Chemistry alumnus

2. What is the purpose of university chemistry education?

3. Why are you doing chemistry? (for alumni, why have you done chemistry?)

4. What do you like most about your chemistry experience so far? (for alumni, what did you like most about your chemistry experience?)

5. What do you dislike most about your chemistry experience so far? (for alumni, what did you dislike most about your chemistry experience?)

6. What skills do you hope you'll get at the end of this chemistry experience? (for alumni, what skills did you get at the end of your chemistry experience?)

7. Please rate the following skills in terms of their **importance** to you from 1-5, with 1 being the least important and 5 being the most important:

- **Scientific Analysis and Inquiry** - develop, apply, integrate and generate scientific knowledge in educational and professional contexts;

- **Problem Solving Skills** - use a range of skills and methods to identify, analyse and respond to problems and issues;

- **Communication Skills** - convey and relate professional and disciplinary and ideas to diverse audiences in effective and appropriate ways;

- **Teamwork** - work in both independent and collaborative ways with others to encompass diverse abilities and perspectives; and

- **Professionalism and Social Responsibility** - exercise personal, professional and social responsibility as a global citizen.

8. Please rate your level of **competence** in the following skills from 1-5, with 1 being least competent and 5 being most competent:

- **Scientific Analysis and Inquiry** - develop, apply, integrate and generate scientific knowledge in educational and professional contexts;

- **Problem Solving Skills** - use a range of skills and methods to identify, analyse and respond to problems and issues;

- **Communication Skills** - convey and relate professional and disciplinary information and ideas to diverse audiences in effective and appropriate ways;

- **Teamwork** - work in both independent and collaborative ways with others to encompass diverse abilities and perspectives; and

- **Professionalism and Social Responsibility** - exercise personal, professional and social responsibility as a global citizen.

9. Are there any changes that can be made to improve your experience in chemistry? If so, what are they? (for alumni, what changes would you have recommended or liked to have seen?)

10. Is there anything you would like to add?

Appendix C

Staff Interview

Please note that a sample transcript would not be provided due to the potential for participants to be identified.

Interview (Staff):

Investigating the Purpose of Chemistry Education:

An Academic Staff, Student, and Industry Perspective

Research Project

1. What is the purpose of university chemistry education?

2. What do you think of the current chemistry curriculum at university (in general & ANU)?

3. Please rate the following skills in terms of their importance from 1-5, with 1 being the least important skill that chemistry students should possess, and 5 being the most important skill that chemistry students should possess:

- **Scientific Analysis and Inquiry** - develop, apply, integrate and generate scientific knowledge in educational and professional contexts;

- **Problem Solving Skills** - use a range of skills and methods to identify, analyse and respond to problems and issues;

- **Communication Skills** - convey and relate professional and disciplinary information and ideas to diverse audiences in effective and appropriate ways;

- **Teamwork** - work in both independent and collaborative ways with others to encompass diverse abilities and perspectives; and

- **Professionalism and Social Responsibility** - exercise personal, professional and social responsibility as a global citizen.

4. Please rate the following skills in terms of their importance from 1-5, with 1 being the skill that chemistry students are least competent at, and 5 being the skill that chemistry students are most competent at:

- **Scientific Analysis and Inquiry** - develop, apply, integrate and generate scientific knowledge in educational and professional contexts;

- **Problem Solving Skills** - use a range of skills and methods to identify, analyse and respond to problems and issues;

- **Communication Skills** - convey and relate professional and disciplinary information and ideas to diverse audiences in effective and appropriate ways;

- **Teamwork** - work in both independent and collaborative ways with others to encompass diverse abilities and perspectives; and

- **Professionalism and Social Responsibility** - exercise personal, professional and social responsibility as a global citizen.

5. Are there any other strengths that chemistry students possess?

6. Are there any other weaknesses that chemistry students possess?

7. What skills do you want your chemistry students to have at the end of the day?

8. Is there anything you would like to add?

Appendix D

Industry Interview

Please note that a sample transcript would not be provided due to the potential for participants to be identified.

Investigating the Purpose of Chemistry Education:
An Academic Staff, Student, and Industry Perspective
Research Project

1. Tell me more about your job position, and the nature of the work you do with the chemistry/science graduates.

2. What is the purpose of university chemistry education?

3. Please rate the following skills in terms of their importance from 1-5, with 1 being the least important skill that chemistry graduates should possess, and 5 being the most important skill that chemistry graduates should possess:

- **Scientific Analysis and Inquiry** - develop, apply, integrate and generate scientific knowledge in educational and professional contexts;

- **Problem Solving Skills** - use a range of skills and methods to identify, analyse and respond to problems and issues;

- **Communication Skills** - convey and relate professional and disciplinary information and ideas to diverse audiences in effective and appropriate ways;

- **Teamwork** - work in both independent and collaborative ways with others to encompass diverse abilities and perspectives; and

- **Professionalism and Social Responsibility** - exercise personal, professional and social responsibility as a global citizen.

4. Please rate the following skills in terms of their importance from 1-5, with 1 being the skill that chemistry graduates are least competent at, and 5 being the skill that chemistry graduates are most competent at:

- **Scientific Analysis and Inquiry** - develop, apply, integrate and generate scientific knowledge in educational and professional contexts;

- **Problem Solving Skills** - use a range of skills and methods to identify, analyse and respond to problems and issues;

- **Communication Skills** - convey and relate professional and disciplinary information and ideas to diverse audiences in effective and appropriate ways;

- **Teamwork** - work in both independent and collaborative ways with others to encompass diverse abilities and perspectives; and

- **Professionalism and Social Responsibility** - exercise personal, professional and social responsibility as a global citizen.

5. In your experience, are there any other strengths that chemistry graduates possess?

6. In your experience, are there any other weaknesses that chemistry graduates possess?

7. As an industry leader, what do you expect of chemistry graduates that you would employ?

8. Is there anything you would like to add?

Appendix E

Participant Information Sheet

Researcher:
Rami Ibo - Honours student at the *Centre for the Public Awareness of Science,* The Australian National University.

Project Title:
Investigating the Purpose of Chemistry Education: An Academic Staff, Student, and Industry Perspective.

General Outline of the Project:
The aim of this project is to find out students', chemistry educators' and industry employers' perspectives of chemistry education. Online surveys will be used to collect data from ANU chemistry undergraduates, postgraduates, post-doctoral fellows, and alumni. Online surveys or interviews may be used to collect data from the University of Canberra and the University of Western Australia chemistry staff. Interviews will be used to collect data from ANU chemistry staff and industries that may employ chemistry graduates such as IP, DIICCSRTE, TGA, DSTO, CSIRO, DE, and the APVMA. Two hundred participants are expected to take part in this project, the results of which will be presented orally in a presentation at CPAS, will be written as a thesis, may be presented at a conference, and may be published in a peer-reviewed journal. It is hoped that this will benefit the RSC in ANU for example to help further develop novel teaching programs that best cater for the three main stakeholders mentioned above.

Participant Involvement:
This research project is voluntary. 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 a question. You have 2 weeks after the interview to withdraw. If you withdraw, your data will be destroyed.

You have been selected because you belong to one of the following categories: Chemistry undergraduate, postgraduate, post-doctoral fellow, alumnus, staff member, or industry leader.

If you are a <u>chemistry undergraduate, postgraduate, post-doctoral fellow, or alumnus</u>; you will be asked to complete an online survey on the purpose of chemistry education. It should not take more than 10 minutes to complete.

If you are a <u>staff member</u>, you will be asked to complete an interview that will be audio recorded using a smartphone. The interview will be about the purpose of chemistry education. The audio recording will be transcribed for analysis. The research will take place in Canberra and should not take more than 60 minutes to complete.

If you are an <u>industry leader</u>, you will be asked to complete and interview that will be audio recorded using a smartphone. The interview will be about the purpose of chemistry education. The audio recording will be transcribed for analysis. The research will take place in Canberra and should not take more than 60 minutes to complete.

You will not be offered any incentives. Neither the online survey nor the interview questions seek personal or sensitive information. Hence, it is highly unlikely that risks, discomforts, hazards or side effect associated with the research. You may request a copy of the transcript after it has been produced. You may request a copy of the summary of the findings.

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. The data will be stored on a USB drive, laptop, and desktop computer that will all be password protected and placed in secure premises.
Any published material will not reveal the identities of the participants. Following the transcription of the interviews, the names of the participants and any other mentioned names will be replaced by pseudonyms

Data Storage:
The data will be stored a USB drive, laptop, and desktop computer that will all be password protected and placed in secure premises. The data will be destroyed after 1 year of publication in peer-reviewed journal or within two years of thesis completion, whichever should occur first.

Queries and Concerns:
Please contact the Primary Researcher: Rami Ibo – Email: u4668226@anu.edu.au

Supervisor: Merryn McKinnon – Email: merryn.McKinnon@anu.edu.au; Phone: +61 2 6125 4951

Ethics Committee Clearance:
The ethical aspects of this research have been approved by the ANU Human Research Ethics Committee.

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: 6125 3427
Email: Human.Ethics.Officer@anu.edu.au

Appendix F

Interview Consent Form

Investigating the Purpose of Chemistry Education:
An Academic Staff, Student, and Industry Perspective
Research Project

<u>Researchers:</u> Dr Merryn McKinnon and Mr Rami Ibo.

1. I …………………………………….(please print) consent to take part in the Research Project: *Investigating the Purpose of Chemistry Education: An Academic Staff, Student, and Industry Perspective*. I have read the information sheet for this project and understand its contents. I have had the nature and purpose of the research project, so far as it affects me, fully explained to my satisfaction by the research worker. My consent is freely given.

2. I understand that if I agree to participate in the research project I will be asked to attend an interview. This will take up to one hour and will involve questions about the purpose of chemistry education.

3. I understand that while information gained during the research project may be published in reports, conferences, and in academic journals or books, my name and position title will not be used in relation to any of the information I have provided, unless I explicitly indicate that I am willing to be identified when quoted.

4. I understand that my personal information such as my name and work contact details will be kept confidential so far as the law allows. This form and any other identifying materials will be stored separately in a locked office at the Australian National University. Data entered onto a computer will be kept in a computer accessible only by password by a member of the research team.

5. I understand that although any comments I make will not be attributed to me in any report or publication, it is possible that others may guess the source of information, and I should avoid disclosing information to the researchers which is of confidential status or which is defamatory of any person.

6. I understand that that I can request a copy of the transcript after it has been produced.

7. I understand that I may withdraw from the research project up until and during the interview, without providing any reason and that this will not have any adverse consequences for me. I understand I have 2 weeks after the interview to withdraw. If I withdraw, the information I provide will not be used by the project

☐   I consent to have my interview audio recorded by the interviewer. I understand that the recordings will be stored securely at the Australian National University and will be deleted at the conclusion of the study.

Signed …………………………………. Date ……………………